AC 2011-981: INTERDISCIPLINARY DESIGN THE SAGA CONTINUES

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Interdisciplinary Design - The Saga Continues

Abstract

The College of Architecture and Environmental Design at California Polytechnic State University, San Luis Obispo is the only college in the nation that has departments of Architecture, Architectural Engineering and Construction Management in the same college. The institution has a 60 year tradition of collaboration between the engineering, architecture and construction disciplines, particularly at the lower division level. To enhance this collaboration, the college committed to providing an upper division interdisciplinary experience to every student in the form of a project based, team oriented five unit studio that every student would take. This new course, launched in 2009, requires small teams of architecture, architectural engineering and construction students to complete the schematic level design of an actual building for a real client.

While developing a college wide interdisciplinary course sounded simple in theory, it has proved to be much more challenging in practice. The course is in its second year and continues to offer new challenges that fall into three major areas: institutional, logistical and pedagogical. The paper describes how the challenges listed above have been overcome particularly concerning the role of the faculty in the course and the merging of very different department cultures. This paper reports on the progress of this course using survey assessment data and direct performance indicators. This same data provides valuable support to the 3 a-k ABET program criteria. Finally, the future of the course and the suggested improvements are highlighted.

Introduction

The Architectural Engineering Department (ARCE) at California Polytechnic State University, San Luis Obispo (Cal Poly) is one of the few ABET accredited engineering programs in the United States that exists outside a college of engineering. Housed in the College of Architecture and Environmental Design (CAED), ARCE resides with the departments of Architecture (ARCH), Construction Management (CM), Landscape Architecture (LA), and City and Regional Planning (CRP). The college has a 60 year tradition of collaboration between the disciplines at the lower division levels.

While CAED has always excelled at bringing students together in lower division classes, there have only been isolated attempts to bring the students back together at the upper division level after each has learned his or her respective discipline. In 2009 CAED launched a senior level interdisciplinary course that integrated the ARCH, ARCE and CM students into a single course utilizing real projects with real clients. While developing a college wide interdisciplinary course sounded simple in theory, it has proved to be much more challenging in practice. The course is in its second year and continues to offer new challenges that fall into three major areas: institutional, logistical and pedagogical. As the course has matured the specifics challenges have also evolved. This paper chronicles the continued successes and pitfalls of bringing an interdisciplinary experience to the masses – an upper division, project based, team oriented course that all students would take.

Institutional Challenges

Department Head Commitment - A first critical hurdle in the implementation of the course has been the commitment and support of all department heads involved. At the end of each quarter a meeting has been held with all department heads and faculty involved in the course to assess the successes and short comings of the course. The support and active involvement of all department heads has been critical in providing required resources and brokering solutions that make such a course work for all departments.

Course Format - Even with the full commitment of the department heads, finding a common course format that works for all departments has proved a difficult challenge. A key question has been the size or number of units of the proposed course as the course had to fit into each department's existing curriculum. Because the ABET accreditation criteria for engineering programs[1] requires that every student be able to function on multi-disciplinary teams, a large enrollment default course was needed. A five unit studio laboratory during a single quarter was ultimately chosen for the new course. The change and approval process was easiest for ARCH because it fit within their existing curriculum structure, no curriculum changes or faculty vote were required. The CM department was already in the process of a major curriculum renovation which involved a transition to studio labs, so making this new course mandatory and expanding it to five units was readily accepted by the faculty. The change has been most difficult for the ARCE department due to a highly impacted curriculum of typically 3 unit courses.

One concern initially expressed by ARCE faculty was what existing courses would be sacrificed to make room for this new 5 unit course? It appears that this question has been answered with the new interdisciplinary project based course replacing a prior 3 unit "senior project" course. The additional 2 units for the new interdisciplinary course were gained by eliminating a 4 unit general numerical analysis course taught by computer science and replacing it with a 1 unit focused numerical analysis lab taught by ARCE faculty. The changes were difficult but seem to have now been accepted and embraced by the faculty.

A second and more difficult question that is still lingering among the ARCE faculty is would there be sufficient engineering content to justify a five unit studio within the very impacted curriculum? In now the second year of offering the course in a 5 unit format, this question persists among the ARCE faculty. Modifications to the pedagogical structure of the course are now in process to address this question.

Course Numbering - Although the class functions as a single entity with faculty and students from multiple departments, each student currently signs up for the course in their own department. For example, ARCE students sign up for ARCE 415, CM students sign up for CM 415, etc. This process insures that (1) a faculty member from each department is assigned to teach the course, and (2) faculty members are ultimately responsible for assigning the final grade to students in their department. There is currently discussion about creating a common course number for students in all departments.

Faculty Assignments - It was quickly determined that a faculty position from each discipline would be needed nearly full time to implement the course. The course needs to serve roughly 250 students per year. Based on student demand, it was determined to offer one lab per department per quarter for a total of three labs (3 labs of 24 students or 72 students) per quarter, allowing each department to commit a faculty member each quarter.

Selection of the faculty to teach the course is likely the most critical decision to ensure a successful course outcome. Since professors traditionally work as individuals to synthesize and implement department and course goals, team teaching of this magnitude is a paradigm shift that requires significant time and commitment. The ideal implementation of the course requires the professors to work as a "high performance team". Key aspects of high performance teams are honesty, trust, respect, open communication and a commitment to the team.[2] The cultural differences between the departments cannot be trivialized as they create challenges similar to those found in business mergers and acquisitions. Fifty to seventy five percent of all mergers and acquisitions are considered failures. The ones that are successful typically have merged the cultures of the firms versus imposing one culture on the other.[3] The ability of the interdisciplinary faculty team to successfully merge the disparate department cultures into one integrated course is critical to success. At Cal Poly, selection of the faculty members to teach the course has been evolving to identify faculty teams that can successfully work together. Identifying these faculty teams has been one critical role of the department heads and continues as an ongoing challenge to the success of the course.

Logistical Issues

Class Room Facilities – The unique aspects of teaching a large scale team based interdisciplinary studio has demanded a teaching space or spaces that can accommodate a variety of student group sizes in a variety of teaching modes from a private mentoring session with two or three students to a large scale public lecture for the entire class of 72 students. Three adjacent classrooms in a new building were designed for and specifically dedicated to this new upper division interdisciplinary course. Yet, even these brand new facilities have not fully met the pedagogical demands.

The class room facilities have worked very well in regards to student work areas. Each student team of 6 interdisciplinary students (see Figure 1) is assigned a team work station. The modular furniture available in the class room has allowed students to modify the work space configuration to meet the needs of the team.

Each of the three class rooms dedicated to the course has a central area for lectures in addition to the work stations for the student teams. The lecture areas, while fine for lecturing to 25 to 30 students, are completely inadequate for lectures to the entire class of 72 students. As a result, lecture given to the entire class of 72 students have been delivered in either (a) larger university lecture halls that require advance scheduling and that are not always available, or (b) more often in one of the three classrooms resulting is very sub-standard learning conditions for the students. The lack of a large capacity lecture hall readily available to the course has proven to be a major logistical and pedagogical hurdle.

Figure 1. Sample Student Interdisciplinary Team

Another logistical hurdle has been the lack of university computers in the class rooms. While the goal of the class is to foster integrated interdisciplinary design, the lack of university computers available in the class room typically means that students are working on their “team” project in scattered locations throughout the university. While most students have laptops, they do not have access to the software necessary for each discipline and only available on university computers. Access to both computers and the necessary software in the class room is critical to the student learning that occurs as team members from different disciplines work side-by-side to solve a problem.

As part of each class room, there is a faculty ready room where faculty can meet separately from the students or with a small group of students. This faculty ready room has been a great benefit for privately mentoring small groups of students and for private faculty discussions related to the development of the course.

Pedagogical Issues

Learning Objectives - There has been considerable effort toward developing a common set of learning objectives for all disciplines in the course. Key faculty, with input from the department heads, drafted two common learning objectives that have formed the basis for the course. While the wording of the learning objectives has continued to be refined, the primary emphasis of the learning objective has not changed since the implementation of the course. The current version of the two common learning objectives is as follows:

1. Ability to create an interdisciplinary project proposal by a team that includes architecture, architectural engineering, and construction management scopes of work.
    a. Basic understanding of all parts of the interdisciplinary project proposal.
    b. Ability to incorporate student’s discipline specific expertise into the interdisciplinary project proposal.
    c. Ability to effectively convey all parts of the interdisciplinary project proposal to varied stake holders, both in written documents and in verbal and graphical presentations.

2. Ability to function effectively on an integrated design and construction team including the use of
    a. Basic design management skills
    b. Collaborations and knowledge integration
    c. Effective communication using verbal, written and graphical methods.

As the interdisciplinary course has evolved over the last several years, it has exposed a weakness in the ARCE curriculum that prevents ARCE students from fully participating in and benefiting from the course. The ARCE curriculum is excellent at educating students in fundamental structural principles and then the application of those principles for a comprehensive final engineering design of structures. This education prepares them well to become professional engineers developing final engineering designs after the basic project parameters have been established. However, the current curriculum does not adequately prepare architectural engineering students to participate in the early conceptual design stages of a project with their fellow ARCH and CM peers. As such, a new learning objective for architectural engineering students is currently being considered for the course as follows:

3. Ability to create and present a conceptual engineering design.

Teaching Approach - It has been relatively easy for the faculty to concur on the two primary learning objectives for the interdisciplinary course. The larger challenge has been in developing a common teaching approach since each department interprets these objectives through their own department culture. As an example, ARCE utilizes a strong lecture format with focused assignments and projects whereas the architecture department is established around a looser studio environment where students are given guidelines and encouraged to explore and create. As a result, the current in-class teaching approach utilizes a combination of several formats.

General lectures are given to the entire group of students from all disciplines. They are typically delivered to all 72 students in a large class room setting, although there has been some experimentation with giving the same lecture three times to each individual classroom of students. These general lectures convey technical or project information to create a common platform for the students to communicate with each other on critical aspects of their projects. These lectures may also focus on educating "non-major" students to specific industry tools such as cost estimating to ARCE and ARCH students. Similarly, the general lectures may cover a topic such as permit regulations, presentation skills, or business practices that may benefit all students.

Discipline specific lectures are given to students from a specific discipline and tend to be more detailed and technical in nature. These lectures are focused on extending the technical knowledge in the student's discipline that is needed to effectively work on the specific project. For instance, we have found that upper division ARCE and CM students are well versed in detailed engineering calculations and quantity take-offs, but have rarely been exposed to conceptual engineering design or estimating concepts. This conceptual education in their respective disciplines is essential to functioning effectively on their interdisciplinary team (see Figure 2) and is the genesis of the new third learning objective introduced for ARCE students. In addition, there may be specific technical topics that are not covered in the basic curriculum that are essential to the specific project selected each quarter. For example, the current project used in the interdisciplinary course is the renovation and restoration of a historic building. This project will require introducing the students to basic concepts in historic preservation, renovation techniques, earthquake retrofit, etc.

Figure 2. Sample of Student Work
Concept Integration of Engineering and Architecture

Faculty instruction, while important, must be restrained so that it does not consume the majority of the class time and infringe on the studio time needed for mentoring and student teams working on the project. The class meets three days per week for 5 hours each day. With multiple faculty teaching the course, the tendency toward more and more faculty instruction can be difficult to curb. Having the students "rub shoulders" side-by-side with team members of different disciplines as they work on the project is a key element of student to student learning in the course.

Mentoring between faculty and students in the course occurs on both a formal and in-formal basis. Formal mentoring sessions are held several times during the quarter where the faculty team meets with each student team, one team at a time, to review the team's work on the project and to evaluate if all members of the team are fully participating. Informal mentoring occurs as faculty are available to student teams working on their project design.

Process versus Product - Is the process of learning to be an effective team member more important than creating a technically correct integrated building design or vice versa? This has been a fundamental debate, focused on the product versus process issue, that continually arises as the course has evolved. For engineering faculty, the need for technical accuracy seems to be a higher priority than for the other disciplines which seemed to emphasize the team building and interaction process more than the substance of the project deliverable. This is a critical consideration given the short ten week window from which to take diverse students from differing backgrounds, meld them into a team and facilitate the creation of a quality project.

Project Selection – The course has been successfully taught using a wide variety of project types as the vehicle for student learning. Thus far the projects selected have ranged from a new 60,000 square foot visitors center for a botanical gardens with a large parking structure, to an 8,000 square foot existing building renovation with small addition to a new 1,000 square foot residence for a green building competition. Based on the experience thus far, the single most important variable in the project selection has been the project size with the smaller size projects being more amenable to student learning. If the project is small, the students have more time and energy to focus on the interaction between the disciplines rather than just falling back into their own respective silos due to time constraints on delivering the project submittals.

A second critical variable in project selection is the type of project. The use of building renovation as a project type offers some significant advantages over new construction. The design process requires time to synthesize the program requirements into a physical shape for the building. This planning process lends itself to the skills of the ARCH students leaving the ARCE and CM students not as fully engaged at the start of the quarter. Using an existing building limits the planning process and allows the teams to more quickly focus on specific layouts. In addition the ARCE students are immediately engaged on the project since they need to understand the buildings existing strengths and weaknesses.

Grading - With multiple faculty and students with different department grading cultures, the course requires the creation of a transparent and equitable grading system. Individual professors with varied backgrounds have differing expectations and needs within the course. Students bring diverse capabilities and work ethics to the course. Unlike other courses that utilize teams, in this course each student brings a unique expertise to the team. If a single member is not performing, it is not likely that the rest of the team will not be able to "cover" for that member. A simple to administer yet fair grading concept must be developed to respond to these and other similar challenges.

The first learning objective, create an integrated design, is graded using a combination of team project submittals and individual student scores for in-class activities and homework. Each team submittal includes a presentation and a detailed written client package with backup material. A grading rubric is developed which allows any faculty to grade any or all portions of the team submittal and presentation material (see Figure 3). However, if a specific faculty member grades one team in a specific area, such as structural framing, that same faculty member must grade all teams in that same area. The grades from various faculty are averaged resulting in a single team grade for each submittal.

Submittal / Presentation #2
PowerPoint Presentation

	Weight 0.25
Introduction	10
Delivery Style	10
Organization	10
Audiovisuals	20
Content	40
Q&A	10
Total	100
Total	100

11x17 Client Summary

		Weight 0.5
General (5)	1a. Cover, Title & Team Name 1b. TOC 1c. Design Problem Statement	5
Goals (5)	2a. Design Goals 2b. Design Objectives	5
Program (10)	3a. Program Elements 3b. Prototypical Users 3c. Activities	10
Drawings (40)	4a. Master Plan 4b. Site Sections 4c. Precinct Scale 4d. 3D Views 4e. Building Plans 4f. Building Sections 4g. Building Model	40
Cost (10)	5. Cost Estimate	10
Value (20)	6. Value	20
LEED (10)	7. LEED	10
	Total	100

Figure 3. Grading Rubrics – Interim Submittal

The second learning objective, function as an effective team member, is primarily assessed through faculty observations of the team and team self reporting. As part of the submittal process, each team member evaluates him or herself and fellow team members. This information is used by the faculty to work with struggling team members and serves as a tool to adjust grades based on individual performance within the team.

Final student grades in the course are the purview of the professor in the student's major. For example, final course grades for ARCE students are assigned by the ARCE professor teaching the course.

Course Assessment

The course is now well into it's second year. Student assessment data has been gathered each quarter. Each student assesses his/her abilities relative to the learning objective prior to entering the course and upon completion of the course on a scale of 1 to 5, with a score of 1 being little or no understanding and a score of 5 being a thorough understanding. Does the course accomplish the student learning objectives?

Learning Objective 1 - Create an integrated building design. Analysis of the data yields the following conclusions (see Figure 4):

- 12% of the students felt they had not improved, 33% felt they had somewhat improved (1 point increase, out of 5) 54% of the students felt they had significantly improved (2 point or more increase, out of 5).
- Prior to the course CM and LA students were generally more confident in their abilities to create an integrated design than ARCH and ARCE students. It is therefore not surprising that the largest gains from the course were shown for ARCH and ARCE students.
- After completing the course all disciplines felt more confident in their abilities to create an integrated design with ARCH and ARCE showing the greatest improvement.

Learning Objective 2 - Function effectively on an interdisciplinary team. Analysis of the data yields the following conclusions (see Figure 4):

- 16% percent of the students felt they had not improved, 41% felt they had somewhat improved (1 point increase, out of 5) and 33% of the students felt they had significantly improved (2 point or more increase, out of 5).
- Prior to the course CM students were much more confident in their abilities to function effectively on an interdisciplinary team that the other disciplines.
- After completing the course students in all disciplines felt more confident in their abilities to function effectively on an interdisciplinary team, with ARCH showing the greatest improvement.

	Learning Objective #1 Create an Integrated BuildingDesign			Learning Objective #2 Function Effectively on Interdisciplinary Team		
Student Major	**Prior to Course**	**After Course**	**Average Change**	**Prior to Course**	**After Course**	**Average Change**
ARCE	2.0	3.8	+1.8 (+36%)	2.6	4.0	+1.4 (+28%)
ARCH	2.4	4.4	+2.0 (+40%)	2.7	4.5	+1.9 (+38%)
CM	3.1	4.3	+1.2 (+24%)	3.8	4.5	+0.7 (+14%)
LA	3.0	4.4	+1.4 (+28%)	2.9	3.6	+0.9 (+18%)

Figure 4. Learning Objective Assessment

Knowledge of Non-Major Disciplines - Students were asked to assess their knowledge of disciplines other than their major prior to the course and after the course. Analysis of the data yields the following conclusions (see Figure 5):

- ARCH and CM students had a high knowledge of ARCE prior to the course, and LA students did not. This is attributed to the fact that ARCH and CM students take a five course sequence in ARCE prior to this course, and LA students do not.
- All students left the class with a significant understanding of the other three non-major disciplines as indicated by a score of 3.0 or higher for all students for all non-major disciplines.
- The lowest scores after the course were for ARCE student knowledge of LA and LA student knowledge of ARCE. These two disciplines are the most dissimilar represented in the course. Other than general education requirements, the two majors do not have a single course in common, so the results make sense.

	Prior to Course	After Course	Average Change	Prior to Course	After Course	Average Change
Discipline	**ARCE Students**			**ARCH Students**		
ARCE	--	--	--	2.9	3.7	+0.8 (16%)
ARCH	2.9	3.9	+1.0 (20%)	--	--	--
CM	2.7	3.9	+1.2 (24%)	1.9	3.5	+1.6 (32%)
LA	1.7	3.1	+1.4 (28%)	2.1	3.4	+1.3 (26%)
	LA Students			**CM Students**		
ARCE	1.8	3.0	+1.2 (24%)	2.8	3.6	+0.8 (16%)
ARCH	2.8	3.8	+1.0 (20%)	2.5	3.8	+1.3 (26%)
CM	2.0	3.4	+1.4 (28%)	--	--	--
LA	--	--	--	1.8	3.5	+1.7 (34%)

Figure 5. Knowledge of Non-Major Discipline Assessment

Student Comments - Student comments were generally favorable and focused on the positive aspects of working with other disciplines, and real projects with real clients. The feedback from the students followed similar trends to those noted in 1996 at Rensselar Polytechnic Institute where an interdisciplinary studio involving architecture and civil engineering students was developed. Positive student comments from that studio experience showed that exposure to real project and real clients was highly rated.[4] Areas that the Cal Poly students felt needed improvement were the balance of lecture time versus work time, conflicting professor directions, unclear submittal requirements and difficulty in scheduling team work outside of the class hours.

Future Plans

The course has been successfully taught for one and a half years. Based on discussion among the faculty that have taught the course and review of assessment data and student comments the following suggestions are being implemented this year.

- Document a written course framework that is independent of the specific project used. Individual projects can then be overlaid on this framework to provide consistency and simplify the start up effort for each quarter.

- Develop a rotation of faculty that brings new blood into the course but retains enough institutional memory to ensure a smooth transition and successful course.

- Develop additional assessment tools to measure student progress. One specific area where additional tools are needed is in the measurement of effective team growth.

References

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[2] A Guide to the Project Management Body of Knowledge (PMBOK Guide), Fourth Edition, Project Management Institute, New Town Square, PA, 2008: 253-254.

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[4] Donald Watson, Dennis Tanczos, George List, "Integrating Architecture and Engineering in the Curriculum: a report on a joint architecture-engineering design studio", ASCA Summer Conference University of Wisconsin-Milwaukee, August 2-4 1996.