# AC 2008-919: FROM 0 TO 60 IN 1 YEAR

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# From 0 to 60 in 1 Year

## Abstract

The University of Cincinnati began a conversation in the fall of 2006 with two area all girls' schools with the hope of providing these students the opportunity to become better informed regarding engineering and technology. Working with Mount Notre Dame High School and Mother of Mercy High School, the team first defined a program then developed that program for the schools and their students. One year later sixty young women participated in the first offering of a new course at these two schools. This paper describes the characteristics of the program and the methods used to present the course to the schools and their students.

## Program Development

Mt. Notre Dame and Mother of Mercy high schools individually contacted the University of Cincinnati with a request to work with them to promote engineering as an area of study for their students. A working group was formed along with Princeton high school (which has a large minority population.) The working group had no formal charter and no funding, only a common interest in providing greater opportunities for students.

The first major decision addressed was the establishment of the goals of the program – what did the collaborators want as an outcome of the efforts? The group concluded that rather than teaching engineering, the program goal would be as many students as possible should leave high school with a working knowledge of the practice of engineering. A related, secondary goal was established that students would have a clear understanding of the study of engineering and engineering technology and be equipped to make an informed decision to select (or not select) an engineering course of study for college. It is important to note that in order to serve their students well the high schools needed the course content and projects to provide an understanding of both engineering and engineering technology.

The next major step was to establish a pedagogical approach appropriate and meaningful for the student population. Through discussion, review of available materials and investigating existing programs the collaborators settled on a project-based approach to presenting the course. The decision was based on providing students engaging activities that demonstrated engineering concepts through problem solving rather than providing students significant material to read and learn. A text was identified that facilitated this approach – Engineering Your Future: A Project-Based Introduction to Engineering[1].

With the course objective established and an appropriate text as a resource, the syllabus was crafted to accomplish the learning objectives. The course was developed in a modular fashion with the modules devoted to a branch of engineering / technology (e.g. civil, electrical) or a topic common to all branches (e.g. design, communication). The modules typically contain three elements:

1. Activities performed in the class room
2. Instruction on the topic
3. Readings from the text or other materials provided to the students

Table 1 provides an abbreviated version of the syllabus. Note that some topics are completed in one or two class sessions while other topics can span several weeks.

**Table 1 Abbreviated Syllabus**

| Topics | Activities | Sections |
|---|---|---|
| Introduction to Engineering and Engineering Technology | Student assessment<br>Product dissection | Chapters 4 -5 |
| Working in teams / managing time | Desert Survival<br>Develop Teamwork Rubric | Chapter 13 |
| Communication: written, oral, presentations; Intro to Technical Writing | PowerPoint presentations<br>Using Excel | Chapter 7 |
| Communicating Ideas | Sketchbook activities<br>Innovative Creations | |
| 2-D CAD | AutoCAD | |
| Engineering in Context: Civil Engineering / Architectural Technology | Simple truss design<br>Sustainable Urban Engineering | |
| Engineering Design; How Things Work | The Design Process;<br>Reverse engineering | Chapter 15 |
| Engineering in Context: Mechanical Engineering / Technology | SAE Design Challenge 2<br>Solar Vehicle | |
| Engineering in Context: Materials Engineering / Technology | Introduction to Materials Tech<br>Carbon Nanotubes | |
| Engineering in Context: Aerospace Engineering / Technology | Visit GE Aircraft Engines Facility | |
| Engineering in Context: Manufacturing | Manufacturing products that solve problems | |
| Problem Solving; Creativity | Dissecting a JETS problem | Chapter 14 |
| Engineering in Context: Electrical Engineering / Technology | Ohm's Law; Solar Energy Challenge | |
| Engineering in Context: Chemical Engineering / Chemical Technology | Thermodynamics video;<br>Sterling Engine project | |
| Succeeding in Engineering<br>Semester Projects | Study habits | Chapter 9 |
| Project Presentations | | |

The group identified the constraints faced by the schools and recognized that these were different for each school. Constraints included: limited resources, availability of qualified teachers, classroom space, room in the school's curriculum, and technology availability. It was also clear that the schools had slightly different expectations of which of their students would participate in the course. One school was interested in serving their highest performing students, another wanted a survey course students could self-select, and a third wanted to attract students who ordinarily would not have considered pursuing engineering. From the university's perspective, increasing the number of students enrolling in STEM related disciplines was a goal that suggested that all student groups were of interest.

The teachers selected to present the course were veteran instructors chosen because of their interest in leading such a course. While the text selected provided a good resource for describing engineering functions and disciplines, it was not sufficient to present an engaging view of the various engineering disciplines and topics. One of the teachers has a degree in engineering, but this is a rare luxury since most teachers are not trained appropriately to present this breadth of engineering topics. To support all the schools (and to enable additional schools to participate in the program in the future), the decision was made to have faculty from the university provide instruction on these topics. In addition, the University sponsored a workshop for the high school instructors during the summer. The workshop focused on how to lead engineering type projects, classroom management for a project-based course, instructional resources, and appropriate assessment methods.

**Program Characteristics**

Given the particular goals established for the course and the constraints imposed by the student population and school attributes, it was clear that the program needed some distinguishing characteristics to allow it to be successful. These are described in the following paragraphs.

*Accessible* - as many students as possible should be able to participate and benefit from the course. As the content was developed the collaborators kept the pre-requisite knowledge to a minimum and did not assume that students had familiarity with math beyond geometry or science beyond an introductory physical science course. While each school had a somewhat different target population, this approach enabled the content to be useful to all groups. Schools could (and did) choose to augment the material to be suitable to their own needs and students. For example, for the school targeting high performing students, references to physics and pre-calculus were brought into the project discussions. Except for that school, enrollment was not limited to advanced placement students. The other schools hoped to attract students to STEM who might not ordinarily consider such disciplines through the project-based nature of the course. Through purposeful design of the content and selection of projects, students with varying academic backgrounds had the opportunity to participate.

*Flexible* - each school had different resources, different students and different expectations. The course needed to be flexible enough to accommodate these variations while providing a cohesive and appropriate program of study. Significant variations included schedule and classroom availability. Two schools used block scheduling, the other a traditional 7 period day; one met in a science lab, another in a computer classroom and the third in a classroom with drawing boards and computers. In two schools the course was taught by an instructor in the science department, in the other school the instructor was from the technology education program. Since the student groups differed somewhat the specific projects and the length of time spent on projects varied. In all cases, interested parents who are engineers volunteered to make presentations to the class according to that schools schedule.

The syllabus provides the structure for the course and the basic roadmap through the topics but schools chose activities and made decisions regarding time spent on topics that fit their particular situations. A school with an experienced CAD instructor spent considerable time on that topic while another school with no CAD experience spent minimal time on the topic, spending more on problem solving strategies. Some schools participate in the Junior Engineering Technical Society TEAMS competition[2] and incorporate preparation for this competition into the curriculum. The collaborators expectation was that the schools would cover the topics on the syllabus so as to provide a breadth of understanding of various engineering disciplines and concepts but the depth to which each was addressed was guided by the needs and resources of each school.

*Affordable* – the schools needed to be able to offer the course with existing resources and staff. No new teachers would be hired and there were limited resources for training or purchasing supplies or materials. With our goal of providing many project-based experiences, careful attention in selecting projects was required. Fortunately there are a number of very good resources that provide freely available project plans, many of which are now linked to state and national educational standards. Table 2 provides a list of the freely available resources that were most significant to this effort. Some projects have a modest cost associated with them (Future Scientists and Engineers of America[3] is a good resource) or affiliation / sponsorship (e.g. A World in Motion[4] is an excellent resource.) We identified and reviewed many projects and selected those projects that:

1. Would interest the students
2. Were affordable
3. Enabled students to learn engineering concepts

**Table 2 Project Resources**

| Title | Type of Resource |
|---|---|
| Teach Engineering [5] | Math, science, and technology lessons and activities |
| Try Engineering [6] | Lesson plans for science and technology |
| Teachers' Domain [7] | Lesson plans, activities, videos etc on science and engineering |
| California Industrial & Technology Education Consortium [8] | Projects related to construction, manufacturing, transportation, energy and engineering |
| Project STEP [9] | Lessons and activities in science, engineering and mathematics |

In order to support the schools in the teaching of the course, the university sponsored a summer workshop. During this workshop the author of the text (who is also experienced at presenting pre-engineering in high schools) described methods for teaching pre-engineering in high schools, addressed best practices, and facilitated classroom management by leading the instructors through projects.

*Scalable* – the course was developed so that other schools could also participate. The materials, curricula, pedagogy, etc. allow many other schools and students to take part so that as many students as possible would have an understanding of the practice of engineering. One of the primary issues addressed was the presentation of engineering content. High school instructors typically do not have the education or experience to present a broad range of engineering topics. College faculty are often willing to present a class or two to a local high school but it is rare for a college to have the resources to provide a faculty instructor for an entire course. To address these issues, it was decided to use technology-based instructional modules to present engineering disciplines and concepts. Faculty and staff from the university developed content to describe different disciplines, instruct on engineering applications, and present over-arching topics. These individuals were then filmed presenting the content and these were digitized and made available as streaming media through a web site. In this way, students had access to the content at their convenience and anyone with access to the web site could view the materials. Figure 1 is a screenshot of one of these modules.

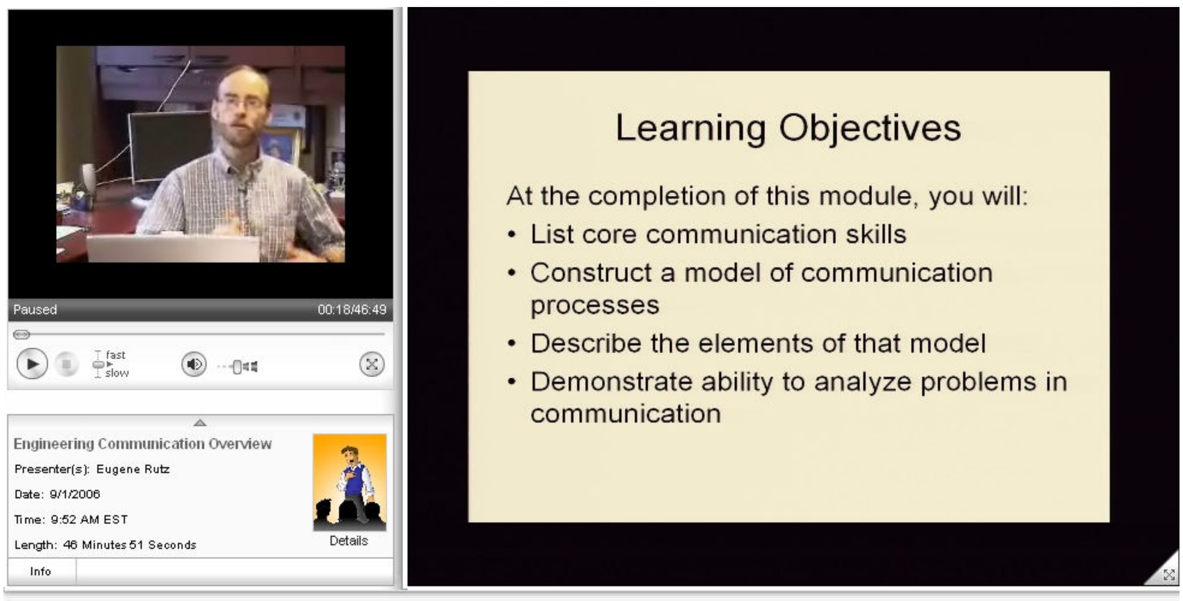


**Figure 1 Instructional Module**

The combination of instructor-led classroom projects and instructional media delivered through the web provides both the means for most schools to present the course and a pedagogical approach that facilitates student engagement. Likewise, proper attention to minimizing cost of needed materials and flexibility in presenting the content allows other schools to participate without significant investment of resources or burdensome changes to teacher workload.

**Program Implementation**

With the constraints and school-specific expectations, each high school implemented the course somewhat differently. At Mt. Notre Dame high school, one section of the course was offered as a year long course available to juniors and seniors. At Princeton high school two sections of the course were made available for the school year with enrollment open to sophomores through seniors. At this school, students could opt to take the course for “weighted credit” or not. At Mother of Mercy high school two sections of a one semester course were offered to juniors and seniors.

The instructional modules, presentation materials and supplementary student material were made available to the students through the university's Blackboard course management system. Special permission was needed (and granted) to give the high school students and instructors access to the Blackboard site. Figure 2 illustrates the layout of the content in the Blackboard system for the electrical engineering topics. The significant web-based resources used by the high school instructors were also provided via the Blackboard site.


**Figure 2 Materials Available Through Blackboard**

Material was typically presented as follows:

- Introduce the project through class room discussions
- Describe engineering and technology contributions / connections to the topic
- Conduct the project during class time
- Students view related instructional modules as home work
- Student presentations or reports on project and engineering connections to the project

Students were evaluated on class room participation, quality of the presentation or report, and their understanding of principles. In some cases, students were given a brief quiz on the instructional module to encourage viewing and appropriate attention to the content.

**Unfinished Business**

Since this was the first year of implementation, there was much to be learned regarding all aspects of this effort. For example, some projects were better received than others and some were better at enabling students to appreciate the practice of engineering. At the conclusion of the school year, the working group will evaluate which projects should stay, which should be removed and which should be modified.

Based on formative assessments, additional work needs to be put into making connections between the projects, the engineering concepts covered, and the practice of engineering. Faculty at the university will add content and modules as these are identified by the high school instructors.

The instructional modules have proven to be adequate at presenting topics. Based on student feedback, additional modules will be developed and some modules will be re-done for better clarity, more appropriate content or both.

Students were provided a pre-course assessment to measure their understanding of engineering and various engineering concepts. A post-course assessment will also be administered to help to quantify the learning gains provided by the course. This evaluation will be the subject of a future paper.

To make the instructional modules more readily available to a broader group, a distribution method that does not rely on access to a content management system like Blackboard is needed. Several possibilities are being investigated. Discussions are also underway with the textbook publisher regarding making the technology-based content available with the text.

Increasing enrollment of women in STEM disciplines remains a work in progress. The reception of students to this course indicates that while work is needed, a collaborative program that is purposefully designed to engage students can lead more students to pursue engineering and technology.

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