From Recitation to Group Dynamics: Transforming a Civil Engineering Course
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Project Summary

To improve student learning with hands-on activities, a civil engineering professor overhauled the recitation component of CE 461 (Structural Analysis) by encouraging students to discuss problem-solving approaches even before they picked up a writing tool, to work on assignments structured as ill-defined problems, and to complete a model-building activity using innovative materials to simulate building structures.

BACKGROUND

Baseline Course Structural engineers are responsible for the analysis, design, and construction of structures. The most basic level of these responsibilities is *analysis*, mastery of which is needed before buildings and bridges can be successfully designed or constructed. An engineers' analysis of a structure—whether existing or proposed—involves examining the structural geometry, materials, supports, and applied loads, and then determining the effects of those variables on the structure. For example, before a bridge can be adequately designed, an engineer must determine what forces and deformations are induced by applied loads and how they are distributed throughout the structure. Only then will the engineer know what forces the bridge must be designed to resist and how to sufficiently size a structural member. Forces and deformations can be accurately predicted for a given structure and loads using classical analysis techniques, which are taught in CE 461, Structural Analysis. The course covers classical, mechanics-based methods for determining behavior of structures. Methods of analysis for beams, columns, frames, and trusses are studied.

The course has both a recitation and lecture component (see syllabus). Students examine structural systems within well-defined parameters, such as loads, dimensions, materials, and supports. Most of the course is dedicated to teaching students how to solve for forces and deformations within structural members caused by given loadings (see assignments). Examinations (in-class exams and a final exam) are problem solving questions.

Analysis The recitation was originally designed such that it was primarily an extension of the lecture. After teaching the course for a semester, I determined that this method was not a very efficient way of encouraging student learning. Student participation and attention seemed to wane considerably during each of the recitation periods. I requested feedback about the course from students at midterm and again at the end of the semester, and received comments such as:

- "...Maybe it could be possible to use part of recitation for homework help or work in groups."
- "Having three hours of lecture in one day was terrible. I liked the days for discussion where we got to do problems and turn them in—it also gave me a chance to ask questions on subjects as I was working through a problem myself."
- "...More examples that we have to work ourselves in lab."
- "Lecture for three hours on Mondays is VERY painful!"
- "...During the recitation there could have been more problems that we worked on our own."

Obviously, there was a need to restructure the recitation period. CE 461 is a critical course in the development of students in civil and architectural engineering disciplines. Structural analysis forms the foundation for many subsequent design courses, which represent the culmination of the curriculum. Not only is it important for students to solidly grasp the technical aspects of structural analysis, but it is equally important that their attitudes towards structural engineering are positive. I approached restructuring the recitation period with goals of better fostering student learning and improving positive attitude formation toward structural engineering.

I overhauled the recitation period after the initial semester of teaching. Students now work in small groups during most recitation sessions. In addition, they have to discuss approaches to a problem before they are allowed to pick up a pencil to attempt to work through a problem.

IMPLEMENTATION

The first time I taught CE 461, student response to the recitation periods was not satisfactory. The approach I used that semester was to primarily work examples on the board for students. Time was occasionally provided for students to work in groups on small problems, but these sessions were not well-structured and needed more focus.

In Fall 2006, I restructured the recitation in the following manner (Syllabus Fall 2006):

- I encouraged group dynamics by allowing students to discuss a problem with their peers before attempting to start problem solving on paper. By doing this, students were able to benefit from hearing and thinking through multiple ideas and were encouraged to learn from other members in class.
- I no longer used the recitation time to show solutions by working them out on the board. Instead, with students working in groups, I was able to work with a smaller set of students (three or four) and provide input and guidance in a variety of ways applicable to the needs of each group.
- I included a hands-on activity that my students could engage in. In this activity, each group was provided with a schematic of a truss under a specified loading. The group was tasked with solving for the force within each truss member and denoting whether each force was compressive or tensile in nature. Next, each group was asked to build a scale model of the truss using chains, twine, and wooden rods that I provided (see photos). Students were required to assemble their models such that any member identified as compressive was constructed with a wooden member and any member identified as tensile was constructed with twine or chains. Each model truss was then loaded with the specific loading from the problem statement. By doing this, students' analysis work was partially checked—if they incorrectly identified a compressive member as a tensile member, and used a piece of twine to construct that member, their truss would not be able to support the load!

I designed an ill-defined problem (1-4) for each lesson/topic in the lecture. I provided a photograph of a structure on campus along with instructions that the students look at the actual building and make their own observations. Then, using theories learned in the lecture, students were tasked with completing an open-ended, practical assignment.

STUDENT PERFORMANCE

Spring 2006 (Baseline Course) Homework Homework assignments for the spring 2006 semester were comprised entirely of textbook problems. These problems usually involved a very idealized structure presented to the students in an extremely simplified form. Most problems consisted of a structural beam or frame composed of straight line segments. These are commonly called "stick structures" and are a valid, simple method of treating a structural analysis problem. It was my thought that these problems, while well-intended, primarily drove students to find a worked solution somewhere in the text that very closely resembled the assignment. In fact, students were generally successful in achieving this.

Two problems became apparent: 1. Students were able to find a worked solution or closely follow an example problem worked in class, to produce a correct solution that required no synthetic or critical thinking, and 2. Students were never faced with the task of examining an actual structure and reducing it into a "stick structure" for analysis. While the latter is not necessarily a trivial task, it is a step that is not usually addressed in structural analysis courses. However, it becomes a very real, practical problem when students enter the work force. It seemed that problems with a practical twist would benefit students by sparking synthetic, critical, and deliberate solutions.

Fall 2006 (Transformed Course) Homework My experience with the assignments students completed in spring 2006 caused me to re-examine the assignments for the fall semester. I decided to include an ill-defined problem with most of the existing homework assignments. To account for the increase in assignment density, I reduced the number of well-defined "stick structure" problems in each assignment set. The ill-defined problems were considerably more practically-oriented than the textbook problems. For each major course topic, I requested the students visit a specific structure on KU's campus. Students were asked to analyze a particular aspect of the structural behavior, such as solving for structural loads, member forces, or member deflections. To accomplish this, students needed to make a number of physical measurements, approximations, and engineering judgments that they did not have to consider when they were presented with the tidy, well-defined text problems. I believe that this did stimulate synthetic thinking, although some consternation also resulted on the students' part.

Fall 2006 (Transformed Course) Exams For the transformed course, the exams also included problem-solving questions. I feel that the students are prepared for this type of exam question. The restructured assignments provided a platform to better understanding of concepts.

Results Having taught the baseline and transformed courses in consecutive semesters, I have evaluated learning by looking at grade distribution from the two semesters. The transformed course showed a dramatic increase in students earning an A as opposed to the baseline course where more students earned a C.

While teaching this course, I obtained feedback from the students through a mid-term evaluation. This was helpful in evaluating progress of students throughout both semesters.

REFLECTIONS
Student response toward the recitation encouraged me to restructure this portion of the course. Initially, the recitation was a dreaded component of the course. After restructuring it, student responses were much more positive. Students seemed more engaged and interested when they were solving problems in small groups. The classroom was more energetic and lively; students asked more questions about the material and were more involved in the learning than before.

This change actually required minimal effort. I simply changed the examples that I had been working on the board for students to in-class problems for students to work themselves. Since I had already been using these problems as in-class examples, I already had the solutions worked out and could use this to help the groups work more effectively. After collecting students' work at the end of each recitation, I posted my own solutions to the problems on the course website.
I received positive feedback concerning the truss-building project and would like to develop more mini-projects such as this one in the future. Students especially liked the fact that there was an element of discovery when they tested their completed models and were able to check whether they had solved the problem correctly or not.

I received mixed feedback concerning the ill-defined problems. While a number of students were excited to be tackling real engineering problems, other students expressed concern over the lack of one single "right answer." Although this was exactly the intention of the assignments, many students were somewhat uncomfortable with this approach. A common question was "How do we know what to assume in order to solve the problem?" My response to that question was another question: "If you were currently employed by an engineering firm and tasked with solving this problem, what would you do?" Students invariably replied, "We would ask a co-worker or a mentor!" This was a great lead-in for me to suggest that they ask a peer, faculty member (including myself), co-worker at their internship, or turn to printed and online resources. I believe that providing the students with some guidance as to where they could look for suggestions, recommendations, and experience helped assure them that they were not in a helpless position. In the future, I would like to address this before any ill-defined problems are assigned. I think that this would add to student confidence in their ability to tackle problems and raise their comfort level with the assignments.

In addition, I would like to concentrate on three or four ill-defined problems, rather than assigning one with each new lesson. This approach would allow me to dedicate a greater point value to these problems, hopefully raising the incentive for the students to invest greater efforts in them.