

## **Integrating Experimental Learning into Architectural Structures Curriculum**

Project period: 10 weeks

Principal Investigator:

### **Description:**

Structure not only holds buildings up and enables buildings to take on a shape, but structure also unites the space and form of buildings. Assistant Professors Rui Liu and Peter Marks in the College of Architecture and Environmental Design performed a survey that explored the perceived relationships between architects and engineers, and evaluated the influence that engineered systems education has on an architects' professional career. More than 95% of 689 registered architects who responded the survey indicated they worked with structural engineers within past 24 month, but only 60% responses agreed their architecture education at school was sufficient to understand the structural selection and design criteria. Following this survey, and after teaching one and half years' architectural structures at Kent State University, I have surmised the basic goals of structural education for Architecture students:

- (1) Understanding of form synergy and building structures;
- (2) Understanding selection criteria for appropriate structural systems;
- (3) Conceptual design of structures for gravity and lateral loads and integration of structural design with architectural objectives;
- (4) Basic hand and computer aided structural analysis;
- (5) Understanding of structural design principles, and capability of seeking practical design solutions for building structures; and
- (6) Effective communication with structural engineers.

There are three required structure design courses for architecture students. ARCH20301 Introduction to Building Structures emphasizes fundamental concepts of building structures. ARCH30301 and 40302 Structural Systems I and II discuss structural design principles for steel, timber, concrete, and masonry structures. However, the teaching method for the three courses is traditional "lecture – example – homework – exam" approach, which originated in civil engineering programs. From my personal observation and studio projects reviews, many architecture students are not able to apply basic structural design principles, and demonstrate their understanding of these principles in their projects. I concur with Professors R. Gary Black and Stephen Duff from University of California, Berkeley that "*a higher aim (of architectural structures education) is to enable (architecture) students to use structure as a creative design force throughout all phases of design, ..... To do this, students must understand buildings at the level of their detailed structural behavior.*" (Black, R. G. and Duff, S., 1994).

Three experimental learning projects have been incorporated into my sections of the three courses, i.e. [truss structure competition](#) in ARCH20301, building [catenary arch structure](#) in ARCH 30301, and [concrete frisbee competition](#) in ARCH 40302. Students enrolled in my classes started to learn fundamental concepts, behaviors of structures, and design principles through reflection on participating in these projects. Very positive reviews have been received from

students. Based on this experience, I would like to develop more experimental learning projects and integrate them into architectural structures curriculum.

### **Goals:**

The goal of this course enhancement project is to develop experimental learning projects for the three structure courses. These projects include

- Hand-on lab experience to learn fundamental concepts
- Computer modeling using free educational programs RISA 2D and 3D
- Constructing structural models using the 3D printing and/or laser cut technologies

It is expected that architecture students enrolled in structures courses will actively participate in experimentation, reflectively experience and observe experimental phenomenon, and conceptualize the fundamental concepts, and structural design principles. Integrating these experimental learning projects into structure curriculum requires changes of students and instructor's roles. Students are the center of the classroom, and they must be willing to actively get involved in the experimentations, capable to use analytical skills to reflect on and conceptualize what they see, and apply what they learned from structures courses in their design studios. The instructor must motivate students or get them self-motivated, and assist them with conceptualizing with new knowledge.

Specifically, the following projects (at least but not limited to) will be developed this summer:

- (1) Summation of two and three forces;
- (2) Measurement of strains of a cantilever beam;
- (3) Stable vs. unstable, redundant vs. non-redundant truss structures;
- (4) Buckling of columns;
- (5) Axial, shear, and moment diagrams developed using computer modelling;
- (6) "Zero reactions" using computer modelling;
- (7) Deformation of frames with various boundary conditions under lateral force; and
- (8) Analysis and construction of building structures.

### **Impact:**

Structure courses are required for architecture students in the College of Architecture and Environmental Design. There are about 150 students enrolled in ARCH20301 (three sections) and ARCH40302 (two sections) this spring. Integrating experimental learning into traditional lectures will help students gain a better understanding on detailed structural behaviors, optimal structural system selection, and design principles. Because multiple sections are offered by two part-time instructors and me (tenure track assistant professor) for each course, the experimental learning projects will be implemented in my classes first. The effect of these projects on students' learning will be studied and compared with other sections. After the effectiveness is approved, I will work with other instructors to implement these projects in all sections of structural courses. In addition to structures courses, architecture students are required to take courses of construction methods and materials, and environmental technologies. It is expected

the experimental learning in structures can inspire instructors to bring this learning and teaching method in other building construction courses.

### **Activities and Timeline:**

This is a 10-week project. The work plan is discussed below:

- Week 1: Develop a template for these projects. Previously developed projects are in different formats. A template is needed for development of these projects. The template should include but not limited to objectives, description of the experiment, lab activities, questions for discussion, format of project report etc.

The experimental learning projects will be developed from Week 2 to 9. Each experiment or computer modelling process will be videoed. The videos will serve as supplemental materials for student learning. In week 10, the projects developed including three previous established projects (truss bridge, catenary arch, and concrete frisbee) will be incorporated in the three structure courses. A detailed plan to evaluate the effect on students' learning will be developed in week 10.

- Week 2: Summation of two and three forces
- Week 3: Measurement of strains of a cantilever beam
- Week 4: Stable vs. unstable, redundant vs. non-redundant truss structures
- Week 5: Buckling of columns
- Week 6: Axial, shear, and moment diagrams developed using computer modelling
- Week 7: "Zero reactions" using computer modelling
- Week 8: Deformation of frames with various boundary conditions under lateral force
- Week 9: Analysis and construction of building structures
- Week 10: Curriculum modification and development of detailed evaluation plan.

### **Communication Plan:**

A model for teaching structures in Architecture Education will be developed in this project. The model will be introduced in one faculty meeting of the College of Architecture and Environmental Design this fall, 2015. The preliminary finding will be presented at the annual University Teaching Council conference this fall, 2015. It is expected that a manuscript will be prepared and submitted to conference of *Architecture Research Center Consortium* or *Journal of Architectural Education*.

### **Evaluation Plan:**

A preliminary evaluation plan is discussed here and a detailed plan will be developed in the Week 10 of the project. Six goals of architectural structures education are listed on the first page of the proposal. The success of experimental learning in structures should be reflected in achieving the six goals, students demonstrating their capabilities of applying basic design principles in their studio projects, and ultimately using structure as a creative design force throughout all phases of their designs. Three evaluations are proposed:

(1) Comparison with students who took my classes before.

I have already developed “course outcome assessment” for my structure courses ([ARCH20301](#), [ARCH30301](#), and [ARCH40302](#)). The purpose of the “course outcome assessment” is to evaluate the effect this course has had on students’ knowledge. The survey is given twice, one at the beginning of the semester and the other on the last day of the class. The same assessment will be performed for the students who will take the course with experimental learning sessions. The results will be compared with students who took my sections before.

(2) Comparison with peers

There are multiple sections offered by different instructors for each of the three structure courses. A same “course outcome assessment” will be performed for all the students who take different sections. The students doing experimental learning will be compared with their peers enrolled in other sections.

(3) Evaluation of their performances in studio projects

A survey will be developed in Week 10 for studio instructors and project reviewers to evaluate students’ performances of applying knowledge gained from structure courses in studio projects.

**Professional Background:**