“Integrating Design Throughout the Curriculum for Architectural Engineering Students”

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The study of Architectural Engineering at Oklahoma State University is an integrated mix of liberal studies, design, and technical education. Established in 1909, the Architectural Engineering program has long enjoyed a focus on the integration of design and design-related issues into the five-year curriculum. The primary objective of the program is to prepare students for success and leadership roles in the professional practice of architectural engineering. Our belief in the importance of an education focused on design to achieve this objective is reflected in the curriculum structure – open-ended design problems are incorporated into every year level of the student experience.

As the flow chart below illustrates, the five-year curriculum is conceptually organized to gradually increase the amount of architecture-related coursework over the first two years in the pre-professional program. Application is required for entrance into professional school, and only those students who meet the requirements are accepted. As the student continues within the professional school curriculum, the content becomes focused on architectural engineering coursework in the primary area of structures. In the fifth year of study, elective coursework allows each student to direct his studies towards a secondary area of interest in either construction management, advanced structural design and analysis, or environmental controls. Throughout the ten semesters, design experiences occur at every year level. These design experiences are supported by rigorous coursework focused on engineering science and higher math. A required component of study in the humanities complement these analytical courses, and allow for a well-rounded graduate to emerge from this curriculum.

Architectural Engineering Curriculum Chart. Courses with design content are shown white.
In the first year of study in the pre-professional program, architectural engineering students are taught by faculty who are licensed architects. The first semester course is entitled “Introduction to Architecture”, and is a two credit hour course. In this course, architectural engineering and architectural design students are challenged to view the architecture they experience in new ways, by understanding and describing essential qualities in terms of form, space and order. Additionally, two quick sketch problems are offered, one focused on architectural design and one focused on architectural engineering design issues. In the first design sketch problem, a standard set of parts is provided from which the students create a design for a clock tower within the time constraints of one hour. The importance of this first design problem lies in the fact that for many students, this is an opportunity to see that there is more than one correct answer for a problem – a key element of education in the design process.

One Hour Architectural Design Sketch Problem.

Students work in teams to assemble their towers on this one hour Engineering Design Problem.

“Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition
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The architectural engineering design sketch problem is solved in teams of four students, which allows for a discussion of the importance of teamwork in the professions. In this design problem, students are given a set of materials and asked to create a tower supporting a cantilever system within the time constraint of one hour. They perform this task without the assistance of any lecture or information on basic structural system concepts. The towers are then tested to failure, and their performance leads very naturally into a discussion on the fundamentals of a structural system. By organizing the session in this way, the students are eager to learn what was right and what went wrong with their design process!

The first architectural design studio is conducted in the second semester of the first year of study. Like all architectural design studios at OSU, this is a six credit hour course which meets for sixteen hours a week. In this course, students undertake a variety of simple design problems aimed at increasing their intuitive sense of order and design logic. The course begins with a series of abstract design problems demonstrating ordering principles, patterns, and focal points.

3D Nine Square Project

Point, Line and Plane Composition

These abstract problems provide a foundation of knowledge that the students are then asked to apply in the creation of spaces for human interaction and habitation for the final two projects of the semester. The first of these architectural problems is centered on the creation of a vertical construct. The problem is introduced with a lecture on the fundamental principles of structural systems, and architectural engineering faculty provide design critiques throughout the project duration. Students test their structural concepts in study model form, while considering material selection and the implications of the materials. Basic design principles such as order, repetition, hierarchy, focus, and materiality are required to be exhibited within the design solution. Students complete the two week project with a final model of their design. Architectural engineering faculty participate in the evaluations of the projects – projects completed by both architectural engineering students and architectural design students.
Rough Study Model and Final Project of a “Twisted Ladder” structural concept.

The final design project of the first year studio is focused on the creation of a small building, such as a museum or artist studio. In this four-week project, students must apply all that they have learned about fundamental design principles including ordering systems and structural systems. Additionally, students struggle with a concept search and issues of image as well as the more functional aspects of the design problem requirements.

A Project for a small science museum, a typical final project for the first year of design studio.
In the second year of the pre-professional student experience, students enroll in two consecutive architectural design studios. In these studios, basic ordering principles are further applied to simple architectural problems designed to accommodate human activity. Graphic communication skills are also a focus, to allow the architectural engineering student the ability to express ideas with a variety of graphic media. Students are instructed in the basics of perspective drawing and the principles of shades and shadows, and are tested on these skills. A series of projects allow the students to demonstrate their proficiency in graphic communication of their design solutions.

Second Year Student Work; a graphic presentation for a Mercedes Automobile Gallery.

The second semester of the second year in the design studio further includes a variety of design problems focusing on programmatic planning issues, vertical and horizontal circulation, simple structural systems layout, and site design. A listing of typical design problems given in this semester would include a golf clubhouse, a library, and a branch bank.
Second Year Student Work; a graphic presentation for a golf clubhouse project.

Upon acceptance into the professional school, architectural engineering students begin the rigorous coursework in basic architectural engineering courses: Structural Analysis I, Steel I, Concrete I, Timber Design and Environmental Controls. These technically oriented courses are primarily taught by registered professional engineers. Within these courses, simple analysis and design problems are introduced to allow students the opportunity to apply the knowledge gained through lectures and discussions of the material properties. These beginning architectural engineering courses focus on individual material code requirements (AISC, ACI, and NDS), and in these courses students gain the ability to analyze and design basic structural components of a building. In addition, building code requirements are introduced, helping to instill within the students an understanding of all the factors and requirements involved in the design of an entire structural system. The Environmental Control course is taught based on the requirements of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), and includes a project for the design of a mechanical system for a specific building type and size. Students develop individual design solutions to this open-ended problem, and produce calculations and drawings to communicate their design.
The fourth year of study for the architectural engineering students includes a design studio shared with architectural design students. As expected, the complexity of the architectural design problems are increased, and building systems are required to be integrated into the design solution. Typical design problems for this studio would include a multi-story infill project focused on urban and contextual issues, and a mid-rise hotel or courthouse to allow the students to demonstrate proficiency in form and space design, structural systems, multiple cross-circulation systems and life safety, and a basic knowledge of materials.

Fourth Year Student Work; a project for a new hotel in downtown Tulsa.

Technically-oriented, design based engineering forms the core of the Advanced Steel and Advanced Concrete courses, during the fourth and fifth years of the curriculum. These advanced courses introduce more intricate aspects of structural design, and give the students views of the current state of engineering design and construction techniques of building structures. In addition, these upper-level material specific courses give the students the experience of working in teams to design and detail the structure of a multistory building.

In each of these advanced material specific courses, student teams are given a schematic set of design parameters for a building, including occupancy and building usage type, geographical location, and geotechnical information. The teams are then required to analyze the structure three-dimensionally, design all of the structural members in the building, and produce construction documents for the structure of the building. These teams are responsible for all aspects of the design, including the selection of the building geometries, dimensions, and skin system. Teams research the governing building codes and other design reference sources to determine the structural requirements for the project and the service requirements for the building (HVAC, exiting and circulation requirements, mechanical/electrical/plumbing and fire code requirements). Upon the completion of this research, plan layouts and floor to floor heights can be established. Once the building geometries are complete, structural loadings (both vertical and horizontal) and preliminary structural member sizes are determined, and the structure is modeled three dimensionally in an analysis program. The results of the analysis program are interpreted by the student teams and the structural members are redesigned until both the strength and deflection requirements for the project are met. The final results are then presented in the
form of structural drawings that show the final design and detailing for the structure of the building. These design problems are meant to simulate actual structural engineering design problems to give the students an academic experience that has direct application to professional practice.

The capstone design course for the architectural engineering student occurs during the fifth year of study. This nine hour credit course meets in the studio twenty hours a week, and is taught by two architecture professors and two architectural engineering professors, one specializing in structures and the other in environmental controls. This design and development studio course, shared with the architecture design students, envelops the total design process from project research to construction documents.

Students are initially provided a project program detailing the type and usage of the building, and the space requirements for the project. Student teams then perform extensive research to supplement their level of understanding about the project. This research includes an investigation of governing building code requirements, ADA requirements and local building ordinances, an analysis of the project site, and estimates on building service requirements and systems.

Once the research is complete, each student begins the design process, working individually to develop a schematic design for their building that encompasses the requirements as outlined in the project program and supplemental research. This initial design phase includes schematic structural and mechanical layouts. At the end of the Schematic Design phase of the project, the students present their designs to a professional jury consisting of practicing architects, engineers and other professionals with knowledge of the project type. Each student presents his project graphically through drawings and models, supported by a verbal presentation. The jury members then provide verbal feedback on the students’ work, and prepare written comments for the students’ use in the Design Development phase of the project.

In the Design Development of the project, the students further develop their solutions, taking into account comments from the jury members and professors. Structural and mechanical requirements for the course extend past the Schematic phase at this time, and the students are
required to produce calculations to help determine structural member sizes and mechanical and lighting requirements for the project. Additional architectural, structural and mechanical drawings are required during this phase of the project as well. The architectural engineering students develop a series of structural details for conditions that are unique to their design. The Design Development jury again places the student in front of a group of professionals to review the progress of the project and give technical advice to the student to consider as the Construction Document phase begins.

The formal jury review of a students’ Design Development work.

For the Construction Document phase of the course, the students create a set of working drawings for their design. Both the architectural and architectural engineering students are required to provide architectural, structural, mechanical, and lighting drawings, with the architectural students focusing on architectural drawings and details, and the architectural engineering students focusing on structural drawings and details. The students learn the process of manufacturing a set of working drawings, including drawing order, sheet format, detail reference, and production of details. The final product is a set of drawings and calculations that document the technical and aesthetic aspects of their design.

This capstone design course at Oklahoma State University allows students to experience a design process similar to professional practice, from initial Schematic Design through the Construction Document phases of a project. This design experience is crucial in providing an education that will graduate productive interns, and establish the foundation in design needed to allow graduates to become leaders in their field.
The Architectural Engineering program at OSU recognizes that the creation of architecture is a complex endeavor involving professionals from a variety of fields. Design occurs at all levels of a project, and within and between all related disciplines. As noted by Mario Salvadori, “Lucky is the client whose architect understands structure and whose structural engineer appreciates the aesthetics of architecture.”¹ The most successful architectural engineers in professional practice are those who have a general knowledge of all aspects of architecture and technology, in addition to an expertise in the specific area of engineering design. The incorporation of design experiences into all levels of the architectural engineering curriculum is fundamental to this success.


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