Under Construction: Curriculum Reform in Progress

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For the last several years, in engineering education there has been an emphasis on applications, case studies and problems based education. Much of this work has been devoted to improving individual courses. Our project team has completed a first iteration of curriculum reform which uses applications, woven throughout the engineering curriculum as a means to motivate learning and provide relevance to course work. This paper reviews our work to date, summarizes what we are learning about the systems required for sustained reform, and outlines our direction for the next step of work. We will also discuss the impact of this project on our department and some of the interesting dimensions of what is required to pull off reform across the curriculum.

Our Initial Vision

We have identified a problem with engineering education. Our pragmatic students want to know why before they are motivated to learn, but we wait until senior design and capstone courses to show them. By not tapping into the students motivational core at the beginning of their university education, we have missed one of our best educational opportunities.

Using our architectural engineering program at Kansas State University, we have developed, implemented and tested a new model of an integrated, application-oriented curriculum. Our department focusses primarily on undergraduate education, with two large B. S. programs (330 students in architectural engineering and 240 students in construction science and management). We have a large number of faculty who have returned to the classroom after working in the engineering and construction industries(1). We are in our final year of a three year curriculum reform experiment supported by the Department of Education's Fund for the Improvement of Post-Secondary Education (FIPSE).

Our model restructures the traditional engineering education sequence by integrating concepts, overviews and application awareness into the curriculum, beginning at the earliest contact with the student, and continuing throughout the student's education (2). We intentionally focused new courses in the critical first and second years where students have little contact with department faculty but potentially would benefit the most from the motivation of seeing applications for the fundamental theory they are learning.

The first element of our reform model is an "Orienteering Track". This cornerstone course was designed as a two-semester sequence of weekly activities, presentations, and outside-of-class experiences. The objective is to provide the freshman student with an experience-based, conceptual understanding of how buildings work, what architectural engineers do, how architectural engineers think, and what architectural engineers need to know. Throughout the first year, students are introduced to our entire faculty, listen to overview presentations of major career options in architectural engineering, take field trips to construction sites and building science laboratories on campus, and hear from practicing professionals from across the country. This lays a foundation for understanding what the profession is about and provides a context from which entering students can view their course of study and educational experience.

When our students are sophomores, they are in the heat of the theoretical battle (engineering physics, differential equations, etc.). In "Theory Connections", the second element of our reform, we group students in collaborative teams to reinforce their understanding of architectural engineering applications using problems-based learning activities. These experiences are designed to show how various aspects of buildings perform in accordance with the principles of physics and how they can be modeled with mathematics. Our learning adjectives for this element are: 1) understanding how physics applies to buildings, 2) using mathematics to model building performance, 3) developing team problem solving abilities, and 4) using critical thinking skills for building analysis.

The third element of reform, "Professional Applications", builds on the knowledge and experience of the earlier tracks by identifying and developing effective ways to integrate applications into existing upper level courses. Professional abilities and skills that students need in order to be successful architectural engineers (program outcomes) have been identified and will be progressively developed through sequenced clusters of third, fourth, and fifth year courses. This element focuses on educating our faculty about more effective ways to integrate applications, model theory connected to practice and program outcomes into the context of the courses they are teaching. Annual Teaching and Learning Workshops and Peer Teaching Teams are two programs we have initiated in support of these changes. We are also developing a resource of prototype examples of various instructional methods to assist faculty in successfully integrating applications in their courses.

These reforms do not eliminate any of the theoretical bases that are essential to engineering education. Our central thesis has been: students will be more motivated, better able to organize and retain technical information, and better at assimilation and problem solving if they are exposed to the applications and introduced to the realities of their profession at the beginning of and throughout the curriculum.

The Implementation

We have sequentially developed these reform elements and phased them into the curriculum. The first year of our project, beginning Fall '93, entering freshmen became our control group, matriculating through the first two years of the curriculum prior to any reform implementation. This group has been surveyed throughout their freshman, sophomore, and junior years. Subsequently, entering freshmen Fall '94 and '95 are participating in all the curriculum changes and will be compared to the control group. In addition to designing the Orienteering Track, Theory Connections, and materials for Professional Applications, we have developed surveys, written cognitive exams and tracked the academic performance of the three classes of freshmen students.

This extensive educational research component has been administered by the KSU Office of Educational Advancement, from the beginning of the project. Their evaluation guidance, questioning, probing and overall involvement has brought a level of scholarly work to our reform efforts.

Lessons *We've Learned*

At the time we are writing this paper, evaluation data is still being collected and summarized. The results will help quantify the statistical significance of the impact of reform efforts on our students. Unexpectedly, the impact on the faculty project team, and we believe the department as a whole, has been significant. Many lessons have been and are still being learned. The following summarizes a few of these:

1. Faculty as well as students need assistance to make connections.

The transference that we expect our students to make from course to course and connections from course work to applications will not happen without intentional design. Faculty play the key role in displaying how connections are made. Therefore, we've implemented a faculty development system that provides a framework and guidance to accomplish this task. We did not anticipate that this would constitute a major part of our work.

2. Students can become more fully a part of a department culture during the freshman and sophomore years. Our work has focused on providing an application-oriented educational overlay on the curriculum. However, one of the most obvious changes has been the social element that as resulted due to providing structured group experiences during the first two years of the program. These findings support recent study of the impact of freshman experiences (3). This is something that is hard to measure but easy to identify. Intentionally pulling freshmen and sophomores aside to experience various aspects of a profession and academic program builds community and relationships. This is observable in subsequent courses, involvement in extracurricular organizational activities, as well as conversations and gatherings in halls. This enthusiasm has at times seemed disrespectful, but the ramifications of engaging 18 and 19 year old college freshmen and having them more comfortable in a department's environment will take some adjustment.

3. Reform efforts are greatly enhanced by outside resources and ideas. Most of the individual components of the reform efforts we have initiated have been developed, tested and refined at other places. Our team has benefitted by tapping into these resources at a national level through workshops, conferences and writings. These projects, and more specifically people, have influenced our thinking, inspired our work and have been instrumental in shaping various elements of our reform. The translation of other work in our setting has not been direet, but has been very useful.

4. Reform requires a lot of teamwork. Individual courses or instructors can make great strides working independently. However, curriculum reform requires the negotiating and consensus building that only happen in team structures. At times this has been difficult and seems to impede our reform. This project began as a team effort and has survived because of the team format that has in part been an outgrowth of this project.

Current.Re-design: Our Next Step

As with any prototype, we are continuing to observe, gather data and make decisions regarding future modifications. We have observed many things that have worked well - field trips and time with faculty as freshmen - and several things that haven't worked - abstract exercises, class formats. We are still administering surveys, collecting data and determining results. The academic calendar doesn't wait for research results and we are moving ahead with the next iteration of a reform in progress. Some of the major features of our re-design include:

1. ***Orienteering Track-*** We are restructuring this sequence to fit into a one-semester, 15 week seminar/course for one hour credit. This will coordinate with orientation activities at the college level and have more focus and continuity than the current format offers.

2. Theory Connections - Our intention is to change this course from a two-semester, one hour seminar format to a twice a week, two hour problems-based learning course for 3 hours of credit. Emphasis in this modified course will be on problem solving, computer modeling and major program outcomes, This will allow us to add two additional learning objectives; demonstrate initial level of understanding and proficiency of major program outcomes, and acquire "computer as a tool" skills as a medium for making application connections across the curriculum.

3. ***Professional Applications -*** We will be focusing on providing resources and accountability for measurable improvement and curricular reform to continue after FIPSE finding. These resources will include; teaching applications examples, workshops in conjunction with college and university initiatives, and matching finds for travel related to instructional improvement. A program outcomes overlay will supplement the current course /

credit model and require closer teamwork among the faculty.

4. Evaluation -We are currently working with our evaluation team to determine the appropriate level of future surveys and monitoring in order to follow the impact of continued educational reform. We are also developing a cognitive exam, patterned after the F. E.(Fundamentals of Engineering Exam), which will assist in tracking how our reform efforts impact retention of fundamental theory in the first three years of the curriculum. This exam is designed as a 3-hour practice exam that will be used to diagnose areas of deficiency for the student and observe trends in performance of our students.

Departmental Changes

A great teacher once said, "you don't put new wine in old wineskins." In order to sustain reform and improvement, many aspects of the way a department does business need to be rethought and restructured. Our efforts have been greatly enhanced where overlap with other on-going activities have allowed a natural forum for discussion of these ideas with our colleagues. Some of these activities and other changes which have been made at the department level are described below:

1. ***Mission and Gods -*** Encouraged by increasing emollients and not commensurate finding increases, we have had to look at enrollment management in our department. We have revisited our mission and goals to gain focus and objectives for our future. Our team members were able to bring their national level exposure to teaching reform movements to the table and impact our department mission and it's goals.

2. ***Classroom Environments -We*** have begun to see a broader acceptance of relatively new strategies (such as collaborative, team-oriented problem solving), among faculty and students alike. This has brought about a new, highly enthusiastic exchange and inquiry. Encouraging students to take a very active role in shaping their educational environment has resulted in a more demanding, more encouraging, sometimes raucous classroom demeanor. It has also encouraged greater interaction between students and faculty. Though some educators may see this as disrespectful, as noted earlier, we've experimented with and embraced this change and have seen levels of eagerness and student involvement previously displayed only by a limited few. Additionally, we've observed both tenure-track and senior faculty attempting new classroom instructional strategies. These changes have forced us to rethink physical aspects of our instructional spaces. We have renovated classrooms and are designing new spaces to accommodate a wider variety of approaches.

3. Class Formats and Teaching Methods - We are experimenting with new ways of modeling engineering concepts and principles. Our reform ideas, both curricular and instructional, have been readily accepted by some, and viewed skeptically by others. This was anticipated. We feel both positions are necessary and provide a healthy "checks and balances" system in reviewing any change of this magnitude. There are 13 teaching faculty in our department. All teach approximately four courses per semester, principally to undergraduate students. Each faculty member teaches a mix of lecture/ recitation types of courses and laboratory/ studio type courses. Class sizes range from 16 to 160. With such a variation of responsibilities, we have attempted to share experiences in commonly taught, multiple-section courses, and have encouraged individual experimentation in other, more singularly delivered courses. We are in the process of developing a department-wide template that more effectively standardizes the measurable goals and outcomes of a course, while maintaining the individual freedom of course organization, expression, and delivery, critically important to any university.

4. ***Program Outcomes and Assessment*** - The development of professional skills and abilities sequenced throughout the program will become a more intentional way of attaining educational objectives in connection

with-applications of fundamental engineering knowledge.

5. ***Faculty Evaluation*** - Coincidental with the project outlined in this paper, we have undergone a Board of Regents driven evaluation of all faculty - both tenured and nontenured. We've developed a department document outlining guidelines and procedures. This comprehensive document has received the endorsement of our faculty. It invokes new methods of determining individual contribution in the areas of teaching, research, and service - and how faculty will be evaluated relative to these contributions.

6. Generalizing the Model - We will begin to explore generalizing our curriculum reform model by studying how we will modify and implement the proven elements into our Construction Science and Management program.

Summary

Change is difficult work. Accepting the change initiated by this project has been difficult for some faculty and students because it has required moving out of comfort able patterns. There has also been the awkward nature of the early start-up phase of new courses and department operational structures. During this time many new exercises, requirements and processes have not been refined and imperfections are quite obvious. Reactions and criticism should be expected when reform is in process, but must be responded to and worked through.

Reform is invigorating. The challenges, exposures, and growth that have resulted from our educational reform efforts have brought new life into our teaching and student learning. The teamwork structure now substantially in place supports continuous improvement efforts that will allow a more scholarly and community approach to the classroom work we do. As we strengthen application connections and make additional connections across the curriculum, we will continue to see real change.

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References:

1. Our educational environment is further discussed in: "Breaking Down Barriers that Separate Engineering Theory from Practice", S. Moser, T. Roberts, C. Waters, ASEE Regional Conference Proceedings, April 1995, Wichita, Kansas.

2. The initial design is detailed in: "Application Oriented Engineering Curriculum, an Integrated Approach", S. Moser, M. Bluhm, S. Garrett, A. Goodman, ASEE Annual Conference Proceedings, June 1995, Anaheim, California.

3. A. Astin, "What Matters in College?" pp. 398-408, Joey-Bass, San Francisco (1993).

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