2006-1289: CROSS-DISCIPLINE, CROSS-COUNTRY: A COLLABORATIVE DESIGN STUDIO INTEGRATING ARCHITECTURE AND ENGINEERING

Kevin Dong, Cal Poly-San Luis Obispo

Kevin Dong, S.E. is an Associate Professor of Architectural Engineering (ARCE) at Cal Poly – San Luis Obispo. For the past five years he has been teaching classes that emphasize structural systems and structural design to various majors (Architecture, Architectural Engineering, and Construction Management) within the College of Environmental Design and Architecture. His class work utilizes his 13 years of experience with Ove Arup & Partners (ARUP), where he worked in both the San Francisco and London offices. As an Associate with ARUP he worked on a wide variety of projects within the United States and abroad. A trademark of all the projects was the concept of integrated design where the building solution incorporates the design efficiencies and aesthetics from each building discipline. This approach to design is stressed in all of his courses for engineers, architects, and construction managers alike.

Thomas Leslie, Iowa State University

Thomas Leslie, AIA is an Associate Professor of Architecture at Iowa State University. He received his B.S.A.S with High Honors from the University of Illinois, and his M. Arch. from Columbia University. For seven years he practiced with the office of Norman Foster and Partners, London, working on the Joslyn Art Museum in Omaha, Nebraska, the Al Faisaliah Center in Riyadh, and the Center for Clinical Sciences Research at Stanford University, where he was Foster's site architect.

In 2000 he accepted a teaching appointment at Iowa State, where he teaches building design, technology, and history. The Association of Collegiate Schools of Architecture has recognized him with their annual New Faculty and Creative Achievement Awards; and he is the author of Louis I. Kahn: Building Art, Building Science, and co-author of the forthcoming Design-Tech: Building Science for Architects. Leslie has published numerous articles on the role of technology in architectural history, covering topics ranging from the role of plate glass in Chicago architecture of the 1890s to the transformation of airline terminals in the Jumbo Jet era.

Cross-Discipline, Cross-Country: A Collaborative Design Studio Integrating Architecture and Engineering

Overview

This paper describes the goals, implementation, and outcomes of a collaborative design studio incorporating two universities, which are separated by two time zones, and involving professors who teach architectural design and architectural engineering. Using their past experience as design consultants, the instructors describe how this unique course helped foster stronger communication skills, enhanced small group skills, and introduced students to the total design process from site analysis through architectural and structural design.

Premise

As college instructors a primary goal is to prepare students for the future. We do this by,

- Teaching critical thinking skills so individuals can become problem solvers
- Teaching speaking and writing strategies so individuals can become better communicators
- Assigning group projects so individuals learn about group dynamics
- Exposing students to problems that reflect real life situations so students can learn from past mistakes and become confident enough to tackle future problems

Each lesson is necessary for preparing successful students in today's working environment. All of the skills acquired in completing the lessons are necessary to work in a collaborative and integrated manner. Yet, with all of our collective knowledge as a faculty, we struggle to infuse truly integrated and collaborative design projects that fully integrate the four points noted above. We are limited by time and material constraints, facility limitations, or maybe lack of funding. This past year, two schools – one an Architectural Engineering program on the west coast and the other an Architectural Design program in the Midwest - were fortunate enough to present students with the opportunity to work collaboratively on a design project. One school formed architectural design teams and the other structural design teams. Together project design teams were formed to solve the program presented at the beginning of the winter session. Again, the premise was to simulate relationships and processes used in the working world.

Goals/Learning Outcomes

The goals were modest since this was the initial offering, but the eventual outcomes were not. The proposed learning outcomes can be summarized as follows:

- Further develop communication skills; verbal, written, and graphic
- Further develop small group working skills
- Understand how to work regionally and ultimately globally

- Further develop design skills when the "other" design team establishes the constraints.
- Develop project management skills, such as forming a project binder (documentation) and establishing delivery dates and project deliverables

The initial purpose of the class was to expose students to a real world experience using design techniques acquired by the faculty members while working in practice. A primary objective for the engineering students was to expose them to projects that were not merely a box, but were elegant building solutions that promoted "structural diversity", addressed site as well as internal programming issues, and exposed students to the total design process. A primary objective for the architectural students was to understand the impact of structural design on architectural design and how to incorporate structure into the building solution rather than design around it.

Likewise, we explicitly intended this project to address the different cultures and values of our two professions—architecture and engineering—and to present students with opportunities to learn from these. Architecture is necessarily—notoriously—subjective in its assessments and methodologies. As important as it is for engineers to understand the broad cultural and aesthetic contexts in which architects practice, it is also critical for architecture students to recognize the value and constructive constraints offered by allied disciplines that are based on more objective methods.

Collaboration and integration are both powerful buzzwords in design and engineering education, but the two instructors' experience in practice—during which they worked together on the design of a large medical laboratory—suggested that the typical collaboration between their two fields in an academic setting didn't adequately convey the commitment and interdependence between architect and engineer that practice demands. Desk crits or short-term consultations don't offer the level of shared responsibility or peer critique and learning that a multi-year collaboration demands. We wanted our students to gain from the depth and rigor that would come from a full-semester project.

Such full commitments between disciplines are rare in academic settings. While collaborative work between design disciplines (as at the University of Illinois, where an annual joint studio for East St. Louis pulls together landscape, urban planning, and architecture students) or between engineering students (for instance Drexel's Geometric and Intelligent Computing Laboratory) are common, the difficult boundary between design and engineering is a difficult one to cross. We sought to introduce students to both the creative friction that naturally arises between the two, and to offer opportunities to understand the potential for overcoming this and working as a broadly-based team.

As we developed the class in more detail, the project became a vehicle to promote additional critical working skills. It became apparent that the first two learning outcomes were really the hallmark of this class – communication and small group dynamics. It was imperative that students learn how to communicate clearly and concisely since their teammates were located 2000 miles away. Today, we have many ways to communicate with others: telephone, facsimile, e-mail, text messaging, and of course in-person. We often take for granted how to communicate with others who study the same discipline – we speak the same "language" and find it hard to explain things to other consultants. The task set to the students was to describe technical or

abstract thoughts into layman terms such that everyone could work on the same page. Students learned how valuable a well-crafted letter or e-mailed sketch could improve their communication. They also learned that well-written documents take time to produce and the additional time spent improving a letter was typically less than the time required to explain things over the phone after a poorly crafted letter was sent to their partners. The class was organized so that after the kick-off meeting, all correspondence between team members was via phone, e-mail, and instant messaging.

If we think about the total design process, teams innovate where they initiate the design or process, then collaborate with others to create a seamless design, then integrate on their own using the guidelines developed in the collaboration process, and then communicate their discoveries back to the team, It's an iterative process we can term "eye see squared" or IC^2 (innovate, collaborate, integrate, communicate). The studio was staged to facilitate this type of process.

The Program

The selected project was a glider-port. This building type was chosen for two reasons: potential for a variety of building materials, potential for long-spans, incorporation of a multi-use facility, and the fact that one of the universities had a glider club in which to draw inspiration. The program called for space to accommodate administrative, classrooms, etc… plus space for 7 gliders. The site was located in South San Francisco along the Bayshore Freeway and is currently under laid by landfill material (See Figure 1 below). One of the reasons for selecting this site was its relationship to the prevailing winds, position to adjacent water and land features, and a requirement for a seismic component to the structural design.

Figure 1: Site Plan

Innovate: the kick-off

The kick-off meeting was held in San Francisco, California, with two objectives: to introduce the site / project program and to form partnerships. The schools stayed at the same hotels, ate meals together, and traveled together in an effort to form partnerships early in the design process. This is analogous to partnering meetings that occur on projects to help form stronger bonds between the team members. But we learned that even working relationships take time to form and can't be forced. The relationships between team members did form and like all friendships they require time to mature, in this case cohesive working relationships were formed at a later phase in the project.

The group traveled to the site for a short briefing by the land developer. Students were told about the history of the land and the surrounding infrastructure, existing site conditions, environmental concerns, and the developer's future plans for the site. After the briefing, we conducted our first group design activity. The students were broken into five groups and each assigned a specific task regarding site analysis: circulation, perimeter features, existing structures/infrastructure, topography, and land features. Conference space was donated by a local engineering firm allowing the students to quickly collaborate their ideas and formulate short presentations to present to the larger group. This was a successful part of the program since site analysis was a relatively new process to both groups: so it put the groups, in some respects, on equal footing. Since the site was quite large, it exposed students to a myriad of existing conditions and environmental issues facilitating a collaborative effort in arriving at responsive site solutions as well as creating their slide presentations. The site analysis was the first stage in the problem solving process, answering questions such as "where should the runway be placed?" and "in what orientation?", "how do we get people to the site?", "what resources are re-usable and which resources need to be developed?", etc….

The second objective coming out of San Francisco was to form design teams. We hoped after the students worked together for a few days they could select who they wanted to work with for the remainder of the project. We polled each pair to identify three possible teams they would be willing to work with, and from this, the final teams were formed with two engineers and two or three architects. The kick-off meeting was successful from a technical perspective, but the most common comment from both schools was that the "final" design teams should have been formed in San Francisco from the beginning. And in hindsight, the authors agree that in future sections of this studio we will form the design teams on the first day or prior to the kick-off meeting. This would allow for better partnerships among the design teams, but not necessarily the group as a whole. Another comment from the students was that in the real world "you don't always get to choose who you work with", so learning how to work with someone who may not be entirely compatible to your working style is beneficial as well.

Collaborate (The design charette)

Following the initial meeting, the teams began work on their designs, communicating on a daily basis to ensure that the architectural work was informed by the structural and environmental needs. Two months into the project, the first design coordination meeting was held. During this

time teams met face to face on the Midwest campus. Students learned the value of face-to-face negotiations and communication, the value of relationships in the working world, and acquired a deeper appreciation for each other's work. Student assessment responses indicated that the most valuable time spent on the project was during the collaborative design meetings. Students felt they better understood the design concepts implemented on the project and had a clearer vision on how to proceed with the project. The meetings also enabled students to bond as a team, understand the priorities of each other's design, and generally understand the give and take necessary to complete a project successfully. Even with all the technological advances made in communication, students felt nothing could replace meeting on a personal basis.

At this juncture the architectural design was at 75%SD. Between the visit to San Francisco and the visit to the Midwest, most coordination was conducted via e-mail and cell phone. The engineering goal to this point was to establish a viable gravity load and lateral load resisting system – essentially provide enough information or guidelines about the structural system so that the architectural team could proceed with their work, yet not invest an inordinate amount of time on the structural design since it might change. Design is a fluid process. Revisions and refinements are a natural byproduct of design, so the goal for the engineering students was to describe a few basic rules for the architects to follow - rules that were easy to follow and easy to implement - while not restricting the freedom of the designers. In other words, have basic structural engineering principles been communicated clearly and concisely such that the architectural design could proceed?

Most projects were evaluated (structurally) using two different materials and two different lateral load resisting systems to arrive at a structural proposal that not only matched the architectural solution, but was also structurally efficient. In order to arrive at the most efficient system, the ARCEs formed a list of items requiring coordination and established goals prior to traveling to the Midwest so that they could begin production work in earnest when they returned home.

This meeting captured what we were trying to achieve with this class. There was a lot of give and take and a lot of "teaching" by the students to each other. Students discussed where columns were needed and why and where columns could not be placed and why. The structural designers learned how braced frames and shear walls impact interior circulation and architects learned that shear walls and braced frames are required to make a building seismically strong. The ARCE's sketched structural details on how things would go together and the ARCH's sketched architectural renderings showing how it was supposed to look. All the things we try to prepare the students for in the classroom seemed to come together during this 48 hour time period. In the end, the students learned to appreciate the power of a sketch and more importantly the value of speaking and working with each other face to face.

In a typical classroom setting we cannot replicate the give and take experienced in the design charette. Each design team had the same process going on in one form or another. It was during this part of the project that the teams started to gel, forming relationships where communication flowed freely and interaction amongst disciplines began to take hold. In order to encourage more interaction/collaboration in future sections, interdisciplinary exercises are planned for the kick-off meeting to help build relationships. The hope being that more contact time with the small group will advance communication in the early portions of the design phase.

On your own again – Integrate

After returning from the design charette, the idea was for each designer to return to their "office" and complete their structural design. For the most part this happened. There were still coordination issues, but more fine-tuning rather than addressing massing issues or fundamental scheme design principles. Since the charette was such a success, correspondence between team members increased and more collaboration occurred.

Another obstacle was the 2000 mile separation and the two-hour time zone difference. We scheduled design studios such that the meeting times overlapped to help foster collaboration, but students typically communicated in the evenings after classes. And as mentioned before, most communication was conducted via e-mail, telephone, and to some extent text messaging. At this point in the project, students conducted business similar to working in a consulting office. Images were sent attached to an e-mail and then a marked-up sketch was sent back with a phone call so that design issues could be resolved.

The Presentation - Communicate

Upon completion of the project, oral presentations and project binders were presented to faculty and invited practitioners from industry. As with any assessment vehicle, the presentations and ensuing feedback from the visiting practitioners provided the students with another perspective on how building design can be approached and design issues worth considering for future projects.

On the architectural side, presentations consisted of models and drawings showing site planning, building design and program deployment, and integration of structural, cladding, environmental, and life safety elements. In addition to local architects and faculty, review teams included members of a local soaring club, who had periodically visited reviews to serve as the "client".

On the engineering side, presentations were typically slide shows, structural drawings, skeletal models showing the framing scheme, plus any props required to convey the structural principals behind their designs to the reviewers. Students were required to keep the knowledge of their audience in mind, again reinforcing the concept of clear and concise communication and a reminder to use simple terms to describe complex engineering principles. Three practicing engineers of with various structural expertise plus both instructors presided as the jury for the student presentations. Projects were reviewed for technical merit as well as architectural sensitivity – how well was the architectural intent preserved. Most design solutions expressed the structure to reinforce the architectural space so sensitivity to the total solution was imperative. A sample of a structural and corresponding architectural solution is shown on Figures 2 and 3.

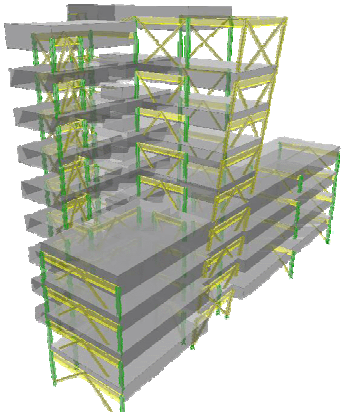

Figure 2: Structural Frame

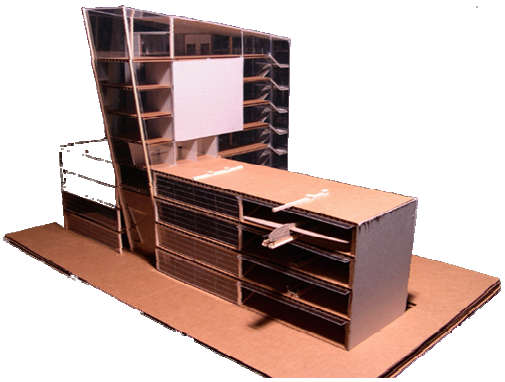

Figure 3: Architectural Model

Project binders were started at the beginning of the process, January 2005, and ended with their final submittals, June 2005. The binders included all correspondence between team members, internal correspondence between "office" mates, and supporting technical information – documentation expected when running a project in the working world. The binders were a constant reminder of how important written documents are in real world situations. If you want to see how the project evolved into its final shape or if you have researched a particular study previously and want to embellish it, the project binder provides the historical data necessary to retrace your thought process and move onto the next phase.

Lessons for the Instructors

Student exit surveys were very positive and participants at both institutions have given the course high marks.

			Textbooks and Readings used in Course	Usefulness of Assignments in helping you learn	Usefulness of Class Lectures	Effectiveness of interactions between instructor and class	Effectiveness of instructor's individual interactions	How well Course Elements worked together to help student learn	How Syllabus helped students understand goals and requirements of course	Challenge level of the course	Student's educational background prepared student	Student worked up to his or her potential in this course	Student believes what they were asked to learn was important	Overall, how much did student learn	Student was treated with consideration	Student's overall rating of instructor's effectiveness	Student's overall rating of course		AVERAGE
Arch 602 (control)	Studio	S 04	NA	3.83	3.67	4.33	4.33	3.83	3.50	3.50	4.33	4.17	4.50	3.67	4.33	4.17	3.83		4.00
Arch 602/404 (subject)	Studio	S 05	NA	4.83	4.84	5.00	5.00	4.83	5.00	4.50	4.84	4.33	4.92	4.75	4.92	5.00	5.00		4.84
Change, %				126%	132%	115%	115%	126%	143%	129%	112%	104%	109%	129%	114%	120%	131%		121%
Dept. Average 2000-2005			*3.56*	*4.09*	*4.05*	*4.09*	*4.10*	*3.88*	*3.71*	*4.10*	*4.03*	*4.04*	*4.21*	*4.05*	*4.22*	*3.98*	*3.86*		*4.00*
College Average 2000-2005			*3.57*	*4.03*	*4.03*	*4.11*	*4.08*	*3.86*	*3.75*	*3.93*	*3.94*	*4.06*	*4.27*	*3.91*	*4.28*	*4.11*	*3.83*		*3.98*

Table 1: Summary of Student Evaluations

Students felt the collaborative design experience better prepared them for their career in the consulting business and appreciated the challenge of complex structures and architectural constraints. But most of all, they all re-iterated the work it took to communicate to another discipline. This was a positive experience for the students and the two hallmark learning outcomes for the class were addressed:

- Communication skills were further developed when they found themselves teaching other students and themselves about load path, stability, seismic design, and constructability and when you are forced to coordinate with someone 2000 miles away
- Small group skills were improved when the ARCE's were forced to apply their two years of architectural training in preparing possible structural solutions that were sensitive to the architectural treatment of a space or when the architectural and structural solution didn't mesh. What is a viable solution that can meet the criteria required for each discipline?

Numerical evaluations from the architecture students break down these general 'lessons learned' slightly further. Using a similar studio from a prior year, taught by the same architecture professor as a control, this studio's evaluations produced notably better results. Some gains were transparently the result of extra planning required; in particular the need to assemble a robust syllabus was appreciated. However others can be largely attributed to the challenge and results of the collaboration specifically. In particular, students felt more challenged, felt that the studio's subject matter was inherently more important, and felt that they learned far more from this collaborative effort. The result was a studio that ranked well above historical averages for coursework throughout the department.

Written evaluations did make concrete suggestions for improvement, ones we have adopted in the second offering (Spring 2006). In particular, they did not feel that a single "charrette" work session was adequate, and proposed that further 'face time' earlier in the semester would have put communications on firmer footing. We have thus replaced a site visit with a dedicated work session four weeks into the project. Likewise, the scale of the project proposed required a great deal of planning and site design, which left the engineering team out of the 'action' for too long. We responded to this by adopting a smaller scale project, a national student competition for a community Aquatics Center, in which issues of material and structural design occur much nearer to the front end of the design process. Preliminary feedback from this year's studio suggests that these have had the desired effect, as engineering and architectural teams formed more quickly and produced more integrated work earlier.

Additionally, the biggest change will be developing group exercises that encourage collaboration between structure and architecture while allowing students to become familiar with one another. Once those friendships are formed, it's much easier to pick up a phone or write a note to someone asking for advice or requesting feedback. As with any initial offering, the authors feel the challenges can be overcome and these improvements will make future course offerings more successful, but in the meantime we hope to share our thoughts and lessons learned from our first attempt at a truly integrated design studio.