A Methodology for Restructuring Our First Year Introduction to Engineering Sequence at University of Massachusetts Lowell

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Abstract - **This paper describes our approach to restructuring the University of Massachusetts Lowell Introduction to Engineering program for first year engineering students. We describe the methodology and process we used to analyze best practices and to find a solution that fit the strategic requirements of the UML College of Engineering and the specific needs of our growing and changing first year engineering cohort. Much of what we did was based on results of a student survey and a focus group with students who had already been through the introductory program. The new first year engineering program was restructured to stress hands on skills building and rolled out starting in the fall semester of 2014. In this paper we share key learning's from this process.**

Index Terms - First Year Program

INTRODUCTION

University of Massachusetts Lowell is located about 30 miles northwest of Boston in the high technology region. The incoming first year engineering cohort is approximately 700 students and it is growing at approximately 10% per year. The first year cohort consists of approximately 50% on campus residential and 50% commuter students and comes from diverse economic and demographic backgrounds. Many are the first in their families to go to university. First year retention is one of the key problems the college is dealing with. When a new Dean of Engineering was named, amongst his first actions was to form a group to look at restructuring a first year introduction to engineering program that was not effectively scaling and whose increasing resource requirements were becoming unsustainable given rapid growth in first year and transfer enrollments.

Before the restructuring, the first year program consisted of 4 credits in two courses called Introduction to Engineering I and Introduction to Engineering II. Introduction to Engineering courses were run out of the College of Engineering but were staffed with faculty and Teaching Assistants from the individual departments.

Introduction to Engineering I was taken by all students independent of engineering major, usually in the first semester on campus, and had a fall term enrolment approaching 600 plus students and 50-100 in the second semester, mostly transfer students. The course was 2 credits and was run in the form of 2 lectures and 1-2 hours of laboratory per week. Each of the 4 lecture sections with approximately 150-200 students was subdivided into laboratory sections run by a teaching assistant (TA) with a maximum of 19 students per lab section. The lectures consisted of topics ranging from how to get around campus, student clubs and activities, time management, general engineering design concepts, engineering ethics, engineering economics, and talks from industry and faculty. Laboratory work consisted of several team based design projects generally using low cost elements such as Popsicle sticks, soup cans, and etcetera and tried to teach general engineering design principles. Two full time lecturers, approximately 40 Teaching assistants, and 80 laboratory class hours per week were required to run the first introductory course. In addition 8 class hours in the large lecture halls that are at a premium on campus were required.

Introduction to Engineering II, generally taken second semester on campus, was also a two credit course and was run by the five departments with a variety of different curriculum models ranging from hands on experience such as robotics, basic electronics, and MATLAB programming in some departments to having students listen to representatives from industry and faculty talk about career paths in other departments. Some departments taught basic skills such as AutoCAD, Solidworks, or programming and made the introductory course a prerequisite for later courses, while others did not. Introduction to Engineering II generally used a lecture/laboratory model with larger departments offering more than 12 sections during the second semester. One of the issues raised by students and administrators with regard to the Introduction to Engineering II course was a lack of consistency from department to department in terms of what was covered in the second course.

The curriculum model used before the restructuring was taxing the resources of the College of Engineering in

terms of TA's, faculty, and laboratory and classroom infrastructure. In spite of Herculean effort by the teaching staff, feedback from the students was consistent that the course model was not providing students with the skills they thought necessary for them to succeed, or a real understanding of what engineers in the different disciplines did to help students decide on a major or confirm their major choice. The new Dean decided that what we were doing had to change and formed a committee consisting of the first year instructors from each of the 5 College of Engineering departments: Electrical and Computer, Mechanical, Plastics, Civil, and Chemical and Nuclear. He gave the committee the following charge when redesigning the first year introduction to engineering sequence:

1) The total credits (4) cannot increase and he would prefer a reduction in credits because there is a desire to reduce the total degree credits.
2) Achieve a reduction in the cost of running the first year program.
3) The new first year program should focus on teaching core skills to help students succeed in engineering programs (e.g. improve retention).
4) Allow students to explore different majors through hands on open ended design activities to better understand what engineers in each major do.
5) Make use of the new "maker space" design center to relieve classroom and laboratory infrastructure constraints.
6) The program must scale to an incoming cohort of up to 1000 students.
7) Be ready with the restructured program at the beginning of the 2014 academic year (less than 6 months from the start).

A wide variety of first year engineering program models exist and the committee decided to conduct a systematic assessment of course models at other universities [1-5] to help design a program that would work for our students. Representatives were sent to the FYEE conference to understand better what other schools were doing. The overall process we followed as we restructured the program is as follows:

1) Survey different types of programs at peer and peer aspirant institutions, especially those with similar size and student body makeup.
    a. Investigate how program models align with our strategic goals
    b. Investigate how program models scale and their cost to operate
    c. Investigate how programs would work for OUR first year student cohort with its diversity and mix of residential and non-residential students.
2) Design a detailed survey for engineering students who had already taken the introductory course sequence to better understand what they actually learned and how useful they felt it was as they progressed through their respective programs (year 2 through 4 students).
3) Conduct a focus group of selected senior and graduate students in each department to survey their feelings about potential program redesigns based on their experiences with the original program.
4) Come up with two proposed course models and brief the Dean and Chairs Council and have them select the final format for the course from the two final recommendations
5) Present at the results at the end of semester Engineering Retreat to all the faculty of the College of Engineering
6) Obtain any required Faculty Senate Approvals required to change or introduce new courses.
7) Design the detailed curriculum and roll out the program starting in the fall semester of 2014

STUDENT SURVEY AND STUDENT FOCUS GROUPS

The first year committee developed a "Survey Monkey" based online survey consisting of 30 questions on the status of the first year engineering program. It was sent out to all undergraduate students in the College of engineering. Approximately 16 percent of all the students in the college of engineering responded. The data were analyzed by major, by year in school to understand what the students felt about the current program and what they felt they wanted from the revised program. Overall there were clear points gleaned from the survey as summarized below:

- About 10% of the students came into the Introduction to Engineering Sequence as undeclared engineering majors.
- Vast majority of the students knew what discipline they want to go into when they came to campus and did not change. Approximately (91%) did not change their major after introduction to engineering.
- Students clearly wanted more skills taught in the introductory courses (such as programming, CAD, Matlab, etc.) that will help them in their engineering education
    - Students wanted more hands-on experiences and projects relevant to their majors (59%).

  - Students wanted less "soft skills" in the introductory course and almost all wanted fewer talks by faculty (58%).

- Students did not like the format or content of the existing introduction to engineering I course: only 26% of students surveyed said that the Introduction to engineering I course better prepared them for their major and only 38% thought that the course gave an accurate representation of their chosen major.

In the Introduction to Engineering II course, the students wanted major specific skills and hands on projects (61%).

To get feedback on the proposals that were on the table, we formed a focus group, and of course fed them Pizza to get them to come. Two or 3 students, either seniors or first year graduate students, who had gone through the undergraduate program were selected from each major department. Students were grouped into tables with one representative from each major. Without telling them the school that offered each program, we had each table look at least 3 of the 6 initial course models from different universities. Students in the focus group echoed the survey results in that they wanted more hands on projects in their area and they wanted a course model that emphasized core skills required for student success. Based on the focus group we came up with the two semi-final course models described in the next section

REDESIGNING OUR FIRST YEAR ENGINEERING PROGRAM: TWO PROPOSED CURRICULUM MODELS

After multiple iterations on potential curriculum designs based on the survey and what we believed was implementable in the short run given all the constraints, best practices at peer institutions [1-5], alignment with the Dean's strategic goals, input from the focus group, and feedback from the department chairs we developed two potential course models:

Model 1: Project based First Year Elective offered by the Departments.

The first course model which we called "Freshman Elective" is based on the concept of students taking a minimum of one department sponsored first year introduction to engineering elective course. Students have the option to take additional introductory courses to explore different majors if they wish. The courses run both semesters to balance out resource loads and minimize stress on infrastructure and teaching resources (Instead of offering 12 sections of Introduction to Engineering II second semester and 1 section first semester, we offer 6 sections each semester since it can be taken any time the first year). Each department run Introduction to Engineering course teaches core skills appropriate to that major and includes at least 1 or 2 open ended design projects to give students a feel for the type of problems that students solve as engineers. The introductory course are either 2 or 3 credits (2 was ultimately selected by the Dean to reduce credits) and run as either 1 or 2 lectures per week plus 2 hours of lab. General topics such as how to get around campus, student clubs and organizations are covered by a series of videos that students watch on their own.

For example the Electrical and Computer Engineering introductory course teaches programming in MATLAB for the first 7 weeks and students do projects using an Arduino microprocessor and basic electronic components in the second 6 weeks. Students also learn to use basic test equipment such as an oscilloscope, voltmeter, etc. Mechanical Engineering students learn MATLAB and use it to control a CNC machine on which they do a series of projects. Civil and Environmental Engineering stresses Autocad in their introductory course and Plastics engineering stresses 3D printing and SolidWorks. The introductory courses are designed so that there is some overlap in content between courses so that students can take a different intro course than the department they were selecting (an example is mechanical engineering and electrical and computer engineering that both have a MATLAB component). This allows us to balance out the number of sections each department must offer and compensate for student scheduling issues.

Model 2: Skills Modules

The second course model which we called "skills modules" requires first year students to select and take a minimum of four one credit modules over the first year from a selection of skills modules offered by the college. Examples of the proposed modules include: AutoCAD, Matlab, Arduino programming, robotics, alternate energy, chemical processes, transportation systems, SolidWorks, basic electronic test equipment, etc. The purpose of this approach is to allow students to explore different engineering disciplines and to provide a breadth of skills across the college. Departments would be allowed to require students to take certain modules as prerequisites for higher level courses. For example Civil Engineering might require an Autocad module, whereas ECE might require a MATLAB module or a basic electronic test techniques module.

DESIGN AND ROLLOUT OF THE NEW PROGRAM

The department chairs and the Dean were briefed on the outcome of the redesign process. While the committee members tended to favor the "skills modules" approach, concern was raised by the chairs about managing the logistics and about balancing load of these modules. Based on views expressed by the department chairs and the desire to have the new program ready to roll out the following fall, the Dean selected the lower risk first year design elective course *model 1* because he felt that it would

involve fewer logistics issues, would scale better, and would be easier to rollout quickly. The Dean determined that he wanted the course to be 2 credits rather than 3 providing a credit reduction for all majors of between 2 and 3 credits (an additional 1 credit first year elective in ECE was also eliminated). The topics currently taught in the original Introduction to Engineering I course such as student activities, how to get around campus, using the Library, etc are covered by a series of video's that are assigned as part of the Introduction to Engineering course. Students watch the videos on their own rather than cover it in lecture which was strongly advocated by the students in the survey and focus groups.

The final step was to brief the faculty in the departments, and this was done college wide by the department first year instructors to the faculty of their individual departments. Course content for the modules was developed over the spring and summer of 2014 so as to be ready by fall semester 2014. Courses were offered in conventional classrooms and laboratories during the fall 2014 and then use the "maker space" Design Center starting in the Fall of 2015.

Conclusions and Observations

The Introduction to Engineering course sequence at University of Massachusetts Lowell was very expensive to run, taxed the classroom and laboratory infrastructure of the college, and in the end was not providing students with the skills that they said they needed and wanted to help them succeed in their time at UML. The original two course 4 credit sequence was eliminated and replaced with the option to take one or more 2 credit major specific first year elective course. The restructured sequence reduced program credits for most students by 2 credits, and eliminated 40 TA lab slots and 4 faculty class slots in the first course providing a significant reduction in the cost of running the first year program. The new major specific first year elective courses were redesigned to stress core skills required for success in each major along with design projects that help students to understand what types of problems engineers in their discipline had to solve. The first rollout of the new Introduction to Engineering course began in the fall of 2014. Some compromises had to be made in terms of content and credits to meet the overall goals and schedule of the program, but surveys after the first 2 semesters indicate that the students are getting more out of the new course sequence.

We observed from the process points from the process that students are key stakeholders in the results of the program redesign and getting their feedback and input was the most valuable source of information on how to design the course. Information and ideas from the FYEE conference also served as a basis for different course models and what works and what does not work. Students found that having a hands-on experience in the first year made them more competitive for co-op and other engineering type jobs. It also tended to level the playing field for students from less affluent high schools that did not have access to more advanced courses. The final point we learned is that things CAN happen quickly, even in a university environment, when the Dean decides that making a change is a priority and the department chairs go along with the need for change.

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