# A Methodology for Restructuring Our first year Introduction To Engineering Sequence at University of Massachusetts Lowell

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

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## ABSTRACT

This paper shares our systematic approach to a restructuring of 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. Input from students as to what they wanted out of an introductory course was a key element of the process; much of what we did was based on results from a detailed 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.

## I. Introduction

University of Massachusetts Lowell is a medium-sized (17,000 students) public research university 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 a rate of approximately 10% per year. The first-year cohort is approximately 50% on-campus residential and 50% commuter students and comes from diverse economic and demographic backgrounds. Many students are the first in their families to go to university. First-year retention is one of the key concerns the College of Engineering 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 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 two, 2 credit 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 therefore had a fall term enrolment approaching 600 plus students and approximately 100 students in the second semester, mostly transfer students. The first course was run in the form of 2 lectures and 2 hours of laboratory per week. Each of the 4 lecture sections, with approximately 150-200 students each, was subdivided into laboratory

sections run by a Teaching Assistant (TA) with a maximum of 19 students per lab section. The lectures were a mix 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 or soup cans 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 per week 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 independent sections were run by the individual departments with a variety of different curriculum models ranging from hands-on topics 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 concerns 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 skills they thought necessary for them to succeed. Students also felt that they were not gaining a real understanding of what engineers in the different disciplines did, to help them decide on a major. 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 set of requirements when redesigning the first year introduction to engineering sequence:

1) The total credits (4) cannot increase, and he would prefer a reduction in the credits.
2) Achieve significant reduction in the cost of running the first-year program.
3) The new first-year program should focus on teaching core skills such as programming, using basic CAD tools, using basic test equipment, etc to help students succeed in future engineering courses and 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 start of the next academic year.

## II. Process for Choosing a New First-Year Curriculum Model

A wide variety of first-year engineering program models exist and the committee decided take a two-pronged systematic approach to figuring out what the new course model should be. The committee believed that to a large degree, students who are in years 2 through 4 have a good idea about what kinds of skills they would want to learn in an introductory class, so we would give great weight to their input. Since the first-year program had not been changed in more than two decades, the committee wanted to look at what other schools were doing with their first-year programs.

The first step of the committee was to conduct an assessment of course models at other universities using the methodologies described in [1-5] as guidance to help design a program that would work for our students. As the committee looked at different curriculum models for the first-year programs there was a focus on peer and peer aspirant institutions, especially those with similar size and student body makeup. The factors that the committee looked at were:

a. How program models align with our strategic goals
b. How program models scale and their cost to operate
c. How the program would work for OUR first year student cohort with its diversity and mix of residential and non-residential students.

The committee then wanted to know what the students thought. The committee designed 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).

Along with the general survey the committee wanted to talk to students directly, and part of the plan was to conduct a focus group of selected upper class students in each department to survey their feelings about potential program redesigns based on their experiences with the original program.

After analyzing the results of the focus group, the survey, and the analysis of other programs, the next step in the process was to develop two semi-finalists for proposed course models and brief the department chairs individually to determine their level of buy-in for the proposed designs and then formally brief the Dean and Chairs Council and have them select the final format for the course from the two final recommendations.

**III. Student Survey Results:**

The first-year committee developed a "Survey Monkey" based 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 and 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.
- A vast majority (91%) of the students knew what discipline they wanted to go into when they came to campus and did not change their major after Introduction to Engineering
- Students clearly want more skills taught in the introductory courses (such as programming, CAD, MatlabMATLAB, etc.) that will help them in their engineering education
  - Students wanted hands-on experiences and projects relevant to their majors (59%)
  - Students generally wanted less of what they called “fluff” such as how to get around campus, clubs and activities time management etc. in the introductory course (58%).
  - Most of the students wanted fewer talks by faculty (61%)
- 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%)

**IV. Feedback from the Student Focus Group**

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 three 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 read and discuss 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 hands-on projects in their area of study, and that

they wanted a course model that emphasized skills such as programming, CAD, test equipment, that are required for student success. Based on the focus group we came up with the two semi-final course models described in Section V.

## V. Two Proposed Curriculum Models for the Restructured First Year Program

After multiple iterations on potential curriculum designs based on the survey and what we believed was implementable given all the constraints, best practices at peer institutions, the Dean's strategic goals, input from the focus group, and feedback from the department chairs, we developed two semi-finalists for the course model:

### *Model 1: Project-based first-year elective offered by the departments.*

Course model 1 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, the hope is to offer 6 sections each semester since they can be taken any time the first year. Each department-run Introduction to Engineering course teaches 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 courses are 2 credits and run as some combination of 1 or 2 lectures per week and 2 hours of lab. What the students called “soft skills” or “fluff” such as how to get around campus, student clubs and organizations, et cetera, would be covered by a series of videos that students would watch on their own. Topics such as engineering ethics and economics are covered in other required courses. Time management and use of the student tutoring services are integrated into each of the first-year electives.

### *Model 2: Skills Modules.*

The second course model recommended by the committee requires first-year students to select and take a minimum of four one credit, half-semester modules over the first year from a selection of skills modules offered by the college. 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.

## VI. Design and Rollout of the Program

The individual department chairs and the Dean were briefed on the outcome of the redesign process. While the committee members tended to favor the skills modules-based *Model 2* used at an increasing number of schools, concern was raised by the chairs about managing the logistics and about balancing the load of these modules. Based on concerns 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 of between 2 and 3 credits for all majors (an additional 1 credit first year elective in ECE was also eliminated). 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; the plan is to use the "maker space" Design Center starting in the fall of 2015.

Examples of the restructured course models:

- The Electrical and Computer Engineering introductory course teaches programming in MATLAB for the first 7 weeks and students do hardware/software projects using an Arduino microprocessor and basic electronic components in the second 7 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 with 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 courses have a MATLAB component). This allows us to balance out the number of sections each department must offer and allow students to change majors in the first year without any time loss or need to take additional courses.

## VII. Conclusions, Observations and Key Learning

The former 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 first-year experience that they said they needed and wanted to help them succeed in their time at UML. The original two-course,

four-credit sequence was eliminated and replaced with a two-credit major-specific first-year elective, in the process reducing program credits for all students by 2-3 credits. It also eliminated 40 TA lab slots and 4 faculty class slots, 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 hands-on skills required for success in each major along with design projects that help students to understand what types of problems engineers have 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 of the program, but surveys after the first semester indicate that the students are getting more out of the new course sequence.

Our biggest take-away from the course restructuring and design was that including the students as active stakeholders in the process (not just passive consumers of the content) provided a great deal of value added. Without the survey and focus group results, it is not clear that the committee would have come to the same conclusions.

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