SMITH College

> EGR 100 – Engineering for Everyone – is as an accessible course for all students, regardless of background or intent to major in engineering. …Students develop a sound understanding of the engineering design process including problem definition, background research, identification of design criteria, development of metrics and methods …prototype development and proof of concept testing. Reading assignments and in-class discussions challenge students to critically analyze contemporary issues related to the interaction of technology and society.

So reads the description of Engineering 100 in the Smith College catalog. As is made explicit, the course functions as an introduction to first year students considering an Engineering major at Smith. But what makes EGR 100 unusual is that it is also an overview of engineering for students who want to round out another major, or just get informed -- a classic "Gen Ed" course. This means there are no specific prerequisites except interest and willingness to learn, and that the course features articles as well as textbooks, discussion in relatively small sections, and the inclusion (in some cases, a focus) on contemporary issues.

When in 1999 then President Ruth Simmons launched Smith's innovative engineering program, it was with a call to *pay attention."*Engineers design and build much of the human environment." she said. "Women must not accept so marginal a role in so important a field." She could have said "Americans" in place of women. Women may be only 19% of the graduates in engineering, but U.S. citizens overall are under-informed about what engineers do and how they think about what they do. Before committing to engineering, President Simmons understood, women students need to know "What is this profession? How might I fit in?"

The purposes of Engineering 100 have continued to expand along with the number of enrollees. In a recent school year, 5 sections filled each with 20 students. And of the 100 enrolled, 40-50 will stay in one of the two majors offered at Smith, a bachelor of science in engineering science and a bachelor of arts in engineering science. (Smith also offers a Minor in Engineering.) For the others, there will be the invaluable benefit of learning "…what living in a technologically advanced society is all about."

The first time Engineering 100 was taught, it was a more standard "intro course" for future engineering majors and another course, called Engineering 101 (modeled on David Billington's CEE 262 focusing on bridges and structures) was the course "for everyone." In 2005, the two courses were merged and the name was changed to Engineering for Everyone. Since then, the course and Smith's program overall has attracted leading engineering educators, including Susan Voss, Borjana Mikic, Glenn Ellis, and Andrew Guswa. Guswa, who is bringing a new water resources course to EGR 100 next year, concedes that, being meta-cognitive (forcing students to reflect about themselves in relation to engineering) the course may disappoint some students who just want to build robots, without pausing to reflect on purposes or process. But he and his colleagues' purpose is to demonstrate *how* the concept of design permeates all of engineering, whether civil, mechanical, or electrical.

II How Smith College's Engineering Program came to be.

In the 1990s and before, Smith College offered undergraduates a 3:2 model in partnership with Dartmouth College, which had a long and well-developed five-year program in engineering. The vision for a wholly integrated engineering program at Smith, which would make Smith the first women's colleges to offer undergraduates a full engineering program, came from the then president, Ruth Simmons. The program began to enroll students in 2000 and graduated its first class in 2004. There have been 265 BSE graduates from Smith College since 2004.

Clearly, one motive was to enable women students with an interest in the mathematical and physical sciences to explore engineering as a career. But another was to challenge traditional engineering programs that divide the subject (and their students) into subfields. The faculty wanted to provide a degree in "engineering science," by which they intended a broad background in *engineering fundamentals* and *engineering thinking*. As Smith students proceeded through the new program, they would find themselves taking *fundamental* courses from all fields of engineering, in their first two years, including circuit theory, mechanics, and thermodynamics. In their final two years, they specialize by selecting five technical electives that might *either* be typical of a traditional engineering discipline *or* defined by the student's particular inclination toward a more interdisciplinary set of courses.

Another distinctive feature for majors at Smith is class size where engineering courses are limited to 24 students.

III Goals and Operation of Engineering 100

In the early years, as said, half of the enrollment in Engineering for Everyone would be prospective majors; the other half from outside of engineering. These would include juniors and seniors from Smith and from other institutions within the Five College exchange who wanted *some exposure to engineering* before leaving college. Today, first-year prospective majors are prioritized. But the goals are the same for first years as for non-majors:

- Develop your views on the importance and impacts of engineering in society;
- Use quantitative analyses and modern tools in the engineering design process;
- Work effectively both as an individual and as a member of a team;
- Improve your ability to communicate orally, visually, and in writing.
- Develop as a community of learners;
- Gain an understanding of how engineering can contribute to your personal goals.
- Build your confidence and have fun using modern engineering tools.
- Learn about design by doing a group project.

Following are two variations of the course syllabus.

Energy & the Environment (taught alternatively by Paul Voss, Susan Voss, Denise McKahn or Judith Cardell)

When Susan Voss teaches Energy and the Environment, she has her students first learn about energy through a series of experiments, then, become aware of how much our society relies on energy and, finally, study the effects of fossil fuels on the environment. In parallel to readings about how buildings use energy, students design and build a scale model of their own of a zero-energy building. In Susan Voss' view, *no one can learn (or for that matter, teach) about engineering who hasn't designed or built or measured something*. And even students who are not going on in engineering need to understand and experience that.

The assignment starts out with the construction of the experimental building, using Autocad, from cardboard with a laser cutter. Then, if they are to monitor and control their model buildings' energy use they have to learn about microcontrollers and how to program them. As Professor Voss describes the challenge:

Each structure is carefully designed to meet specific requirements for a New England day in December, to maintain an indoor temperature of within 2 degrees of 70 (using sunlight to heat and opening windows to cool) turning on an LED when it gets dark at night, and storing energy within a thermal mass (concrete or water) to maintain a warm temperature into the night. Students must design their structures using *mathematics* and *theory* based on heat flow, material properties of insulation and windows, and calculations of solar flux

Most important, according to Voss, is to have students compare experimental measurements of the building's performance with theoretical predictions because this, students need to understand, is what will inform engineering design.

Water Resources: Case Studies of the Constraints of Place (taught by Andrew Guswa).

Andrew Guswa, who holds a doctorate in fluid dynamics and hydrology, got his first experience of "engineering for everyone" sitting in on David Billington's course at Princeton where he took his undergraduate degree. He later returned to Princeton for a post-doc focused on teaching. There, he developed the lab experiences for a non-majors environmental studies course meant to meet the gen ed science requirement and participated in the Preceptors' group meetings and in learning theory more generally.

Now that he's at Smith College, which doesn't enforce "distribution requirements," Guswa sees EGR 100 as performing a number of parallel tasks: conveying to students who enroll *both* what engineering is about and what living in a technological society should entail. He is currently developing a water resources version of Engineering 100 that will focus on the history of mill ponds in Western Massachusetts (where Smith College is located), most particularly on a mill pond disaster in Williamsburg that he would like his EGR 100 students to understand, was *preventable.* The course fits into a set of courses he intends to expand upon for students at Smith who, he believes, can learn much from the history of technology. And to draw the lesson that good engineering involves not just the invention *of something new,* but adapting a particular technology to the *constraints of place,* constraints that include: climate, legal framework, culture, and economics.

V Pedagogical Carry-Overs to the Program for Engineering Majors

Although the Smith "case," as all the other cases in this collection, focuses mainly on courses in engineering that are meant to attract and serve non-engineering majors, it would be remiss, in the case of Smith College, which has offered EGR 100 for nearly 10 years, not to report how pedagogical considerations in that course spill over into the more standard engineering courses. A key strategy is to help students develop what the faculty considers to be a "strong intuition" for the fundamental concepts of the courses they enroll in, one that can carry over long after they have taken a specific course. Guswa puts it this way in a "teaching statement" he distributes to his colleagues:

> One goal is to enable my students to develop a conceptual intuition, so that the methodologies (we teach them) are seen as sophisticated ways of accomplishing common sense or intuitive tasks.
>
> Another is to relate new material to problems, applications, and experiences outside the classroom to establish its relevance and to help students recall their learning long after they have taken the course.
>
> And a third: To structure course work in such a way to instill a sense of self-reliance in each student [to be able to] work independently and learn continuously throughout her career.

Perhaps, the Smith faculty's greatest gift to their own majors, apart from their skill in teaching, is to convey that learning itself is a skill to be mastered. When engineering students begin to struggle with multi-stage problem solving, they are provided meta-cognitive exercises to help them improve. Also after an exam or a particular assignment, students are asked to reflect (in writing) on their own performance. The faculty's intent is to foster both responsibility and independence and to provide students with a means to develop new skills.

VII Impact on the Smith Faculty as a Whole

Engineering at Smith is relegated neither to the dedicated Picker Engineering Program, nor even to the multiple departments directly involved in teaching engineering students. It reflects, rather, as promulgated on the program's web site, the central importance of engineering to society as a whole.

> As a creative endeavor at the intersection of design, science, and mathematics, engineering draws on nearly all aspects of the human experience, including our history, politics, economics, arts, and societal aspirations. The work of engineers both exacerbates and offers solutions to some of our gravest societal problems, including climate change, disease, resource limitations, and conflict.

Hence, multiple members of the non STEM faculty at Smith (in the words of one engineering professor), "embrace engineering."

Andrew Guswa, speaking for his own set of courses, finds colleagues at Smith who initiate collaboration about water resources engineering. He has had conversations and even class exchanges with Elliott Fratkin (Anthropology) and Susan Sayre (Economics), Ann Leone (French and Landscape Studies), and Al Rudnitsky (Elementary Science Education). When the Deepwater Horizon Oil disaster struck, faculty at Smith from a range of disciplines, initiated a "learning group" to discuss the issues from their disciplinary perspectives and, when feasible, incorporate these into their teaching. As a consequence, Al Rudnitsky developed a new curriculum on water for elementary students.

Some of the collaborations across campus result in joint papers and presentations. Recently, the Deepwater learning group presented one on fostering integration and faculty learning communities, at the 4th Annual Symposium on Engineering and

Liberal Education, at Union College, 3-4 June, 2015; one at the Annual Meeting of the Association of Environmental Sciences and Studies, also June 2015.

Truly, Smith College has moved engineering from the periphery to the center of the liberal arts.