Taste of Engineering

INTEGRATING ENGINEERING INTO A LIBERAL ARTS INSTITUTION

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Abstract

Studies show that exposing students to engineering early in their college career increases their retention in engineering programs. But how can such an experience be created at a liberal arts partner institution that has no engineering department? The College of St. Catherine, the largest Catholic women's institution in the US, is the liberal arts partner in engineering dual degree programs with the University of Minnesota and Washington University. Recruitment and retention of women in engineering is an important part of the College's mission to educate women to lead and influence. "Taste of Engineering" is a pilot program that both supports women deciding to major in engineering and exposes other students to what engineering is. The program's design rests on the school's strengths as a 100-year-old women's college and center for social activism as well as the current research in women and engineering. It has groups of students gathering together to address socially relevant problems using the engineering design process. Other important characteristics include 1) creating a social nature to the gathering, 2) educating science faculty about the engineering process so they can better identify successful engineering students and relate their courses to engineering students, 3) making the program into a 1-credit course that could be taken by students each semester during their 2-3-years of engineering preparation at the College, 4) tracking the participants' success in the engineering part of their education, and 5) assisting other institutions interested in creating a campus-wide, women-friendly recruitment and retention program at their campuses.

1 "Tasting" Engineering

Historically, engineering students took science and mathematics pre-requisite courses in the first year of college. It wasn't until the sophomore year that students were even exposed to engineering. Freshman programs have recently been installed into many engineering programs to expose students to the engineering discipline earlier.

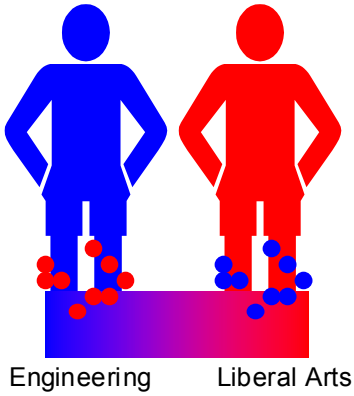

Figure 1: Engineering-Liberal Arts "Smattering" and Connection

Since the College of St. Catherine (CSC) is a liberal arts school, **our role in engineering education is to complement that of institutions with engineering programs**. While innovative engineering schools such as Franklin W. Olin College of Engineering "smatter" liberal arts and social issues into the engineering discipline, we "smatter" engineering into the liberal arts and professional disciplines that our women students have naturally gravitated towards: Education, Health Sciences (Nursing, Physical Therapy, Occupational Therapy, Exercise Science), Business, and Social Work (Figure 1). These "smattering" courses are also an integral part of an engineering recruitment and preparation program necessary for students pursuing an engineering degree through the various dual degree partnerships we have.

This "smattering" strategy is the result of a union of the liberal arts and social activism of the college and the Center of Excellence for Women, Science and Technology (CWST) Strategic Plan for plugging the "leaky pipeline" of girls and women leaving engineering. While supporting women who chose the traditionally male dominated fields of engineering, we also open "backdoor" routes. Socially relevant and hands-on courses entice more women enroll in technical courses and minor programs. Strategically, these routes expose, excite and educate women about engineering and engineering technology opportunities. Financially, they increase the enrollment and demand for these courses and programs. Our current strategy encourages women to enroll in technical courses and then minor in programs that develop engineering problem solving methods.

This synergistic effort of mixing engineering with the liberal arts will create the "partnership" between engineering and the liberal arts that is so needed by industry [3]. By choosing socially relevant topics, we motivate the community-oriented Millennial generation [4] and stay true to our history of social justice and activism.

2 Why "Taste" at St. Kate's?

At the College of St. Catherine (also known as St. Kate's), we hope to have our proverbial cake and eat it, too. Our program prepares women engineers for their engineering education while encouraging the technical fluency of all our students. It is motivated by practical and ideological considerations.

Practically, women will continue to major in the non-engineering courses that they have for years—society can only change so fast. CSC is well known for its fine education of nurses and teachers. Ideologically, the more we can encourage students in these disciplines to *expand* their education to include more technical aspects, the higher chance we have in the future for girls and women to become technologically versed.

Practically, the population of women pursuing engineering ebbs and flows. Creating courses that only they would take or get credit for would be financially unfeasible. Creating courses that appeal to a wider range of students increases their demand and regularity. CSC has a freshman advising program where faculty members often advise student not in their department. By involving faculty from many departments, we ideally make them more aware of engineering, as a field, so they can better advise their freshman students.

Thus, by creating a program where all students can get a "taste" of what engineering is, engineering preparation becomes more viable in an all-woman environment. This fits in with the philosophy of current freshman engineering programs, but also specifically addresses major issues of our all-women environment

2.1 Freshman Programs

There are three main strategies of the latest freshman programs:

- **Freshman programs help retention** by introducing engineering design process early on. Several engineering schools have freshman design class that challenge students to build devices from a box of materials. This experience helps remind students that engineering is a creative process. It also allows them to experience the indescribable satisfaction of making something work [1].

- **Freshman programs help develop success skills** by having students practice them in a "semi-professional" setting. Written communication, project planning, ethical decision-making and collaborative problem-solving are the essential "soft skills" required for success in any professional engineer. The freshman program at Bucknell University, for example, has students create an ADA-compliant project proposal for the university. This experience impresses upon the students the importance of making sound technical suggestions and being able to present the required information to persuade (often non-technical) decision makers about ethically and economically motivated projects [9].

- **Freshman programs model ways to satisfy Engineering Curriculum 2000** (EC 2000) criteria in an engineering educational project [3]. Not only are these programs ways to introduce communication, teamwork and planning skills in an engineering context, these programs set the expectation of students for this integrated approach in the remainder of their engineering education. They create a generation of students who associate such problem-solving strategies as inherent to what engineering is.

The early introduction of engineering and the balance of technical and professional skills also benefit the female engineering population [2] which often magnifies problems seen in the entire student population. Women often go into engineering because they are "good at math and science" but are not always aware of what engineering really is. With the historical method of keeping engineering out of the freshman year and keeping the material theoretical rather than hands-on and relevant, it is only out of "ignorance and tenacity" that they make it through even the most prestigious of engineering programs [5].

Thus, freshman programs serve an important role in the education of women engineers. They introduce students to what engineering is. In short, they give students a "taste" of what life as an engineer might be like. The freshman programs do not replace the disciplined approaches that students will learn in the remainder of their education. They do, however, accomplish three significant outcomes:

- They exercise the **creativity** of the students,
- They emphasize the **broad qualities** required of engineering professionals, and
- They make the supporting **math and science courses relevant** to the end-goal of being an engineer.

In short, they help students re-commit to the engineering field. When the courses are over, the engineering students often are able to confidently state as Samuel Florman did in *A Civilized Engineer*, "I wanted to be an engineer."

2.2 Considerations for an All-Women Environment

The three outcomes of freshman programs are of particular interest to the College of St. Catherine. We have a strong interest in engineering education of women as any future leader needs to be not only technologically literate but also savvy. The freshman programs are promising but must be modified to handle the college's particular situation.

The College of St. Catherine (CSC) is the largest Catholic women's institution in the US and is currently the country's largest women's educational institution. It is the liberal arts partner in engineering dual degree programs with the University of Minnesota and Washington University at St. Louis. We are currently in negotiations with the University of St. Thomas for a similar program.

We are not the only college with engineering dual degree programs. However, with a women-only undergraduate school, we find that the problems of students entering and staying in engineering programs are magnified. Some issues that plague our students include:

- **What is engineering?**
  - **"Late starters" in engineering:** Women who are interested and prepared for engineering in high school often objectively decide that it makes more sense to go to a school with engineering and have a chance at finishing in 4 years rather than go to two schools and finish in 5-6 years. This means that our students who do decide to go into engineering may come to it in the freshman or sophomore year of their education, later than a typical engineering student.
  - **Difference between science and engineering:** Of those students who do come to the college for the engineering dual degree program, most of them are committed to liberal arts *and* engineering. However, their education is stratified, that is, they take their all their supporting science and mathematics courses while at CSC, then they leave for the

engineering institution and do all their engineering there. The design paralleled historical programs but needs some adjustment based on newer findings about effective engineering education. Currently, women are not exposed to engineering until their 3rd year, in other words, *after* they have left for the partner engineering institution. Additionally, college professors, eager to keep talented students at the school and in their majors, often "recruit" students into their particular majors. With no idea of what engineering is and how it differs from the sciences, students often switch out of engineering because of familiarity with the sciences and unfamiliarity with engineering.

- **Recommitment to engineering**
  - **Ignorance and tenacity:** The stratified coursework also tries engineering students who may not enjoy the supporting courses such as physics and math. They often adhere to the engineering discipline through a "blind faith" that they really *do* want to be engineers, but they are still unsure of what that really means.

- **Engineering Advising:** Liberal arts college faculty are often not versed in what engineering is, how it differs from science and math, and the demanding supporting coursework required of the students in the first two years of college. There are two avenues of concern:
  - **Faculty advising and course scheduling:** Engineering faculty are very aware that if students do not start on the math-track with Calculus I, the student may well fall behind an entire year. Many engineering schools recognize this and have supplemental or separate advising for their incoming students. Since our college is small, and the number of women taking higher-level math courses is even smaller, some courses such as differential equations are offered only alternate years. It is essential that freshman and sophomore advisors are aware of the planning required in preparing students for engineering.
  - **Peer-mentoring and role modeling:** Many engineering schools have also recognized the power and influence of peer-mentoring. Whether they have programs that match upper-class students with lower-class ones or whether they create projects that require upper-class students to interact with lower-class ones, they realize the importance of such connections [8]. Since our college is a liberal arts institution with few women in the engineering program, it is essential for us to capitalize on the engineering students we currently have in the pipeline.

3 Building an Engineering Preparation Program in a Liberal Arts Institution

It was recognized that a well-constructed freshman program could help alleviate some of these issues at our college as well as other liberal arts college partners. However, the population of women deciding to enter engineering varies over the years, many times in single-digit numbers. The administration deemed the effort was important to the mission, so we faced a problem not unlike that faced by a high-tech firm launching a new cutting-edge product. We had to create the freshman program (product) to retain our current engineering students (forward-looking customers), but the current numbers (current market demand) would not sustain such a program in the immediate future (need time to build the market base, do advertising, etc).

3.1 Necessary Starting Pieces

In 2003-04 a few key factors came into play: CSC's Centers of Excellence for Women, Science and Technology (CWST) received monies for Clare Boothe Luce scholarships and a faculty member received a National Science Foundation Bridges for Engineering Education grant with the University of St. Thomas. Both of these provided the impetus and preliminary "capital" to move the engineering objectives forward.

The following programs focus on introducing and integrating engineering with other disciplines. Already underway, each program address the issues cited above in different ways and degrees:

- ***Makin' and Breakin'-Exposure to Engineering Design Concepts***. This was piloted in 2003 and supported by the National Science Foundation Bridges for Engineering Education Grant. It is being offered in Winter 2005 and 2006.
    - *What is engineering? Issue.* Elementary education students who take this course to satisfy their normal liberal arts curriculum are equipped to use engineering as a means for connecting science, math, and language arts topics in their classes. This course also influences undecided freshmen and science and math students who may not feel that those fields are their calling. The course is currently being staged into our 2-year Associate of Arts (AA) degree program so that those students are exposed to engineering technology trades and careers. Partnerships with area technology colleges are being established for those women who may decide to pursue a trade career rather than a 4-year college degree.
    - *Recommitment to engineering issue.* Engineering students can take this course but right now, it will not transfer to the engineering institution. However, *o*ne engineering student is serving as a volunteer Teaching Assistant in order to keep her interest in engineering alive.
    - *Engineering advising issue.* Advising can never start too early in a student's education. In addition to introducing students to engineering earlier, the education majors who teach will be able to give their students sound advice on how to prepare for success in engineering.

- **Science, Technology, Engineering and Mathematics (STEM) minor** currently supported by 3M (Pre-college pipeline). Over the next 5 years, the program will deliberately weave engineering problem solving methods into the STEM courses.
    - *What is engineering? issue.* Although it has education majors in mind, the minor will be open to all students. Since we are also targeting science students in this interdisciplinary minor, they will get a sense of what engineering is and how it complements and differs from science.
    - *Recommitment to engineering issue.* This is not directly affected by this minor program, but does offer engineering students interdisciplinary opportunities to see how different disciplines they are required to take can come together in engineering. The minor ends with a capstone that can provide them experience in working with a term-long open-ended problem.
    - *Engineering advising issue.* With faculty from different departments coming together to create the minor, they become more aware of what engineering is and how it folds together with their disciplines.

The most current program, ***Taste of Engineering***, is the first in this strategy to directly address needs of the engineering and non-engineering students. It is currently in its formative stages, but already it is addressing many of the critical issues at CSC.

3.2 "Taste of Engineering" Pilot

When the Clare Boothe Luce scholarships were awarded to the college, it became critical to identify students interested in engineering. The time was ripe to create a "Taste of Engineering" program that would be appropriate for freshman engineering students and follow the basic CWST "backdoor" strategy to expand the appeal.

A pilot was created for Fall 2004. It included a faculty advisor, two engineering students, one math student who was a "late starter" into engineering, one secondary math student and one social work/undecided student.

The students worked with Dr. Carol Pavlish, a Nursing professor who encountered the problem when working with a refugee camp in Rwanda. They engaged in the project voluntarily as there was no actual course credit set up for the pilot, and there was no funding for anything other than pizza and snacks.

Dr. Pavlish introduced the students to the background information. The original problem she presented was that girls, when they start their menstrual cycle, stopped going to school during the week of their period. This meant that they missed 1 out of 4 weeks of school from the age of 12, putting them behind in their education. While giving the background to the problem, Dr. Pavlish described the everyday existence of the refugees, which struck the students to the core.

After Dr. Pavlish's presentation, the students were guided through the engineering design process (Figure 2) [7]. Their first temptation was to jump to solutions, but by having them go through the process, they were better able to define the main problems that tugged at their hearts.

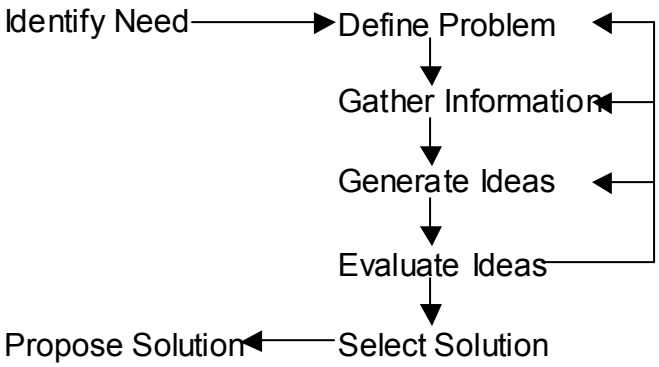

Figure 2: Engineering Design Process

CSC is well known for its social activism. Catholic Social Teaching is at the heart of its liberal arts education. Students often do a service-learning project for their capstone. The "Taste of Engineering" pilot, however, was the first time the students learned concrete methods of problem solving for the social injustices that they were so acutely aware of.

Moreover, the students needed to be sensitive to not only the clients' needs, but also the clients' pride. It was determined that they needed to come up with *ideas*, not products. The women in the camp were resourceful and entrepreneurial people. They had the desire and commitment, but not the resources or technical knowledge to solve the problems they faced. This was a perfect project for "newcomers" to the engineering process. The students saw how the engineering design process helped them focus.

The students determined three main problems to address:

- **Menstrual management:** What resources and materials were available in the camp for better control of the menstrual flow? Was there a way to construct renewable materials?
- **Cooking:** This occupied most of the women's time. Were there other means for cooking the beans distributed to the refugees other than firewood which was scarce?
- **Avenues for income:** With the limited movement and resources defined by the camp, money seemed a flexible medium for trade. The women were growing eucalyptus trees. One student who worked in a co-op wondered if that might be a source of income since eucalyptus oil is a pricey item in the United States.

Once these directions were defined, the students set about gathering information. They posted their information on Blackboard and met once a month to evaluate their findings and determine the new information that needed to be gathered. Due to their schedules, they were unable to build any prototypes and do actual testing, but they did make connections and gather resources for the different problems, evaluating the feasibility of each idea. They are currently working on their final report for Dr. Pavlish.

3.2 Preliminary Metrics

A preliminary survey was given to students at the beginning of the pilot to gauge their perception of how their liberal arts education was going to affect their work in this project. There were only 5 students who started the project, and only 3 who completed it, so the findings were more anecdotal than statistically significant. The general results shows that students realized that the particular problem posed would require them to use most, if not all, the subjects currently required by the liberal arts core. These include history, philosophy, theology, social science, lab science, and math/statistics.

Preliminary and informal consultation with Dr. Andrea M. Olson, an Industrial Psychology professor was conducted during this pilot. Formal consultation will begin with the next phase of the project. Besides

determining the connections of liberal arts and engineering preparation on these socially-relevant problems, evaluation will also be conducted with students continuing on to the engineering program to determine if this early "taste" helps their retention and performance in their engineering coursework.

4 Results and Analysis

From the single pilot some major issues were successfully addressed, but major logistical issues needed to be addressed. A new action plan is now in effect in response to these findings.

4.1 Lessons Learned

- **What is engineering? issue**. The experience showed students the wide range of skills required to solve a real problem. Moreover, students were highly motivated by their sense of social justice, and realized that engineering provided methods to create feasible solutions.
- **Recommitment to engineering issue**. The experience honed the engineering students' interests in engineering. Moreover, they realized how their broad liberal arts education developed their critical thinking and sensitivity.
- **Engineering advising issue**. A presentation was given during a Faculty meeting about "Taste of Engineering" and was met with great enthusiasm. Some faculty gave professional support, volunteering to be consultants for students as they researched their topics. Others offered their classes as "labor". For example, a Masters of Library and Information Studies professor offered to make related topics projects for her graduate library search classes. Other professors, particularly those from Social Work and Occupational Therapy, were intrigued with the whole engineering process. The idea of *making* solutions to the problems they were tackling wasn't part of their normal mode of operation. The prospect made their eyes sparkle. Since this presentation, professors have become very aware of the engineering opportunities available to students.

The pilot also uncovered some logistical problems:

- **Student issues.** The pilot showed that students, no matter how interested in the topic, could not do the work required for this project on a purely voluntary basis. It was difficult to schedule the meeting regularly since students had conflicting class and work schedules. Food, the only budget we had for this pilot, can only pull overworked students in so far and so long. The students were able to use Blackboard to communicate their research findings but the team interdependence and personal relations were not developed as much as hoped. There were some initial conversations between participants, especially those at different stages of their education. They discussed the technical challenges, ways of problem solving, and experiences with different professors.
- **Financial sustainability.** Materials and some resources are required to keep the course rigorous and meaningful. Additionally, a faculty instructor needs to be financially compensated since volunteerism is not a viable long-term solution for any program, no matter how promising.
- **Faculty sustainability.** With only one faculty with engineering education and experience, sustainability required finding out if other faculty would become engaged in the project.

These results confirmed the suspicions that it was necessary to either 1) tie the "Taste" with existing courses or 2) create a credited class in order for the program to be sustainable.

4.2 New Action Plan

With the knowledge gleaned from the pilot, a new action plan was created (Table 1). This strategy addresses a number of key issues:

1. It satisfies the requirements of the Clare Boothe Luce scholarships
2. It creates an interdisciplinary social nature to the meetings
3. It involves science and math faculty in the engineering process so they can better identify successful engineering students and relate their courses to engineering students
4. It bridges with other departments to build demand and educate freshman advisors
5. It makes the program into a 1-2-credit course that could be taken by students each semester during their 2-3-years of engineering preparation at the College

6. It tracks the participants' success in the engineering part of their education, and
7. It assists other institutions interested in creating a campus-wide, women-friendly recruitment and retention program at their campuses.

Table 1: "Taste of Engineering" Action Plan

Win 2005	• Work with Occupational Therapy Occupational Adaptation course on Wheelchair Accessibility project • Continue with current engineering students on voluntary basis; funding for food • Establish evaluation plan with Dr. Andrea M. Olson (Industrial Psychology) and UMN IT advising personnel to track students while at CSC and UMN
Fall 2005	• Work with Business Administration Advanced Marketing course on Public Transportation project • Work out details of "Taste" course that would also satisfy other science and liberal arts departments, UMN engineering introductory courses • Secure funding for equipment and computer resources for courses • Line up "clients" for future social activism projects – on-campus as well as community partners
Win 2006	• Second rendition of the Occupational Adaptation course on Wheelchair Accessibility project • Recruit for Fall '06 course to be offered as Topics course • Recruit faculty "observers" for first course • Secure funding for some "open" slots in course for students who want to try out engineering but who don't have the money or time for taking course for credit • Make connections with other liberal arts colleges or engineering schools that are interested in a recruitment/retention program for a dual degree
Fall 2006	• Start first credited "Taste of Engineering" course with inter-course project • Work with "observers" to improve course and discuss engineering design process
Win 2007	• Start second credited "Taste of Engineering" course with inter-course project • Start process for putting course on the books
Fall 2007	• First non-engineering faculty involved in course instruction • Serve as consultant for a college or engineering school for a recruitment/retention program for a dual degree

This action plan continues to address the original main critical issues:

- **What is engineering?**
  - **"Late starters"** are identified earlier. They also have the ability to get a better sense of what engineering is and why the different supporting courses are required.
  - **Differences between science and engineering** are clarified. Students understand the synergy between the areas. Moreover, with inter-course projects, they understand the relationship of engineering with other professional disciplines such as marketing and health professions.
- **Recommitment to engineering**
  - **Ignorance and tenacity** are not the sole motivations for pursuing engineering. Students have concrete experiences to reinforce their understanding of what engineering is and

why they are taking the pre-requisite supplemental courses. They also practice using their liberal arts skills and knowledge in an engineering context.
    - **Early exposure to engineering technology** helps students take care of introductory engineering requirements. Conversations with UMN's Institute of Technology advising personnel have provided several models that they accept from neighboring community colleges. For example, the Civil Engineering department has a computer applications requirement that has students work with numerical processing and computer-aided design (CAD) applications. If one of the "Taste" courses covers this material, it could count towards satisfying this requirement for the engineering students. Science students would also be encouraged to take it for the experience with numerical applications, and art students may enroll for the CAD experience.
- **Engineering advising**
    - **Faculty advising and course scheduling** issues are brought to the fore and addressed by observers and future instructors. Instructors of inter-course projects who serve as freshman advisors also become more aware of the requirements of engineering students.
    - **Peer-mentoring and role-modeling** have opportunities to develop due to the multiple offerings of the course. The 1-2 credit course model keeps engineering students enrolled in engineering processes and topics throughout their stay at CSC. Additionally, it creates a community of engineering students, for those taking it for the second or third time will meet up with "younger" students. This vertical integration leads to informal advising, community building, and role modeling [6].

5 Broader Impacts: Practicing What We Preach

The approach of CSC towards engineering is much like the "Engineering for Everyone" approach, but without an on-campus engineering department. The overwhelming reception to the idea of "Taste" shows a commitment by the entire faculty for making these engineering options open for all of their students. Indeed, the preparation of the future society depends not just on the engineers, but the other professionals who realize and value the role of engineers and can work successfully with them.

"Taste" gives the engineering students the necessary freshman exposure to engineering. It also gives valuable experiences to biological, physical and health sciences students so they can see other ways to use their scientific aptitude. For the social activist students, "Taste" gives them an edge. They can *make solutions*, not just advocate for them.

All of these objectives are in line with the mission of the College of St. Catherine's to educate women to lead and influence through a strong grounding in the liberal arts. Next year, new data should give us an indication if this strategy is a valid one.

At CSC, we also practice what we preach. We realize that we cannot plug the leaky pipeline of women in engineering ourselves. As outlined in our action plan, we intend to **offer ourselves as consultants to other liberal arts schools and engineering schools that seek to create women-friendly engineering courses for recruitment and retention**. Only through a concerted, cooperative effort can we tackle the challenge. After all, isn't that what we want our engineering students to learn? Teamwork and cooperation, combined with engineering problem solving, can take on the seemingly impossible.

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