AC 2011-475: AE STUDIO BEYOND PEDESTRIAN ACCESS: CREATING BRIDGES FOR LEARNING

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AE studio - beyond pedestrian access: creating bridges for learning

Abstract

Technological advances in digital technologies have made a significant impact on the fields of architecture and structural engineering. The trends in architectural design towards complex organic shapes and the use of Building Information Models (BIM) have generated a demand for more creative and collaborative interaction between architectural and structural professionals. This paper focuses on the case study of a joint Architecture and Engineering studio (AE Studio) offered at Cal Poly Pomona University, designed to bring the two professions closer during the educational process. The studio is focused on the design of a pedestrian bridge, constructed primarily of wood, with a span of 70-140 ft, and is structured as an internal class progressive competition with students working in interdisciplinary teams and assessment involving the faculty and outside professionals from both disciplines.

Introduction

Cooperation between the engineering and architecture professions presents a number of unique challenges. The differences between the two fields' approaches to education, with a focus on science-based problem-solving and cooperative teamwork in structural engineering, and an emphasis on artistic vision, experimentation and individual creativity in architecture, is one of the hurdles to collaboration that graduates from both disciplines encounter as they enter their careers. Most, if not all, of the learning related to collaboration between the two professions currently occurs in the workplace.

It would be beneficial to provide engineering and architecture students with an educational experience that will launch them on the path of mutually beneficial collaboration. Such educational experience should inspire engineering students to recognize the value of aesthetics in enhancing the quality of built works, to explore their creative capabilities and enjoy the process of generating ideas as part of engineering design process, and, most importantly, to become an active participant in creating aesthetically pleasing and functional designs. Similarly, such educational experience should inspire architecture students to recognize the relationship between utilitarian aspects of design and project viability, to explore their creative talents and seek beauty within these constraints, and to become a willing catalyst of successful collaboration between the two disciplines.

In this paper the authors are attempting to summarize their experience and to demonstrate the benefits of the collaboration between two disciplines during educational process and the benefits of adopting design studio concepts for engineering education in general. The authors believe that this could help to address many issues raised by professional associations of both industries and could serve as a mechanism for the constructive involvement of the design professionals in the educational process.

Structural Engineering Education

Structural Engineering is a sub-discipline of Civil Engineering, but it is not exclusive to the Civil Engineering profession. Structural engineers specialize in buildings, bridges, aerospace structures, ships and other structures. A traditional structural engineering education focuses on the relationships between loads, load resisting systems and materials performance, i.e., the determination of applicable loads and critical load combinations, selection and modeling of an appropriate structural system capable of providing a load path or paths, and selection of materials and structural elements with geometric properties that satisfy the desired demand-capacity relationship. The role of a structural engineer is to ensure that the selected structural system meets pre-determined design performance criteria.

A student with an undergraduate degree in civil engineering with an emphasis on structural design or a degree in structural engineering should typically be able to: determine loads acting on simple structures using prevailing codes; select a basic commonly used structural system; model an idealized version of the system, such that it reliably predicts the behavior of a real system; and evaluate the demand-capacity relationship of all structural elements of the system and their interconnections. In building design the construction materials are primarily limited to steel, concrete, wood and masonry. Usually, only three out of four materials are covered in most civil engineering curriculums.

The programs are intensive in their teaching of math and science and a great amount of training is devoted to objective, critical and analytical thinking, supported by rigorous mathematical analysis, commonly computer-aided. Very little training in engineering education is devoted to aesthetics, space planning, and visual methods.

Structural engineers are valued for their understanding of structural systems behavior, and their ability to quantitatively predict, evaluate and design it to prevent failures. This significant responsibility requires a great deal of training, often forcing structural engineering education to focus on utilitarian systems and solutions and discouraging changes without a prolonged vetting process. Structural engineers' creativity is thus often expressed in their ability to develop the time-tested economical structural systems that meet reliability performance requirements and minimize the risk of failure.

Architectural Education

Architectural education is still largely based on the teaching of artistic composition and techniques and architectural history and theory, with the integration and understanding of technology and building systems often seen as a necessary, but troublesome, aspect of architecture that has to be dealt with to satisfy accreditation and licensing requirements. Originality, creativity and speculation are prized and rewarded. Virtually all architectural education today in the United States is studio-based. Studios are taught every term, while courses focused on structures, environmental controls and construction and materials are generally called "support" classes and are taught for only a few terms each.

While students are, theoretically, expected to demonstrate their knowledge of the integration of building systems, including structural ones, into their designs, in practice this integration is generally limited to designated studios to meet accreditation criteria, or in isolated advanced studios that focus on small-scale design/build projects. However, with the current emphasis on sustainability and a focus on integrated practice in the professions, some architecture schools are beginning to look at ways to more fully integrate technical knowledge into design studios. With developments in digital design and fabrication techniques, and a focus on these new processes in some of the more avant-garde architectural practices, architecture schools are looking more to the kind of integration demonstrated by engineering firms such as Ove Arup when working with architects on complex projects, such as the "Bird's Nest" Stadium and the Water Cube, both designed for the 2008 Beijing Olympics. Trying to retain an emphasis on designs demonstrating originality and creativity, meaning they are not based on well known precedents, while integrating what are generally very sophisticated structural solutions remains, however, a great challenge.

AE Collaboration

The idea of a collaborative relationship between architectural and civil engineering programs is by no means a new concept, but its implementation in undergraduate education is certainly not trivial. It requires engineering faculty with a level of expertise different from that of a traditional academically trained faculty member, an educational methodology that works for both disciplines and the selection of projects that are responsive to the educational objectives. Cal Poly Pomona University presently offers civil engineering degrees within the College of Engineering and architecture degrees within the College of Environmental Design. Although there are some discussions about creating an architectural engineering minor shared between the Civil Engineering and Architecture Departments, no such program presently exists. The emphasis on structural engineering is typically addressed through technical electives. The AE Studio is one such elective.

The impetus for experimenting with this type of collaborative environment was the College of Engineering's desire to build a pedestrian bridge connecting two engineering buildings. The conceptual design by students was attempted as a senior (capstone) project effort on more than one occasion. The results were predictable; the designs produced were structurally sound and economical, but they were lacking in aesthetic and contextual qualities. In layman's terms it just did not "look good". It was clear that external expertise was required to address the missing aspects of the project. This was a case that clearly pointed to the need for collaboration between the engineers and architects.

One of the Civil Engineering faculty members suggested working with the Department of Architecture in the College of Environmental Design so that the design would "look good". The Civil Engineering Department Chair and Dean of Engineering approached the Chair of Architecture with an idea for a joint project. The co-authors, two architecture faculty members, one who teaches the structures classes and one who teaches studios, often with an emphasis on technology integration, took on this challenge with the civil engineering faculty member. This was a perfect project for a pilot collaborative effort; the site was located on campus, the client was readily available, the project and design criteria were well defined and the project size seemed to be appropriate for a 10-week quarter system student effort.

Pedagogical Approach

From the beginning, the faculty had the idea of having the students work in interdisciplinary teams. Both engineering and architecture schools are increasingly recognizing the need for interdisciplinary education as practice has moved towards emphasizing interdisciplinary teamwork. However, while studios combining design-based disciplines such as architecture, interior architecture, landscape architecture and industrial design are somewhat common, studio-based classes with engineers are virtually unknown. Although multi-disciplinary research projects involving civil engineers in environmental planning are becoming more common at the graduate and professional levels, these rarely, if ever, embrace the disciplines of structural engineering and architecture. In some architecture schools, the "comprehensive studio, which addresses an accreditation requirement to demonstrate proficiency in building systems integration, engineering faculty from other university units are brought in as consultants and sometimes engineering students are involved, but this involvement occurs after the architectural design of the project has already been established. We wanted the engineering and architecture students to closely collaborate from very early on in the design process.

While the engineering design lab has some similarities to a studio, the open-ended design process in architecture studios is not analogous to the class methods in an engineering design lab. In architecture there are seldom "right" and "wrong" answers; instead, there are a number of subjective decisions and judgments that are made throughout the design process. A class format with some aspects of the engineering lab and the architecture studio that would allow the engineers and architects to work together had to be developed.

Although the project was already selected for this pilot course, the generic project criteria, which could be used for selection of future projects, evolved over time. The decision to focus on the design of pedestrian bridges with timber as the primary material was intended to address several pedagogical and technical concerns. Bridges are typically engineering driven projects and require the greatest level of collaboration between architects and engineers at all stages of the project, from general concepts to the detailing of the connections. Pedestrian bridges are typically less design intensive than bridges carrying vehicles due to simpler loading and reduced width and span, thus limiting the project size and affording the possibility of a higher design resolution within the available time. The selection of timber as a primary material was intended to emphasize sustainability aspects of the design and to allow undergraduate engineering students to perform analysis and design within the range of their training and abilities. It was also intended to challenge the architecture students to think about the properties of the material, both structurally and aesthetically, as wood has a number of structural limitations as compared to concrete or steel; this meant that the architecture students had to develop designs that could actually be constructed of wood, which imposed some constraints at the outset of their design process.

Along with the need to address the differences in the educational models of the two professions was the very practical issue of figuring out at what point during the design process the architecture and engineering students could productively start working together. In practice, in the design of buildings, usually the architectural design begins first and the engineers' input is sought out once the design has been established. Although this was precisely the process we wanted to change, it was also essentially, where we started with the first class. It took three class offerings before we worked out a more satisfactory and collaborative design process for the course.

The first pilot class offering was developed as two elective seminars, one for the Architecture Department and one for Civil Engineering, run concurrently for two hours, twice a week over a 10 week quarter. The participating students from each department were interviewed and selected by the faculty for the pilot collaboration; the class ended up with seven architecture students and ten civil engineering students because the interest among CE students was so high that the faculty agreed to admit a few extra ones. The class was, essentially, modeled on a typical design studio, with a case study exercise followed by the design project. Despite the initial enthusiasm of the CE students, they were somewhat uncomfortable with the seemingly loose and open-ended format of the studio environment, by the new vocabulary used by the architecture students (what exactly is "materiality"?), by their unfamiliarity with researching and learning through case studies, something that the architecture students do almost every term, and with the unconventional designs proposed by the architecture students. The architecture students were not comfortable with accepting the reality of wood construction and adjusting their designs to meet the limitations of the material, with making basic design decisions early enough for the engineers to complete their analysis by the end of the quarter, and with having an elective that was structured so that they essentially had two studio classes in one quarter.

Several challenges emerged in this first class. It became fairly clear, that (1) the class should be set up as a full studio for architecture students; (2) the engineering students need more detailed orientation on the pedagogical approach used and detailed instructions on case study preparations; (3) that architecture students needed an early introduction to the various types of bridge structural systems and more detailed instructions on the material properties of wood for consideration in their design; (4) the design collaboration between the architecture and engineering students had to start as early as possible in the quarter; and (5) both disciplines needed instructions on the importance of the design schedule and the coordination of their design development documents.

Over the next two years the course was refined to address these concerns. The Architecture Department changed the course to an upper division design studio; this gave the students more units and more time for the class, but also meant that the students self-selected the course. It also meant that the architectural students were scheduled to meet 12 hours each week, for three four-hour sessions, while the Civil Engineering Department kept the course as a 400-level technical elective and the engineering students were scheduled for 4 hrs each week, with two two-hour sessions that coincided with the last two hours of the architectural studio. While this schedule did not allow for as much scheduled collaborative time as the faculty would like, the engineering faculty and students committed to working much longer hours in class than the schedule reflects to enable the interdisciplinary teams more time to work together. The class schedule of project assignments evolved each year to better address the collaborative process, although it is still a work-in-progress. Subject to budgetary constraints, there is a desire by the Department of Civil Engineering to replace the four (4) lecture units with two (2) lecture units and two (2) activity or design lab units. This will increase the contact time from four hours per week to eight hours per week.

The demand for the class every year has either exceeded or met the capacity. The total number of students has ranged between 30 and 34 with 11 engineering students and 19 architecture students in the second year,16 and 18, respectively, in the third year and 16 and 14, respectively, in the fourth year.

Course Organization

The course was divided into three distinct phases:

(1) Case study and Conceptual Design (3 weeks)

(2) Preliminary Design (3 weeks)

(3) Design Development. (4 weeks)

Several lectures were presented by faculty and by guest speakers to introduce or refresh students' knowledge of structural systems, design concepts, material properties, costs and availability, connectivity and analysis, and design techniques. (Attachment A).

Case Study and Conceptual Design Phase

The case study phase involved architectural and structural design review of existing pedestrian bridges in various parts of the world. The class was organized into interdisciplinary teams of four to five students to study one of the pedestrian wood bridges presented during the first class meeting. The case studies included bridges from different parts of the world (Europe, South America, and the United States), exhibiting a variety of structural systems, such as arches, trusses, beams, suspension systems and combined systems. (Attachment B). The teams were required to prepare a case study consisting of a presentation and a written report. (Attachment C)

Since the case study in this format was a new experience for the engineering students, several learning objectives were established for this exercise. The students were required to:

(1) research information necessary to perform a conceptual level demand estimate (consisting of researching applicable local codes, a cursory comparison to U.S. code requirements and a preliminary loading estimate) of the case study structure;

(2) identify the primary structural system and all associated structural elements;

(3) identify the secondary structural system and all associated elements;

(4) develop the conceptual level simplified structural model (consisting of identifying primary elements of vertical and lateral force resisting systems and anticipated force flow load path);

(5) determine demand on critical members and connections using a combination of classical and computer analysis, and present and qualitatively describe structural behavior and the expected critical load path;

(6) identify critical structural integrity concerns and considerations.

For architecture students, case studies, as mentioned earlier, are a fairly common learning tool and a standard approach to any design effort. It is considered trivial and is not described in detail in this paper; the students researched the project and presented historic, contextual, conceptual, functional and aesthetic analysis of the chosen bridges, as well as researching the designers and their design intentions.

It should be noted that typically the architects were able to complete their portion of the case study work in 1/3 the time required for the engineers. Joint and staggered case study presentations by the architectural and engineering members of the team were tested. Although both approaches had their pros and cons, the importance of early closer cooperation between architects and engineers outweighed the time efficiencies derived from staggered presentations and joint presentations were determined to be of greater value. We found that the architecture students were able to start the conceptual design phase of the assigned project while the case study work was proceeding, which allowed the design process for the assigned project to start early enough in the quarter for meaningful design collaboration to occur.

At the end of this phase the students jointly presented their case studies to the rest of the class. This allowed exposure of all students to multiple case studies and generated question and answer sessions which, combined with faculty critique and comments, helped to prepare students for active participation in the collaborative design process. While working on the case studies, the engineering and architecture students were exposed to each other's terminology, and developed a deeper understanding and appreciation of the challenges of each discipline. They were better prepared to ask each other the right questions in language both understood, answer each other's questions early on in the design process, and to collaborate more effectively in the next phase of the class.

All of the architecture students worked on producing individual concepts that were jointly reviewed and critiqued by the architectural and engineering faculty with the active participation of students from both disciplines. These conceptual designs, which represented a design vision presented as a sketch model, were combined, through a self-selection process by students under faculty direction, into approximately 10 distinct designs for further development by interdisciplinary teams for the next phase of the course. At this point in the design process, the bridges had to have a viable structural concept that could, conceivably, be realized in wood and a design that had aesthetic potential.

It is important to emphasize the difference between conceptual and preliminary design. This aspect of aesthetic design is not familiar to engineers, but its understanding is essential to successful collaboration. In practice engineers are typically not privy to this phase of the design and as a result are lacking a basic understanding of the design vision, which impacts their ability to contribute to the subsequent design phases.

Preliminary Design Phase

This and the following phase of the project were set up to work as a progressive competition. By forming the interdisciplinary teams for this phase based on students' interest in a particular design, our intention was to accommodate everyone's preferences as much as possible, so that each team had a vested interest in the success of their design.

The engineering learning objectives for this phase of the course were that the student, with faculty guidance, should be able to:

(1) evaluate conceptual designs and suggest a few options for primary and secondary structural systems;

(2) perform conceptual analysis and estimate preliminary sizes of critical members and identify critical connections;

(3) prepare preliminary two-dimensional or, where required, three-dimensional computer models with appropriate boundary conditions;

(4) prepare preliminary structural drawings, including structural plans, elevations and details;

The learning objectives for the architecture students in the preliminary design phase were that students should be able to:

(1) incorporate structural concepts in the early stages of their design process;

(2) make adjustments and develop the initial design in response to aesthetic, functional and structural criteria;

(3) work collaboratively in interdisciplinary teams;

(4) produce appropriate models and drawings to represent the design projects in coordination with engineering students;

(5) coordinate overall presentations for the mid-term review.

The deliverables included preliminary architectural and engineering drawings, a ¼' scale model of the proposed design shown on a site model, and a joint presentation developed by the whole team. The students were provided with the detailed rubric and rating system that would be used by the external reviewers so that they knew what criteria would be used to evaluate their designs.

The mid-review was attended and judged by professionals and faculty from both disciplines, typically including 2-4 external registered structural engineers, 2-4 external registered architects and 2-3 faculty members. The guests were provided with project design requirements and the grading rubric and assessment form. (Attachment D) They were asked to rate each project on a number of architectural and engineering criteria, including originality and constructability. The team scores as rated by the guests were combined with faculty assessments and observations to select four or five projects for further development for the final review.

The members of the teams that were not chosen to continue past the mid-review joined the winning teams with preliminarily team assignments made by the faculty and final assignments made in consultation with the students to accommodate their preferences. The winning teams led the effort of the enlarged teams through the design development phase.

The team merging process was considered a critical juncture and a teachable moment for discussing the attitudes of teams whose projects were selected and those that were joining them.

The faculty had to pay close attention to team interactions and to emphasize and remind the students about the attributes of professional behavior.

Design Development Phase

During this phase of the project the enlarged teams, typically 6-8 students with approximately equal numbers of architects and engineers, were asked to further develop the selected designs. The deliverables for the final phase of the project included:

(1) ¼” scale model of the design
(2) 1” scale section drawing and model of the project (specific section chosen with faculty guidance)
(3) drawings and models of critical connections (selected with faculty guidance)
(4) set of engineering and architectural drawings through design development phase.
(5) Power Point presentation including an animated walk-through of the design
(6) presentation posters

The learning objectives for the engineering students for this phase of the project required that students should be able to:

(1) finalize the demand calculated during the preliminary phase of the project;
(2) finalize the idealized structural model of the primary structural system;
(3) complete structural calculations of critical structural elements of the primary force-resisting structural systems;
(4) perform final analysis and estimate preliminary sizes of critical members and identify critical connections;
(5) perform final analysis and design of critical connections, typical supports to foundation connections, supports to deck connection, and supports interconnections, if present;
(6) prepare structural drawings through the design development phase, including structural plans, elevations, sections, and selected connections, with critical dimensions and limited notes only.

The learning objectives for the architecture students for this phase of the project required that students should be able to:

(1) finalize major aspects of the design related to the structural analysis quickly so that the engineering students had sufficient time to perform the analysis;
(2) respond to input from the mid-term review and from faculty to resolve all aspects of the design at the level of design development to address aesthetic, functional and structural issues;
(3) work collaboratively in a large interdisciplinary team;
(4) produce appropriate drawings and models for the projects in collaboration with the engineering students; using appropriate digital tools as required;
(5) coordinate final presentation for team.

The design development phase final review panel typically had many of the same guests that attended the mid-review as well as some new guests. The final design rubric and assessment forms were distributed to the panel (Attachment E) and the panel evaluations and faculty observations were used to assess the quality of the projects. The intent of this studio was always to deliver a design concept that would be accepted by the client and would be suitable for construction. Although each year highly qualified projects evolved for implementation, only at the end of the third year of the class, the clients, the Dean of Engineering and the Chair of Civil Engineering, selected a design that will be passed on to design professionals for final design and construction. A sampling of the student designs for this site, developed during the last three class offerings, is shown in Attachment F.

Next Project Selection

With the completion of the first project and with the course evolving from a pilot project to a regular offering, the sources of new projects for the AE studio became an important issue. A few ideas were explored, but ultimately one surfaced as the best choice. The US Forest Service is constantly in need of improving their sites in the national parks and these are perfect locations for timber pedestrian bridges. After a few unsuccessful attempts by various faculty the Architecture Department Chair was able to identify a contact person in the US Forest local to the university who has embraced the idea of a cooperative arrangement. This year the AE studio is developing design concepts for a 140 ft pedestrian bridge in the Angeles National Forest. The close proximity of the site to the university allowed students to visit and study the site. The examples of mid-review designs from this project, developed during winter quarter 2011, are shown in Attachment G.

Observations

In general, the response from both the architecture and engineering professions has been very positive. Guest lecturers and reviewers have all expressed their view that there is a need for more education of this kind and that they have been impressed by the quality and quantity of the work the students have produced in their collaborative design process. The administrations of both Colleges and Departments involved in this class have been supportive of the effort and have begun to explore future larger collaborations including an Architectural Engineering minor and a Master's degree in Architectural Engineering focusing on such design collaborations in studio classes. Student enthusiasm has been steady; there is increasing interest among students in interdisciplinary classes as they realize that this is the future of the professions. It is worthwhile to mention, that a number of the guest design professionals regularly serve as judges for the class reviews and find the experience inspirational and look forward to serving on the panel each year. Here is a comment from one of the design professionals serving as a judge.

> *"The Cal Poly Pomona AE design studio project review process is rewarding to both the students and the reviewers…. The peer review process using professional architects and engineers is unique to this class, and gives the students valuable insight into professional expectations when defending their ideas and designs"*
>
> *Michael A. Waggoner, S.E.*

Course Assessment

An objective assessment of engineering students in a design studio environment involves very different assessment techniques from that of a typical engineering class or lab. This is further complicated by the interdisciplinary nature of the teams. The informal student exit interviews, follow up discussions with former students and judges' interviews, were used to assess the value of this course and helped to identify and strengthen successful practices and eliminate or improve shortcomings. Some of the course's lecture subject matter and timing were adjusted as a direct response to students' and judges' comments. For example, lectures and guest speakers were added during the case study phase. This helped to make significant improvements in the quality of the case study presentations and improved the coordination of the architecture and engineering students' collaboration in this phase.

In the exit interviews the students noted some of the timing difficulties related to the architectural and engineering interaction. It became clear that engineering students were sometimes unable to proceed with the design early in the quarter because the architecture students continued to change the design and the engineering students were too overloaded during the last three weeks of the class to do all of their work at the end. Strict deadlines were established for engineering-sensitive decisions and engineering students were required to monitor these deadlines and sound an alert to the architecture students and faculty (who also monitored the design process) if these were slipping.

Following are comments from some of the architectural and engineering judges that have been involved in the studio for the last three years. They were asked to provide some reflection on why they are willing to take 6-8 hrs of their time, typically on Fridays, to judge students' designs.

Will Sepphired is a registered engineer and architect. He is a principal of his own successful architectural firm. He has been an active member of our judging panel for the last three years and has regularly provided invaluable input.

> *"The… AE Studio is unparalleled in the integration of form making and engineering design within the academic studio setting. Each year the Studio provides students of both disciplines profound insights into the challenges of working with their soon to be professional peers while designing a real world project. The hand-on experience further prepares the students for their divergent professional careers. I wish they taught like this everywhere."*
>
> *Will Shepphird*
> *P.E., A.I.A., LEED AP BSCP*
> *Shepphird Associates*

Judson Taylor is a Senior Principal of one of the leading AE firms in the U.S. and has been a regular on the judging panel.

> *"…. The impressive technical quality of the collaborative projects, from concept to detail, shows the value of the integrated studio model."*
>
> *A. Judson Taylor, Architect (CA), AIA, LEED AP*
> *Senior Principal*
> *Simpson Gumpertz & Heger*

Michael Waggoner, quoted earlier, is an alumni and a principal of a major structural engineering firm. He has also been intimately involved in the AE studio judging process and has provided significant input in the development of this course.

"…The engineering students are able to experience real world pressures of client expectation, and working with an architect to determine quickly, with minimal calculation effort, which ideas and systems are structurally viable. The students work through their solutions to prove that the systems are constructible and can be designed into a building code compliant system."

Michael A. Waggoner, S.E.
Principal
Ficcadenti & Waggoner, Inc.

Former engineering students of the AE studio were asked to write one or two paragraphs reflecting on the positive and negative aspects of this studio a year after they took the course. The following are some of their thoughts.

"…Ultimately, the most important concept learned, now that I'm writing this, has to be the load path. If one cannot trace the load path to the foundation, the system cannot work! I would like to say that this class had a great impact on me. Mainly because of the way it was taught, (by one of my favorite professors!) and the environment it was in. The competition format helps a lot because everyone wants to win. I was extremely thankful for the required presentations that the course entailed. It was amazing that you were able to bring industry professionals to our presentations and I am appreciative of it and want to thank you again for it."

Daniel Mourad, AE Studio student, 2010.

"This class taught me a tremendous amount about team work and about thinking outside the box, much more than any other class that I had. I feel that the AE Design Studio was the most important class that I took in all of my years of schooling. Everything before this built up to support this class."

Bryan Merchant, AE Studio student, 2010.

The studio format requires close faculty observation of each student in a mentorship style that provides students with instant feedback in each class and allows faculty to guide students through the design process. Engineering students that are not used to the studio format may get frustrated with the open nature of the assignment and the open nature of creative process, but continuous faculty input to both architecture and engineering students helps to establish structure and clear goals within this more open-ended format.

Lessons Learned

The studio experience presented a number of challenges for engineering educators and students and several key issues have to be addressed in order to make this kind of studio-based course successful:

1. Faculty selection for working in a studio environment and student orientation can significantly impact studio quality. Engineering faculty must be flexible and be ready to consider, evaluate and propose multiple solutions for structural systems. Architecture faculty must be able to embrace structural solutions as a positive contribution to the design

process and have a basic understanding of how structural systems work and are applied to bridge design. They set the tone and quality of the collaborative effort by example.

2. Careful selection of the design project chosen for the collaborative course is required. Ideally, the project should be one that requires close collaboration of architects and engineers early on in the project, is not too large and does not entail many complex functional programmatic requirements that will take focus away from the technical aspects of the design. Projects may be repeated, as the architecture students are adept – and take pride in – coming up with new solutions to problems every year.

3. It is extremely important that the acceptance criteria for engineering students for a studio type class is significantly above the minimum and that some form of orientation is performed either prior to taking the class or during the first class meeting. The performance expectations have to be clearly communicated to the incoming engineering students in order for them to be able to quickly adjust to this kind of class format.

4. An early structural system review lecture positively impacts students' case study performance and the depth of preliminary designs.

5. Specific deadlines for architectural design and engineering design must be established and strictly enforced to avoid feast-famine work schedules.

6. Faculty must make the final determinations on which projects will proceed to the design development phase, with special consideration given to teams' collaboration and the projects' educational value. Weaker teams tend to have great difficulties in integrating new members and some seemingly weak or difficult designs offer valuable lessons for all. The judges input is very valuable, but it is advisory not final.

7. The usual assessment techniques are not easily implemented in this environment and faculty needs to assume a mentorship role and guide students with thoughtful feedback throughout the course. Objective assessment techniques require additional research and experimentation.

8. The studio based educational environment provides an inspirational and motivational model that is very difficult to capture and to communicate on paper. It brings class energy and excitement that most teachers can sense when the students seem to leap in front of the teacher and are exploring on their own and relying on the teacher only to help them navigate through unfamiliar territory. The following images are intended to provide some insight into the studio environment.


After-class


Collaboration


Cooperation


Teamwork


Creativity

Conclusion

The AE studio format for interdisciplinary education of architectural and engineering students has been recognized by participating design professionals, academic colleagues and university administrators as an example of a successful learning experience for students from both disciplines. This use of the studio format for engineering education has been inspirational and has generated a level of creative excitement that is not easy to generate in engineering classes. It provides an environment where students are able to (1) synthesize discretely learned subjects into unique hands-on experience, (2) practice their teamwork skills in a culture with a different, but allied, profession, (3) practice their verbal, written and graphic communication skills within teams and in front of design professionals, (4) experience a peer review and critique environment and (5) learn to remain professional and project focused. This type of environment, however, requires a specific set of skills from the educators and requires greater resources than those allocated for typical lecture classes. We believe that this case study demonstrates the significant value of the design studio approach for engineering and interdisciplinary education, and justifies devoting energy and resources to further research of this educational model.

The faculties involved in this studio are continuing to refine the course structure so that the interdisciplinary collaboration can continue to develop; we are currently exploring offering another AE studio focused on precast concrete design ideas. We envision the integration of other disciplines, such as construction technology, into these studio courses in the future as the Architectural Engineering minor and Master degree program are developed.

The availability of engineering and architectural programs in our university facilitated the AE studio collaboration, but this model could be used by civil engineering departments in universities that lack an architecture program by partnering with a local university that has an architecture program but none in civil engineering. If no such local university exists, local professional architects, all of whom were educated in a studio-based system, could be brought in as guest critics or adjunct faculty to help to develop a studio-based course for engineers; this would not have the advantages of allowing students to work in interdisciplinary teams, but it would expose the engineering students to the culture and design methods of the architecture discipline. These alternatives would require some experimentation before they could be widely implemented.

Although the hard scientific data has not been assembled yet, feedback from design professionals, faculty observations and informal student interviews demonstrate the high potential value of the use of the design studio in engineering education. This model can also create a unique and inspirational opportunity for design professionals to be involved in the educational process. As the professions and educational accrediting organizations embrace integrated practice, this AE collaborative interdisciplinary studio could serve as a model for universities to address this issue.

Bibliography

The provided bibliography was used as an inspiration for documenting this AE studio experience and is not specifically used in writing this paper.

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Attachment A

AE Studio - Winter 2011

Course Syllabus

(Minor editing and formatting changes were made for inclusion in the paper)

CE Prerequisite: CE433/433L – Timber Design
CE Co-requisite: CE4XX – Design Course (Steel Design or Concrete Design)

Designing and Engineering a Pedestrian Bridge

This course will be a collaborative effort of the Departments of Architecture and Civil Engineering and this quarter will focus on the design of a pedestrian bridge in the Angeles National Forest. Architecture and Civil Engineering students will be working in teams on the architectural and structural design of approximately 120-160 ft pedestrian timber bridge for the U.S. Forest Service.

We will start by examining a number of case studies of existing bridges and then move on to the assigned design project. We expect the final bridge designs to be highly resolved, both architecturally and structurally. We anticipate some lively discussions between members of the two disciplines, revealing the different vocabularies of the two cultures. Architecture students will have to explain what they mean by the term “materiality” and engineering students will need to explain what a SAP model is. Civil engineering students will learn about the open-ended nature of design studio classes, which involve a lot of free-spirited discussion and speculation, rather than lectures and quizzes. They will be challenged by the non-standard shapes architecture students propose which will require thinking beyond standard structural models and they will have to deal with restrictive architectural parameters (yes, we really want it to be that thin and no, we don’t want a structural support there). The architecture students will have to learn about the impact of structural requirements on their visions and to collaborate (ok, in order to keep it that thin, we can add another structural support) to produce a viable design. Civil engineering students will learn to make informed aesthetic judgments and architecture students will learn how their aesthetic choices affect and are affected by structural considerations.

The class will have mid-term and final interdisciplinary reviews, with representatives from both departments and guest-professionals from both disciplines. As the project is intended to be realized, the design projects will be used to move the real bridge forward and one may very well serve as the basis for the actual design.

Process (Case Study – Preliminary Design – Final Design)

Students will work in interdisciplinary teams throughout the quarter. The studio will start with teams researching relevant case studies, focusing on bridges that are largely built of wood. The majority of the quarter will be devoted to team design of the assigned pedestrian bridge. Small teams will be formed for the preliminary design phase of the project. After the mid-review, larger teams will be formed to work on the designs selected to proceed to the final review.

Design Charge

These are the design objectives, as defined by the U.S. Forest Service:

> “The bridge will provide pedestrian and bicycle access across the West Fork of the San Gabriel River, connecting the West Fork day use area and the North Fork San Gabriel Scenic

Bikeway. It will synergize the use of both the day use area and the bikeway, by making the bikeway available to those enjoying the day use area, and making the restroom, parking, and picnic table facilities available to the bikeway users. The primary purpose of these improvements is to provide accessible recreation opportunities, to prevent further erosion to the stream banks, heritage resource and habitat protection, and to address safety concerns. Currently, the public is crossing the stream wherever it chooses or by using a busy highway road bridge that does not have a walkway. A trail bridge will provide a direct and safe accessible route to cross the stream. The project would also include an accessible trail and approaches to the new bridge."

The new bridge should enhance the site by incorporating a structure that has materials and coloring to blend with the environment per the Built Environment Image Guide. The design should minimize the amount of materials used, in order to be consistent with maximizing sustainability and to minimize construction costs. Durability and maintenance also should be considered in the interest of minimizing life-cycle costs and providing a structure with a design life of at least 50 years.

Architecture Student Objectives

Architecture students will provide leadership in the area of conceptual design, basic design direction (from the aesthetic point of view) and architectural detailing. You will be responsible for:

1. Becoming familiar with the design objectives for the project provided by the U.S. Forest Service.
2. Developing conceptual design alternatives working in teams with CE students
3. Evaluating the feasibility of conceptual design alternatives working in teams with CE students.
4. Developing designs working in teams with CE students.
5. Developing critical architectural details for the final project.

CE Students Objectives

The role of CE students is to provide leadership in the following areas of expertise: geotechnical, civil and structural. You will be responsible for:

1. Becoming intimately familiar with the project site and to be the source of information and reason for properly addressing various site concerns.
2. Developing/Complying with Engineering Design Criteria for the project such as, Live, Wind, Seismic and other load criteria. This also includes becoming familiar with the site's soil conditions.
3. Contributing to the aesthetics of the design by developing preliminary alternative structural schemes with preliminary dimensions.
4. Determining loading demand, developing a simplified structural model, performing structural analysis of the structural model using SAP software for critical load combinations and designing key structural elements.
5. Developing critical detailing: support to foundation, primary structural members to supports and any other detailing that impacts aesthetics of the structure.

The architectural studio class is scheduled MWF 2:00 – 6:00 p.m., while the CE class is scheduled MW 4:00-6:00 p.m. The CE students should also be available on Fridays from 2:00 – 6:00 pm for teamwork activities. The CE students are also absolutely welcome and encouraged to meet with their teams during other studio times.

Grading and Attendance

All students are required to attend all classes and complete all assignments on time. Any student who has more than three unexcused absences may be failed in the class. Whenever possible, discuss any necessary absences with your instructor before you are absent or very shortly thereafter.

ARC and CE Student Grading

Item	**%**
Case Studies Presentation	15
Conceptual Design/Design Criteria Development	15
Preliminary Design Presentation	25
Attendance/Participation/Contribution	10
Final Presentation	35

Academic Integrity

Students are expected to be familiar with University standards of academic integrity published in the University catalogue and to conduct themselves in accordance with these standards.

Schedule

Wk	Date	Discussion	Project
1	Jan 3		Introduction of Project and Case Studies, Team formation, selection of case studies
	Jan 5	**Lecture 1:** *Structural Systems, Modeling, Loads and Load Path* **Lecture 2 (Online):** *Engineered Wood – Glulam and Plywood.*	
	Jan 7		Field Trip to project site
2	Jan 10	**Lecture 3: Guest Speaker -** Standard Structures	**Design Project Starts**. Project criteria, code requirements and other issues discussed in first preliminary designs.
	Jan 12	**Lecture 4: Guest Speaker –** Western Wood Preservers Institute	
	Jan 14		
3	**Jan 17**	**Holiday - Martin Luther King B-day**	
	Jan 19		**Case Study** presentations and reports due. (AE joint presentations) **Design Project:** brief presentation of the conceptual designs and AE team formation.
	Jan 21		
4	Jan 24		Conceptual Design Continues
	Jan 26	**Lecture 5:** *Wood Connections, the architecture of structural connections*. **Lecture 6: (Online)** *Design of Bolted Connections, Design of Heavy Timber Connections*	Conceptual Design of Primary Structural Systems due. At least two feasible options are required.
	Jan 28	Design	
5	Jan 31	Design	
	Feb 2	Design	
	Feb 4	Design	
6	Feb 7	Design	
	Feb 9	Design	**Mid Term Review**
	Feb 11	Design	Design consolidation and team organization for Architects
7	Feb 14	Design consolidation and team organization for A/E teams	Top 5 designs team formation. Design Development
	Feb 16	Design Development	
	Feb 18	**Holiday - President's Day**	
8	Feb 21	**Lecture 6:** *Structural Drawings and Calculations*	
	Feb 23	Design Development	
	Feb 25	Design Development	
9	Feb 28	Design Development	
	Mar 2	Design Development	
	Mar 4	Design Development	
10	Mar 7	Design Development	
	Mar 9		
	Mar 11		Final Review
11	Mar 14	1:40 – 3:40 (A) 3:50-5:50 (E)	Project Submittal

Attachment B

Examples of Case Study Pedestrian Bridges

(The information on case studies is typically provided in the Learning Management System)

Case 1: Madison Bridge

This bridge was selected for case study to demonstrate the use of beam type structural system and the use of stress laminated timber deck design concept, and explore the preliminary design approaches to the analysis of curved shapes.

Case 2: Da Vinci Bridge

Panoramia by **winds02**

This bridge was selected for case study to demonstrate the use of arch type structural system and the state-of-the art use of large size gluled laminated beams. This design is based on 1502 original design by Da Vinci across Golden Horn.

Case 3: Reuss River at Flüelen

Photo by **Tomas K☼h☼ut**, published at Panoramio

This bridge was selected for case study to demonstrate the use of arch bridge structural system and the use of leaning arches with moment connections between arches to resist lateral loads.

Case 4: Travesina Bridge

http://www.archistructura.net

This bridge was selected for the case study to demonstrate the use of lenticular truss type structural system and the impact of the construction requirements on the design. One of the design criteria for this bridge was to minimize bridge weight to allow for helicopter delivery to the otherwise inaccessible site.

Attachment C

Case Study Requirements (CE Students/Architecture Students)
(Minor editing and formatting changes were made for inclusion in the paper)

Written Report
The written report is a concise summary of your case study and should provide brief overview of all relevant components. The report should conform to following standards.

Font: Arial, size 11, single space.
Page Layout: Paper 8.5x11 with 1" borders all sides, page numbers bottom, and center.
Paper Length: Title page**,** 5 pages body, attachments.

The report shall consist of the following sections:
- Project Information
- Introduction
- Project Description
- Structural Design
- Construction
- Highlights
- Conclusion (Reflections)

(1) Project Information
This portion of the report shall contain general project information, such as:
- Completion Date
- Location
- Client
- Architect
- Engineer
- Contractor
- Primary Materials

(2) Introduction
This portion of the report would focus on the historical information related to the project. How it was conceived and why was it needed.

<u>ARC: Historical information as above. Also, what is interesting about the design? What other designs might have influenced it?</u>

(3) ***Project Description***
This portion of the report would focus on the specifics of the project. What type of project is it? What are some of the critical requirements of the project? What are some of its unique characteristics? What were some of the challenges for an architect and/or engineer.

<u>ARC: What was the architectural intent and how it was accomplished?</u>

(4) Structural Design
- *Design Criteria*
  This paragraph should describe the design criteria used for the design of the structure. More importantly, what design criteria was used for your evaluation and why? Specifical-

ly: Dead, Live, Seismic, Wind any other loading. Number of the bridges are located in Europe, thus you might need to relate our code requirements to local conditions of the site.

ARC: Describe the basic design decisions that you think led to the specific form.

- *Description of the main structural system.*
  This portion of the report should describe structural systems used: foundation system, vertical load carrying system, lateral load resisting system. The descriptions should be written in scholarly language and should answer at least some of the following questions.
  - What materials are used for the main structural system?
  - What does idealized structural model looks like?
  - What are the primary components of the system?
  - What was the design intent?
  - What is the load-path for vertical and lateral loads?
  - Describe any irregularities in the system, if present.
  - Identify critical detailing and explain how it relates to design intent.

  Note: Most of these questions are best answered with diagrammatic sketches and brief explanations.

ARC: Note that Architecture students will be responsible for coordinating drawings and graphics of the presentation.

- *Analysis and Design*
  Develop simplified structural model and perform approximate analysis and design by hand or using computer software. Describe analysis to be performed, identify computer software used and the assumptions used for developing structural model. You should be able to answer following questions: Does the structural model reflect the actual behavior of the structure? Do selected support conditions properly reflect actual conditions? Does my idealize model reflect properly my connections? What are the most critical areas of the structure? What maintains the stability of various elements of the structure? Are member sizes appropriate?
- *Construction*
  Discuss how the structure was constructed and highlight any special challenges.

(5) System Highlights

This section should highlight most challenging portions of the structure and focus on areas that do not easily fit into standard design and construction practices. This could be main systems, secondary systems or connections.

(6) Conclusions

Describe what impressed you the most in this structure. What would you consider using in your future designs? What would you consider doing differently, if any? Focus on two or three items that you have learned from this study and would like to share with your classmates.

ARC: Draw conclusions as above. Also- How successful is it aesthetically? How well are the details integrated into the concept and the overall design?

Report Supporting Attachments - Calculations and Sketches

This is primary supporting information for your report and serves as the basis for your writings and conclusions. These should also be very helpful as images for supporting your statements in the presentation slides.

(1) Sketches. Provide as a minimum:

1. Simplified structural model of your main structural systems.
2. Plan view and elevation. It is customary to use architectural information to overlay your systems information.
3. Sketch critical connections.

(2) Calculations

This section should provide all preliminary calculations performed in your case study. These do not have to be very precise or detailed. This is your first iteration of the design and should be limited in scope to most critical areas. This is the work engineer would perform in the early stages of the project in order to select a structural system and to identify areas that would require special attention.

PowerPoint Presentation

Present your report using PowerPoint presentation. The presentation should be approximately 10 minutes including time for Q&A questions. This would typically require about 10 slides. <u>It is important that the slides are used to compliment your points and not as a reading material for presentation, unless you are referencing code tables or specific language from the code.</u> Typically you would have an Introductory slide, 1-3 slides on Design Criteria, History, Project Information, 2-3 slides on Structural Design, 1-2 slides on Construction and 1-2 slides on highlights and conclusions.

Few points on slide preparations:

(1) Select colors that are easy to read. (please no red on blue or black, or pastels on white)
(2) Do not overcrowd one slide with information. Do not be afraid of open space.
(3) Typically each slide should make 1- 3 points.
(4) Use font type and size that is readable from a distance.
(5) Stay away from excessive sound and transition variations. This detracts from professional presentation. (Fade and Appear work best for animations)
(6) Provide good introductory slide. (Take the time to present your team and your project before getting into details)
(7) It is not necessary to have presentation outline if you can create an engaging story with your presentation. If you will present in sections an outline identifying section might be helpful.

<u>ARC: Again, please note that Architecture students will be responsible for coordinating drawings and overseeing the graphics of the presentation.</u>

Grading Rubric

Report	50-45	44-40	39-35
Complete	All components of the report covered	Minor components are missing	Major components are missing
Correct	The information provided is of high quality and is reliable	The information provide is somewhat reliable and number of questions are unreliable	The information provided is not very reliable and major questions are left unanswered
Professional	Report is presented in a professional manner with appropriate cover sheet , table of content, index and bibliography	Report is presented in professional manner, but some of the components missing.	The report is not presented in professional manner and is sloppy and unorganized.
Well-written	Good writing style, effective used of the appropriate technical terminology	Writing style is acceptable. The use of technical terminology is not too effective.	Difficult to read writing style and poor use of technical terminology.

Presentation	100-90	89-80	79-70
Slides	Appropriate quantity and quality slides are used. Images are very effective.	Too many or too few slides were used. The slides were hard to read or too packed. Images were somewhat effective.	The quantity of slides was insufficient to make points and/or slides were ineffective.
Notes	Slides compliment notes and present concise summary of the report.	Slides and notes are not effectively integrated and are used as reading outline.	Slides and Notes do not match well and are not very effective.
Delivery	The delivery of the presentation was clear, concise and with confidence.	The delivery was difficult to follow and confidence level was medium	The delivery was sporadic and with low level of confidence

Attachment D

Mid-term Review Rubric

(Modified slightly for this paper)

The intent of this review is to select four or five designs that will proceed to final review. The students are required to complete the Preliminary Design phase of the project for this review. Specifically, they are required to identify, coordinate and substantially resolve all critical aesthetic, functional and structural integrity issues. The selected designs will proceed through the Design Development phase of the project.

Please assign points to each design for each category on a scale of 1-5 (5 being best), except for the last category, "Overall Impression", in which each design can receive between 1 and 10 points.

Mid-term Review Rubric

	5.0-4.0	**3.9-3.0**	**2.9-2.0**	**1.9-1.0**
Aesthetics How attractive is the proposed design and how well are various design elements resolved?	The design is attractive and all design elements are resolved	The design is attractive, but some of the design elements are unresolved, but could be easily resolved.	The design is somewhat attractive and number of elements need resolution	Number of critical elements that would make design attractive are unresolved
Originality How unique is the proposed design and does it stand apart from other designs you have seen before.	Very unusual.	Some original elements.	Seems somewhat familiar.	Variation of the existing designs
Functionality How well does it work?	Works very well	Works pretty well, with a few resolvable problems	Has some difficult to resolve problems	Would require major redesign.
Response to Context How well does it fit into the site and surrounding spaces?	Fits very well into site and context	Largely fits, needs some adjustments	Needs considerable adjustments to fit into site and context	Awkward in site and context

	5.0-4.0	3.9-3.0	2.9-2.0	1.9-1.0
Structural Integrity To what degree selected structural systems resisting vertical and lateral loads are fundamentally sound and are designed to provide necessary capacity for the minimum required demand	Fully resolved	Somewhat resolved	Barely Resolved	Unresolved
Inter-Connectivity To what degree critical connections are substantially resolved and are fundamentally capable of ensuring expected behavior of the system.	Critical Connections are fully resolved	Critical Connections have problems that can be resolved	Critical Connections with major problems that are difficult to resolve	Unresolved major issues.
Constructability How simple it is to construct proposed system for a reasonable cost. Are major issues, such as transporting large components, on-site assembly, labor qualification and intensity, degree of modularity and repetition and etc. attended to?	Construction Issues are substantially resolved	Minor construction problems that can be resolved	Major construction problems that might be hard to resolve	Unresolved major issues.
AE Collaboration How well the design and presentation demonstrates close cooperation between architect and engineer and how effectively critical architectural and engineering issues are resolved? How ready is this design for the Design Development Phase.?	The design is ready for DD Phase and all major architectural and structural issues are resolved	The design is ready for DD Phase , but some issues that are unresolved are easily resolvable.	The design is barely ready for DD phase and some issues that are unresolved are difficult to resolve.	The design is not ready for DD phase and number of critical issues are unresolved.
Cost Effectiveness How likely is it to build this project for under 750,000 dollars?	The project could be easily built within 750k budget	The project could probably be built for under 1.0 million dollars.	The project will slightly exceed 1.0 million dollars.	The project is likely to be well over 1.0 million dollars.

	10.0-8.0	7.9-6.0	5.9-4.0	3.9-2.0
Overall Impression How impressed where you with the project?	This is an award quality work.	This is an impressive design, but does not quite make it to award quality.	This is an acceptable design.	This design is not acceptable.

Mid- Review Presentation Schedule

Presenting	Project ID	Time
Set-up		
Introduction		**2:00 – 2:10**
Team 1		2:10 – 2:30
Team 2		2:30 – 2:50
Team 3		2:50 – 3:10
Team 4		3:10 – 3:30
Team 5		3:30 – 3:50
Break		**3:50 – 4:00**
Team 6		4:00 – 4:20
Team 7		4:20 – 4:40
Team 8		4:40 – 5:00
Team 9		5:00 – 5:20
Team 10		5:20 – 5:40
Conclusion		**5:40 – 5:50**

Project Assessment Form

Project Image	Project Name	Team No.	Aesthetics (5)	Originality (5)	Functionality (5)	Response to Context (5)	Structural Integrity (5)	Structural Modeling (5)	Inter-Connectivity (5)	Constructability (5)	AE Collaboration (5)	Cost Effectiveness (5)	Overall Impression (10)	Total
		1												
		2												
		3												
		4												
		5												
		6												
		7												
		8												
		9												
		10												

Attachment E

Final Review Rubric

(Modified slightly for this paper)

The intent of this review is to select one design that will proceed to construction. The students are required to complete the Design Development phase of the project for this review. Specifically, they are required to identify, coordinate and substantially resolve all critical aesthetic, functional and structural integrity issues. The selected design should be ready to proceed to Construction Document phase of the project.

Please assign points to each design for each category on a scale of 1-5 (5 being best), except for the last category, "Overall Impression", in which each design can receive between 1 and 10 points.

Final Review Rubric

	5-4.0	**3.9-3.0**	**2.9-2.0**	**1.9-1.0**
Aesthetics How attractive is the proposed design and how well are various design elements resolved?	The design is attractive and all design elements are resolved.	The design is attractive, but some of the design elements are unresolved.	The design is somewhat attractive and critical elements are unresolved.	The design is weak; critical elements are unresolved and are unlikely to be resolved.
Originality How unique is the proposed design and does it stand apart from other designs you have seen before.	Very unusual.	Some original elements.	Seems somewhat familiar.	Variation of the existing designs
Functionality How well does it work?	Works very well	Works pretty well, with a few resolvable problems	Has some difficult to resolve problems	Would require major redesign.
Response to Context How well does it fit into the site and surrounding spaces?	Fits very well into site and context.	Largely fits, needs some adjustments	Needs considerable adjustments to fit into site and context	Awkward in site and context

	5.0-4.0	3.9-3.0	2.9-2.0	1.9-1.0
Structural Integrity To what degree selected structural systems resisting vertical and lateral loads are fundamentally sound and are designed to provide necessary capacity for the required demand	Fully resolved Vertical Carrying System, Lateral Resisting System, Foundation System and Critical Connections.	One of the systems is not fully resolved.	More than one of the systems is not fully resolved and might be difficult to resolve	Critical issues in one or more of the systems are not addressed and would be difficult to resolve
Structural Modeling To what degree structural model properly represents the behavior of the selected structural system and sufficient to correctly evaluate the demand – capacity relationship of critical structural elements.	Structural Model detail is appropriate and it reflects the expected behavior of the systems.	The model has minor issues that will not significantly affect design and could be resolved.	Difficult to correct modeling errors	Conceptual errors that significantly misrepresent actual behavior
Inter-Connectivity To what degree critical connections are substantially resolved and are fundamentally capable of ensuring expected behavior of the system.	Critical Connections are fully resolved and reflect modeling assumptions.	Critical Connections have minor resolvable problems.	Critical Connections have major problems that are have not been addressed	Difficult to resolve major connection problems.
Constructability How simple it is to construct proposed system for a reasonable cost. Are major issues, such as transporting large components, on-site assembly, labor qualification and intensity, degree of modularity and repetition and etc. attended to?	Construction Issues are substantially resolved	Minor construction problems that can be resolved	Major construction problems that might be hard to resolve	Unresolved major issues.
AE Collaboration How well the design and presentation demonstrates close cooperation between architect and engineer and how effectively critical architectural and engineering issues are resolved? How ready is this design for the Design Development Phase.?	The design can proceed to construction document phase. All architectural and structural issues are resolved	The design is ready for construction document phase, but some minor issues need to be resolved	The design is barely ready for Construction Document phase and some issues that are unresolved are difficult to resolve.	The design is not ready for Construction Document Phase.
Cost Effectiveness How likely is it to build this project for under 750,000 dollars?	The project could be easily built within 750k budget	The project could probably be built for under 1.0 million dollars.	The project will likely exceed 1.0 million dollars.	The project is likely to be over 1.5 million dollars.

	10.0-8.0	7.9-6.0	5.9-4.0	3.9-2.0
Overall Impression How impressed where you with the project?	This is an award quality work and will become the symbol of CPP College of Engineering.	This is an impressive design, but it does not quite make it to award quality.	This is an acceptable design.	This design is not acceptable for aesthetic or practical considerations.

Final Review Presentation Schedule

Presenting	Project ID	Time
Introduction		**2:00 – 2:30**
Team 1		2:30 – 2:55
Team 2		3:00 – 3:25
Team 3		3:30 – 3:55
Team 4		4:00 – 4:25
Team 5		4:30 – 4:55
Conclusion		**5:00 – 5:30**

Project Assessment Form

Project Image	Project Name	Team No.	Aesthetics (5)	Originality (5)	Functionality (5)	Response to Context (5)	Structural Integrity (5)	Structural Modeling (5)	Inter-Connectivity (5)	Constructability (5)	AE Collaboration (5)	Cost Effectiveness (5)	Overall Impression (10)	Total
		1												
		2												
		3												
		4												
		5												

Attachment F

Final Review Design Examples
(Pedestrian bridge between engineering buildings)

Project Site 1: Pedestrian bridge between Cal Poly Pomona Engineering Buildings

This is the site of the first AE Studio project. The buildings are two engineering buildings. The two story building (Bldg 17) houses faculty offices and laboratory space, while the five story building (Bldg 9) has classrooms and labs. The lack of direct access creates difficulties for disable students and also creates some maintenance difficulties. The height limitations presented major challenge for all designs.

SPACE Frame

This design received the highest score by architectural and engineering professionals during the final review. It was considered to have effectively addressed design charge requirements, to be sufficiently architecturally and structurally resolved, constructible, cost effective and aesthetically pleasing.

RIDGE Beam

This design was the runner up. The basic concept involved a series of vertical columns aesthetically arranged and meeting at the curved glued laminated beam. The deck is suspended from this “ridge beam” and stabilized through special attachment at strategic locations.

Cable Stayed Bridge

This is an example of the design that received lower ratings. The project was not considered feasible and number of structural and architectural issues were not sufficiently resolved

Attachment G

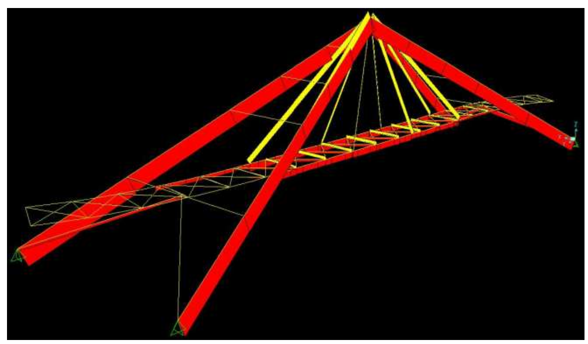
Mid Review Design Examples
(Pedestrian and bicycle bridge across West Fork in Los Angeles Forest)

Project Site 2: Pedestrian and bicycle bridge across West Fork Stream in Los Angeles Forest

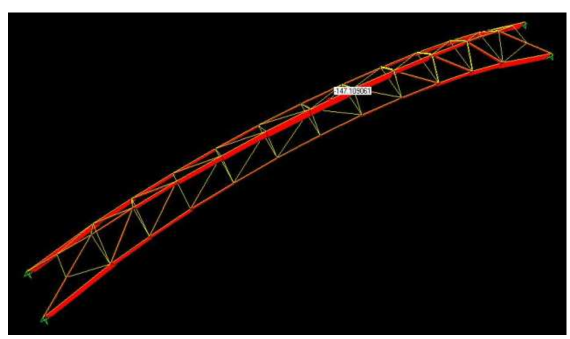
This is the site of the second AE Studio Project. The US Forest Service has received funding and approval for constructing a bridge to allow public access to a biking and walking trail that would otherwise be accessed via highway bridge without sidewalks, thus creating hazardous conditions.

Architectural Design ¼" site model	**SAP Structural Model Example**

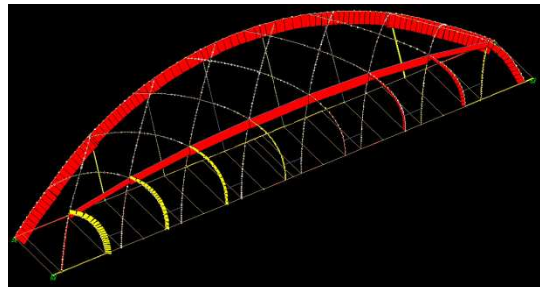
Team 1
The bridge is a simple pyramid with a suspended deck and two stiffening beams below deck. The project received the highest score by judges during mid-review.



Team 2
The bridge uses a trussed arch as its primary structural element supporting a suspended deck and handrails that also serve as stiffening trusses. This concept was within the top five designs, but did not pass the mid-review primarily due to shortcomings related to the AE team interaction.



Team 3
This bridge uses a leaning arch and a complex organic shape structure to provide arch and deck support. This project rated below top the five designs, and was considered too complex for undergraduate engineering students. However, due to a very strong effort by the engineering students and unique architectural design it was considered of educational value and was allowed to proceed.



Team 4
This bridge uses simple truss elements forming a triangular cross section that serves as a structural system for the deck. The top chord and the deck are intended to create two extended lines that overlap over the stream. This project was rated in the top five designs, and was considered to have esthetic value with a very simple solution.