AC 2010-1004: INTERDISCIPLINARY DESIGN: THE GOOD, THE BAD, AND THE UGLY

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Interdisciplinary Design: the Good, the Bad, and the Ugly

- **Abstract**

Today's students are faced with far different challenges upon graduation than those encountered in past years. One of the most significant of these challenges is the need to work within the framework of integrated project delivery where all disciplines work as a cohesive team to produce a project. In 2004, the Construction Management Department at California Polytechnic State University in San Luis Obispo,CA began teaching a three credit hour design/build course focused on integrated project delivery. That course, taught primarily to construction management students, has now evolved into a true interdisciplinary experience that is taught in a team environment by professors from the departments of Construction Management, Architecture, and Architectural Engineering.

The challenges in creating and executing such a course are immense and fall into three major areas; institutional, logistical and pedagogical. This paper addresses these three challenge areas by discussing the specific issues, both good and bad, associated with this course and how they were addressed. It includes assessment data from the course and cites some areas for improvement. In addition, the paper provides a framework for the successful implementation of similar courses around the world.

- **Introduction**

The Architectural Engineering Department (ARCE) at California Polytechnic State University (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, ARCE resides with the departments of Architecture (ARCH), Construction Management (CM), Landscape Architecture, and City and Regional Planning. The college has a 60 year tradition of collaboration between the engineering, architecture and construction disciplines. Several decades ago, all students in the college took a common two year curriculum prior to separating into their respective disciplines. Although that model no longer exists, there is a commitment to interdisciplinary collaboration at the lower division level. ARCE students take three architecture studios side-by-side with architecture students. All ARCH and CM students take a five course structural engineering sequence from the ARCE Department.

While the college has always excelled at bringing students together in lower division classes, there have only been isolated attempts to bring the students back together after each has learned his or her respective discipline for a true interdisciplinary experience. There have been many excellent elective courses and senior projects that have been interdisciplinary in nature, but no experience required of every student. This paper chronicles an attempt to bring an interdisciplinary experience to the masses – an upper division, project based, team oriented course that every student would take.

The challenges in creating and executing such a course are immense and fall into three major areas: institutional, logistical and pedagogical. Institutional issues include university support and concurrence from four different department heads. Logistical issues range from finding open

time within the four schedules to offer the course and securing physical locations for small and large group meeting areas to the seemingly mundane tasks of ensuring all students are in the correct location and finding common times for the instructors to meet. Pedagogically, the course needs a unified and integrated approach that must be agreed to and implemented by all professors. Traditionally professors work as individuals and team teaching of this magnitude is a paradigm shift that requires a significant time and mental commitment. This paper addresses these three challenge areas: institutional, logistical and pedagogical. It discusses the specific issues, both good and bad, associated with this course and how they were addressed.

- **Institutional Issues**

While developing an interdisciplinary course sounds simple in theory, it proves to be much more challenging in practice. Over time, departments develop cultures and traditions that have to be overcome and compromised to make such a course work for all departments. A first critical hurdle is the commitment of all three department heads. Even with that commitment, the challenges continue in determining the number of units the course will require, and finding a common location and time. Architecture has a culture of five unit studio laboratories, while ARCE and CM have more traditional combinations of three unit lecture courses, lecture courses with activities, and three unit laboratories. The new course whatever its size needs to fit into the existing curriculum schedule of all three departments.

Another question considered was whether to develop a new course from scratch or scale a smaller existing interdisciplinary experience into a larger effort. The three department heads held several meetings with those faculty members who had executed previous interdisciplinary efforts to brainstorm and discuss ideas. Those previous efforts included:

CM 431 Integrated Project Services: This three unit lab-based course provides an overview of project delivery methods with an emphasis on trends in integrated services project delivery. CM and ARCH students used a real project to integrate planning, design and construction efforts to achieve maximum project quality and value. The course enrolls up to 50 students.

ARCE 460 Collaborative Design Laboratory: The course offered to ARCH and ARCE students investigated the collaborative nature of the design process as it relates to the structural engineer and architect. This course enrolled up to 16 students.

EDES 406 Sustainable Environments / EDES 408 Implementing Sustainable Principles
The sequence covers two quarters and represents a collaboration of interdisciplinary faculty and guest speakers/panelists. The first course is a four unit lecture and the second course is a project-based four unit laboratory, intended to aid students who wish to collaborate with the purpose of implementing sustainability principles. The course enrolls 16 students and is used by ARCH, LA, and CRP.

Most of the interdisciplinary efforts have been low enrollment electives. 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. The department heads ultimately chose to build on CM 431. Two departments were already invested and it could handle a large enrollment of students.

There was considerable discussion concerning what the course was supposed to accomplish. The department heads and key faculty members drafted sample course objectives that formed the basis for discussion. These objectives eventually morphed into the learning objectives currently used in the course, which are:

- Function effectively on an interdisciplinary team
- Create an integrated building design that includes; architectural vision, space planning, and the integration / synthesis of building systems while balancing real world physical, owner, regulatory, code and contemporary constraints.

The student throughput became a factor in the decision process. As the course becomes mandatory for all ARCE and CM students and approximately half the architecture students, the course needs to serve roughly 250 students per year. To be effective, the course needs to be laboratory based which involves triple the classroom time than a lecture course. In CM and ARCH, a laboratory class consists of 24 students, while they have 16 students in ARCE. The student demand argued for three 24 student labs every quarter with an additional offering during the summer. It was quickly determined that a faculty member from each discipline would be needed for the course to be effective. The final decision was one lab per department per quarter for a total of three labs (72 students) per quarter since it allows each department to commit a faculty member each quarter.

Whether the course would be three units or five units was another subject of considerable discussion and importance as the course had to fit into each department's existing curriculum. The five unit studio laboratory was ultimately chosen but created some challenges for those departments with three unit scheduling.

Curriculum changes require faculty buy-in and support. At Cal Poly, the faculty vote on curriculum changes and the faculty from all three departments had to vote to approve this. Ordinarily, the preferred method would be to try the course on a small scale, work out any problems and then offer it to a larger audience. With each department devoting a faculty member, it requires a large commitment on the first attempt. Adding a new requirement to the senior level schedule requires incentives, flexibility and a transition plan for each year group of students.

The change and approval process was easiest for Architecture because it fit within their current system. There was no curriculum change or faculty vote required since CM431 course was already part of ARCH 4th year studio and they were already running it as a five unit studio lab. 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 not a tough sell. The ARCE department vote was close and required a yearlong session of weekly meetings of the curriculum committee. The ARCE faculty concerns were: what existing units would be sacrificed to make room for this course, will there be sufficient technical structural engineering content to make the course worthwhile and how to accommodate a five unit studio within a tight schedule that relies on three unit classes. The faculty voted to approve the course but true buy-in and commitment will take more time.

- **Logistical Issues**

The implementation of a large scale interdisciplinary studio course creates unique logistical challenges, especially in the areas of class room facilities and communication.

Class Room Facilities: Traditional classrooms are typically configured for a single faculty member teaching a fixed number of students in a specific teaching mode such as lecture or lab. The unique aspects of a large scale team based interdisciplinary studio demands a teaching space that can accommodate a variety of student groups 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.

Photograph 1
Team Work Station

To support this landmark endeavor, three adjacent classrooms have been dedicated to the course in the new CM building at Cal Poly. While many features of the new rooms have worked very well, there have already been lessons learned that could significantly improve the functionality of the class rooms. These three classrooms have team work areas, lecture area and faculty work areas.

Team Work Areas: Students in the course are divided into interdisciplinary teams of no more than six students with ARCE, CM and ARCH students in each team (see Photograph 1). Each student team is assigned a team work station composed of modular furniture that can be configured by the student team to fit their needs and work style. The work stations typically consist of approximately five 2'-8" wide by 6'-0" long tables, five 4'-6" long by 5'-0" tall partitions, five shelves mounted on the partitions and five movable storage cubes. The typical configuration is approximately 12' square for a total of 144 square feet of space. These student team work areas are assigned as a cold lab space, with student access 24 hours a day, and have functioned extremely well. There are 5 team work areas in each of 3 class rooms for a total of 15 team work areas. Unfortunately, the 3 class rooms are not interconnected, limiting student interaction between the 3 classes.

Technology: Typical of most new facilities, the three class rooms are equipped as smart rooms with overhead projectors for computer based presentations. One class room is also equipped with a document camera to project hard copy images. However, a significant difficulty for fostering integrated student work is the lack of computer equipment available to the students in the class room. The class rooms are not equipped with university computers although they are equipped with wireless internet access. Many students bring personal laptops to class, but these may not have the software typically available on university computers that is needed for the project. The result is that the ideal of integrated student work time often gives way to the reality of student teams fragmented in various parts of the university in order to gain access to computers and software needed to complete the project.

Security: The three class rooms are fully dedicated to the interdisciplinary studio course. The student work areas are cold labs, and students are not required to share work space with

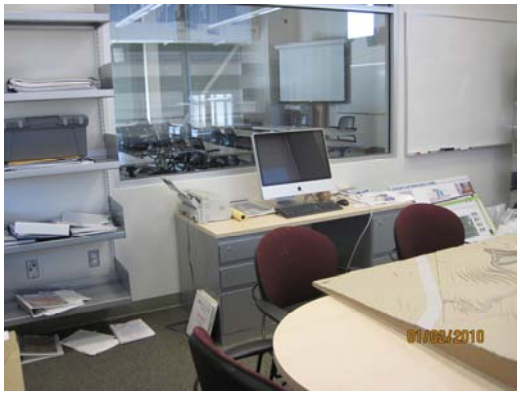
students from other courses. Each student is able to check out a key to the class room for access 24/7. In addition, each student is able to check out keys to lockable cabinets for storage of personal supplies.

Photograph 2
Lecture Space

Lecture Areas: Each of the three class rooms has a central area for lectures surrounded by the team work areas previously described. The lecture area consists of tables and chairs for 24 students (see Photograph 2). These lecture areas allow the faculty to comfortably instruct the 24 interdisciplinary students in each specific class room. These three lecture areas also allow students from each of the three disciplines to be separated for discipline specific instruction. In addition to faculty lectures, this lecture area is also used by student teams for in-progress project presentations to faculty and student peers.

Faculty Ready Room: 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. A glass partition wall acoustically separates the faculty ready room from the main class room space (see Photograph 3). The glazing provides privacy for faculty discussions and for resolving conflicts within student teams, yet provides a visual sense of connection to the students in the main class room.

In addition to the three classrooms there are requirements for large lecture areas and formal presentation areas.



Photograph 3
Faculty Ready Room

Lecture Hall: There are frequently times when instruction for the entire cohort of 72 students in all three class rooms is desirable. The class room spaces, which are comfortable for instruction of 24 students, are totally inadequate for instruction of the entire group of 72 students. This has required significant logistical effort to locate and reserve larger spaces on campus for instruction of all the students. In addition, moving to a larger class room on certain days inevitably results in some missed communication despite best efforts by the faculty.

Presentation Areas: As previously described, interim student presentations are given in the class room lecture space. However, to provide a sense of formality and professionalism for the students, the final presentations are scheduled in a conference room similar to a formal presentation in professional practice.

The second major logistical challenge to overcome is communication issues. Although there is a general acknowledgement that industry specific terms need to be defined, there are subtler levels

of communication that also need to be addressed in the course development. Each department creates and implements a vocabulary within that department which is further developed by a specific professor. Common statements will likely be construed in different ways based on the differing department cultures. An example is timeliness of assignments. When an assignment is due at 4 does that mean 4:30 is acceptable? Traditionally each professor sets their guidelines and will unthinkingly respond based on those guidelines creating unclear direction and student resentment. How does the faculty team support each other yet maintain clear direction for the students? Although these may seem to be trivial communication issues they are not trivial when conflicting information is distributed to such a large number of students.

Effective communication between faculty and students is a necessary component of any successful course. However, a large scale interdisciplinary studio adds significant complexity to communication needs due to multiple faculty from varied disciplines, multiple class rooms of students from varied disciplines and often multiple individuals representing the client for the project. Traditionally there is a single internal professor – class communication channel for any one course. For the integrated course assuming three professors and three distinct groups of students, the number of internal communication channels rises to 15. [2]

There are three primary communication channel areas; faculty to faculty, faculty to student and faculty to client.

Faculty <> Faculty: Perhaps one of the most difficult aspects of developing and teaching the interdisciplinary course is the communication amongst the faculty team. Despite written course descriptions, daily written lecture content plans, dozens of faculty team meetings, hundreds of emails, etc., there were numerous miscommunications that on a few occasions led to the bad and the ugly in faculty interaction. It takes time to communicate, and faculty that plan to participate in interdisciplinary studios should commit to spend the necessary time. Often, confrontational situations can be avoided by simply spending the needed time to read and respond to emails. Faculty must be capable and willing to participate in open, honest, trusting communication to reach a consensus based decision. This is not an easy task for faculty that are used to being in sole charge of all aspects of a course. Face-to-face faculty team meetings are critical, even with the difficulties in scheduling multiple faculty with busy schedules. These faculty meetings need to begin well before the start of the quarter or semester to plan the course and the project. During the course, faculty meetings during student work time were most effective in discussing the needed day to day coordination.

Faculty <> Student: There are several unique features of faculty and student communication in this type of course. Students often express feelings of being in unfamiliar circumstances with unfamiliar expectations. Faculty need to frequently communicate encouragement for students to engage in all aspects of the project and not be limited by perceived discipline boundaries. To help mitigate the feeling of unfamiliar expectations, an email is sent to all students before class each day outlining the schedule for the class that day and the expectations for the student's participation.

A key tool in communicating project submittal expectations to the students was the development of written project submittal guidelines. Development of these project submittal

guidelines takes an exceptional amount of faculty time and effort, and while never perfect, is critical to effectively communicating faculty expectations to the students.

One unique feature of an upper division interdisciplinary course with multiple interdisciplinary faculty is that students will be exposed, perhaps for the first time, to conflicting opinions on technical topics amongst the faculty teaching the course. While faculty may view this as a healthy interchange of ideas; for students, the conflicting faculty opinions can be confusing and discouraging. Faculty need to prepare students to deal with the conflicts by frequently reminding students to expect differing opinions, explaining each faculty member's logic behind the opinion and mentoring students in resolving the conflicting information in relation to their project.

Faculty <> Client: Since the course involves the students in real projects with real clients, client communication is critical. With multiple faculty and multiple client representatives for the project, it is critical to task one faculty and one client with primary responsibility for communication. This insures that necessary communication is occurring, yet helps to filter unnecessary emails and information overload for faculty and clients with limited time and availability. Clients, with their own needs and expectations, should be frequently reminded that the project is an educational tool in an educational process for the students. A short written description of the project goals and expectations, developed by the faculty and client, helps foster clear communication regarding the expected project outcomes.

- **Pedagogical Issues**

Pedagogically there are several goals that must be addressed for the successful implementation of the course. The overarching pedagogical goal is for a high performance faculty team to implement agreed up learning objectives. 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 a significant time and mental commitment. In addition to development of a faculty team, the course requires the creation of a fair and equitable grading system.

It is relatively easy for the faculty to concur on two learning objectives for the interdisciplinary course; function effectively on an interdisciplinary team and create an integrated building design. The challenge lies in developing universal implementation strategies 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.

A more fundamental debate focused on the product versus process issue. Is the process of learning to be an effective team member more important than creating a technically correct integrated building design or vice versa? For ARCE, the need for technical advancement seems to be a higher priority than for the other two departments which seemed to emphasize the team building and interaction process more than the substance of the project deliverable. This is a critical considering the short ten week window from which to take diverse students from differing backgrounds , meld them into a team and facilitate their creation of a quality project.

Project size is critical, since the faculty strive for a balance between these two priorities. A larger project requires more technical input limiting time for team integration.

The implementation of the learning objectives utilizes ample studio time coupled with two types of lecture formats; short general lectures to the entire group of students and detailed technical lectures tailored to specific disciplines. The general lectures/activities serve to create a common platform for the students to communicate with each other on critical aspects of their projects. These lectures may focus on educating "nonmajor" students to specific industry tools such as cost estimating to ARCE and Architecture students. Similarly, the general lectures may cover a topic such as permit regulations, presentation skills, or business practices that may benefit all students equally. The associated activity is geared to reinforce those basic concepts and further their education. The detailed technical lectures are focused on developing specialized knowledge to advance specific project requirements in order to implement viable project solutions.

The ideal implementation of the course objectives 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.[3] High performing teams need to formulate and implement specific decision making strategies. Since the competing priorities of teaching schedules and department requirements make the increased time demands difficult to accommodate, the faculty team needs to determine if consensus is required or if a basic majority is sufficient to make a change that affects the class? The cultural differences between the departments cannot be trivialized and create challenges similar to those found in business mergers and acquisitions. Fifty to seventy five % 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 other. These successful firms have developed an execution process that strongly considers the human element. [4]

Photograph 4 Final Team Presentation

Grading is a pedagogical challenge that required a complex solution. The two learning objectives; create an integrated project and function effectively on an interdisciplinary team require specialized assessment techniques. Course assessment is based on in-class activities, traditional homework assignments and three team project submittals. Differing professors 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 likely that the rest of the team will not be able to "cover" for that member. How that influences the assessment needs to be

carefully considered. A simple to administer yet fair grading concept must be developed to respond to these and other similar challenges.

The course is structured around four major assessment areas: team submittals one, two and three, and a composite activity/homework area. Each team submittal includes a presentation and a detailed client package with backup material. A grading rubric is developed which allows any faculty to grade any or all portions of the material. An excel spreadsheet is used that allows each faculty to enter a score between 1 and 10 for a specific project element. The spreadsheet adjusts the individual score by the weighted percentage and averages all entered scores to achieve the final score. The only requirement is that if a specific faculty member grades one team in a specific area such as structural framing, that same person must grade all teams in that same area. The grades are collated and averaged resulting in a single team grade for each submittal which is reviewed by all faculty. The second learning objective; function as an effective team member is assessed through faculty observation and team self reporting. As part of the submittal process, each team member evaluates themselves 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. In addition to the team grading of the submittals, there is assessment of the in-class activities and individual homework. A grade of 70% is required in this area in order to pass the course. This minimum assessment is structured to require individual accountability and encourage attendance.

The Cal Poly grading solution is still evolving but meets the needs of the current faculty. The submittal and activity grades are assembled and reviewed by all facility members prior to being turned over to the individual professor. Although the class functions as a single entity each student signs up for the course under their own department resulting in the ARCE professor being responsible for ultimately assigning the ARCE student their specific grade.

- **Conclusions**

The course launched in fall quarter 2009 with a full complement of professors and 56 students divided into 10 teams. A 60,000 square foot Visitors Center for the San Luis Obispo Botanical Gardens served as the first project. Included in the project was site development, parking for over 1000 vehicles, and a connection between the visitors' center and the planned amphitheater. Students started with a general site map and client expectations and developed a complete Design/Build submittal package which included site and building development supported by constructability, cost and schedule. In addition to the core departments of CM, ARCH and ARCE, Landscape Architecture joined the team due to the nature of this project.

Lessons learned from this quarter are:

- Team composition is likely the most critical element for student satisfaction or frustration with the course. Team composition is determined by discipline, graphical and software skills, gender and personality types. The personality preferences are determined by self scoring of a Meyer Briggs personality preference assessment. The intense time demands and the limited ability to cover for a weak team mate exacerbate team dynamics. Although these challenges mimic professional experience it does not create an ideal educational setting.

- Project size is critical, especially in determining the balance between the integrated team experience and the technical solution. Each quarter brings a new project and it is imperative that the needs of each client are fully understood prior to launching the project. A small project is better suited than a larger project. If the project is too small faculty has the ability to require a more complete design whereas a large project is difficult to downsize. The fall quarter project was too large for the short time frame. The winter quarter project, a renovation of an 8,000 square foot 1930's building with an addition is expected to better complement the available time.

- Project type is critical; the students should be reasonably comfortable with required technical expertise and use that expertise as a platform to explore the team and integrated project requirements. Winter quarter's project which involves a renovation/seismic upgrade of an unreinforced masonry structure requires technical expertise for the ARCE students that are not covered in regular course work. This additional technical requirement will be included within the course timeline and structure, preferably through some discipline-specific lectures on unreinforced masonry to the ARCE students.

- Departments and assigned faculty needs to acknowledge and accept the additional time commitment to plan and teach course. Varying levels of commitment lead to awkward situations, unclear student expectations and faculty frustration.

- During the initial iterations of this interdisciplinary course, faculty makeup and assignment is likely the most critical college decision to ensure a successful course. Department assignments need to be coupled with the faculty team requirements and buy-in as the culture, protocols, and standards for this critical course are established and accepted.

- Implement a plan to develop the "next" quarter project early. The project can serve to market the course to prospective students. However, faculty teaching the "next" course needs to be responsible for securing the project.

Based on discussion among faculty and review of student comments from fall quarter the following steps are suggested for going forward with the course.

- Develop a course framework that is based on a mutual interpretation and understanding of the learning objectives. Individual projects can then be overlaid on this framework to simplify each quarters start up effort.

- Develop faculty staffing requirements that meet the needs of the individual departments, course requirements and are fair and equitable. As part of the staffing requirements, develop a rotation that brings new blood into the course but retains enough institutional history to ensure a smooth transition and successful course.

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

- Develop a common set of student prerequisites for all departments. Choose projects that complement those prerequisites and do not require intense additional discipline instruction.

- Control professor time commitment by considering the reuse of projects and development of faculty team guidelines (communication plans, rules of engagement, decision making processes, etc.). Integrate the peculiarities of the course criteria into the departments requirements (5 units in the ARCE 3/6 unit environment requires teaching overloads).

Did the fledgling course accomplish our learning objectives? Forty four of the 56 students completed a survey where they self assessed their growth in the two learning objectives on a scale of 1 to 5. Each movement along the scale is considered to be a 20% improvement.

Learning Objective 1 - Function effectively on an interdisciplinary team. Sixteen percent of the students felt they had not improved, 41% felt they had improved at least 20% and 33% of the students felt they had improved by 40% or more.

Learning Objective 2 - Create an integrated building design. Twelve percent of the students felt they had not improved, 33% felt they had improved at least 20% and 54% of the students felt they had improved by 40% or more.

Student comments were generally favorable and focused in the positive aspects of working with other disciplines, and real projects with real clients. The feedback from the students followed similar trends to that 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.[5] 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. As the class continues to mature the learning experience for the students will continue to improve setting the students on a positive course towards Integrated Project Delivery.

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