

***Engineering First* at Northwestern University:  
Where We Are in 2003**

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## **Abstract**

Seven years ago we launched an innovative freshman curricular revision we call *Engineering First*, and it is now possible to see some of the lasting benefits it has added to the McCormick education. This paper will overview of how closely the intended outcomes were met and how *Engineering First* has driven curricular reforms at upper levels of our curricula. Evolution of the pedagogy as well as content of the *Engineering First* courses has occurred, and many discipline-specific courses have now adapted to the enhanced capabilities (and expectations!) that our students have. Most significantly, combining work that emphasizes communication skills with the doing of design (as a hallmark activity of engineers) is now being implemented in senior level capstone experiences. Consequences of *Engineering First* on attracting incoming students as well as on post-graduation careers will be presented.

## **Introduction**

*Engineering First* is the McCormick School's response to the many calls for curricular change coming from the profession and from external concerns, such as the National Academy of Engineering and the National Science Foundation. *Engineering First* challenges its students to develop new ways of thinking, by converting them from learning academic topics in isolation to learning engineering topics in an integrative fashion. Given that engineering at its very essence is "the creation of new things that people want", then young women and men who aspire to advance mankind's well being need exactly this kind of holistic thinking. Most engineering freshmen have little accurate knowledge about what distinguishes an engineering education from one in, say, science, but today's college students actually become energized by getting into engineering academic work as soon as they enter college.

Implementation of a significant revision of the freshman engineering curriculum has required the usual mix of patience, vision, diligence, and attention to details. The process here at Northwestern started by engaging leading faculty to drive this enterprise. Using their collective wisdom they crafted two new course sequences that encompassed the topics of courses in our then-existing basic courses. All-faculty approval was then garnered. A multi-year phase-in plan was implemented. Resources were acquired progressively. Ample communication with students, parents, University administration, and faculty was a priority. Continuous improvement was based on feedback from students, instructors, grades, enrollments, and employers, and this continuous

improvement will, by definition, remain the by-word for its success.

### **What is *Engineering First*?**

This program is the pair of new, sequence courses: "Engineering Analysis" and "Engineering Design and Communications". They are described briefly as follows (and see: <http://www.tech.nwu.edu/efirst/courses.html>).

#### "Engineering Analysis" (GEN ENG 205-1,2,3,4)

This four-quarter sequence course covers topics previously found in five required, stand-alone courses: linear algebra, differential equations, first-quarter college physics (Newtonian mechanics), computer programming, and engineering mechanics (statics and dynamics). Throughout the four quarters there is extensive integration of subjects, sometimes on a lecture-by-lecture basis. This structure intentionally initiates students to working on

problems that require them to integrate multiple academic areas in order to reach a solution. Engineering case studies are used where appropriate.

#### "Engineering Design and Communications" (GEN ENG 106-1,2 plus ENGLISH 106-1,2)

This two-quarter course combines developing enhanced skills in writing with doing design, as one of the hallmark intellectual skills common to everybody who is an effective engineer. The central activity in each of the two quarters is the development, to the level of a full prototype, of a new technology that somebody wants. Students do these projects in teams of 4±1. Instruction is done jointly by faculty from McCormick and the Weinberg College of Arts and Science's Writing Program and is more a matter of coaching rather than making blackboard presentations.

### **How did *Engineering First* Develop?**

The objectives of *Engineering First* were derived from a broad view of how best to benefit students wanting to earn an engineering education. At the heart of this view is the notion that entering students enroll in engineering school with high levels of enthusiasm for learning to do the things that engineers do but are very naïve about what that actually means. *Engineering First* intends to exploit this energy and curiosity in a way that drives their learning. It avoids the time-honored curricular structure of introducing students to engineering with a nearly two-year complement of mathematics, science, some humanities, some computer code-writing, and some basic (read: dry) engineering topics. This traditional structure leaves chiefly to the second part of a curriculum the interesting courses that pertain to their engineering major. *Engineering First* communicates to students that engineers are central to those value creation processes that propel civilization forward.

Thus, the goals and objectives of *Engineering First* are to:

Goal 1. Engage McCormick's students in engineering concepts right from the beginning of their freshman year.

Objective 1a. Enliven the learning of essential mechanics principles.

- Objective 1b. Develop computer usage skills in a context of engineering topics.
  - Objective 1c. Use the synergy of presenting elements of mathematics and physics in a tightly integrated fashion to demonstrate how engineering necessarily deals with the full complexity of systems.
  - Objective 1d. Implement the case-based learning process that the large majority of engineering students favor.
- Goal 2. Establish in our students the necessary concepts for doing engineering design, as an intellectual activity common to everyone with an engineering education.
- Objective 2a. Involve students in activities that encourage creativity as well as innovation.
  - Objective 2b. Respond to the expectations of our freshmen to engage in engineering-related activities from the start of their time with us.
  - Objective 2c. Give our students early experience in working in teams.
  - Objective 2d. Make clear the integrative nature of good engineering.
- Goal 3. Develop relationships between individual McCormick faculty and students right from the very start of their college careers.
- Objective 3a. Provide a small class environment where first year students can complete an engineering design project.
  - Objective 3b. Facilitate dialog between faculty and students on matters related to their professional development.

Thus, one can see that *Engineering First* seeks more to grow new habits of the mind as a result of their learning experience, and it sets students' expectation that their education will be much more than just an accumulation of domain specific knowledge.

## Implementation Experience

One of the essential features of a successful change in an educational program is its capacity for continuous improvement. An understanding by the faculty that they must always be assessing for improvements – those driven by recognition of better learning objectives as well as those driven by unsatisfactory meeting of existing learning objectives – may be uncommon but is essential. Assessment of the courses in *Engineering First* involved many activities, including focus groups, grades earned in follow-on courses, an all-student on-line questionnaire, and a study of over-all academic performance during the first two years. These results have been reported elsewhere [ref. 1], but the significant advances are:

1. Superior skills at using computers to solve engineering problems. (*viz.*, can adapt high-level software to doing engineering)
2. An ability to differentiate solving engineering problems from just doing complex computations. (*viz.*, can integrate understanding drawn from various academic domains)
3. Higher GPAs at the end of the sophomore year *cf.* the start of their freshman year (*viz.*, have a minimal “sophomore slump”)
4. Better engagement with faculty beyond merely their adviser.
5. Functional skills in working on teams.

Examples of the changes implemented during the first six years of *Engineering First* include: 1) a migration of the design projects in the first quarter of “Engineering Design and Communications” from websites to vehicular design, 2) better tutorials for MATLAB®, 3) extra “workshop” sessions to supplement the regular “Engineering Analysis” lectures, and 4) an honors track for “Engineering Analysis”.

The development of *Engineering First* is not without its challenges. One is the need to accommodate the “freshman experience”, including their big adjustment to life after high school and their uncalibrated expectations of college-level learning. Another is the need to assure a succession of faculty to rotate into the teaching roster after the initial converts have rotated out of it. In some cases there is just the problem of finding faculty who have enough courage to teach subjects not clearly of a single domain. Finally, adequate resources are always requisite for success. In the case of *Engineering First* there was the need to create engineering design studios, a student-oriented shop, and PC labs sufficient to support the team-based learning that is involved with both courses.

As a corollary to these challenges, we have recognized quite a few unpredicted consequences that help bolster our certainty that *Engineering First* truly adds significant value to the McCormick engineering education. One is indeed what was intended: the students see themselves in a community of scholars dedicated to their personal development. This often manifests itself now in terms of the confidence our students exhibit for campus-wide involvement and for their penchant to engage in extracurricular projects within the engineering school. The instructors for both the *Engineering First* courses form cohorts that meet at least weekly for the dual purposes of coordination and for the larger issues, such as the effectiveness of the syllabi or the ways to assess student learning. Truly they get into the scholarship of teaching and learning. In fact, the development of new pedagogy occurs regularly in these courses, and new opportunities *effectively* to employ instructional technology continuously emerge from these instructor communities.

### **What’s next?**

Two very significant movements have surfaced as a direct result of being born from the innovation of *Engineering First*. One is the recognition that combining student work in engineering design is enhanced symbiotically by work to improve communication skills (written, spoken, and graphical). The “Engineering Design and Communications” course intentionally combines engineering design with writing (primarily), but secondarily speaking and drawing (free-hand *and* CAD); there are now in the implementation stages new *capstone-level* courses combining engineering design with speaking (primarily), and secondarily writing and prototyping. The pioneer department to do this is Biomedical Engineering (BME), and the second department to join in this year is Industrial Engineering and Management Sciences. An indication that this evolution represents more value-adding to our educational experience is the fact that three of the four college-wide awards for capstone projects last year went to BME projects.

The other emerging development is the formation of a new organizational unit of the McCormick School, the Institute for Design and Engineering Applications (IDEA). This organization will oversee much of the infrastructure as well as the coordination needed to

support the continuing evolution of design-based activities (curricular as well as extracurricular). It will be the focal point for promoting research on engineering design, as a unique form of intellectual activity, and it will foster multidisciplinary enterprises (*viz.* art and engineering) that will extend further the reach of what the fields of engineering can aspire to embrace.

### **Reference.**

1. *"Engineering First at Northwestern University"*, Proceedings of the International Conference on Curricular Change in Engineering Education, Union College, November 2001.

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