

# THE NEW ENGINEERING STUDIES PROGRAM AT SWEET BRIAR COLLEGE

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**Abstract** — *The nation is facing a shortage of graduates from engineering programs in general, and, in particular, an even greater shortage of women graduates in engineering. Sweet Briar College (SBC) recognizes a social responsibility as a women's college to educate women in scientific and engineering disciplines so that they are well prepared to influence technological issues that impact society. To expand SBC's commitment in this area, SBC is in the process of establishing an Engineering Studies Program, only the second such program at a liberal arts college for women. The SBC program is uniquely designed to encourage all SBC students to obtain some level of technical education. This is accomplished through two new majors in Engineering Science (ES) and Integrated Engineering and Management (IEM), a minor in engineering, and engineering courses that satisfy general education electives for all SBC students.*

**Index Terms** — *Engineering Education, Engineering Science, Engineering Management, Women in Engineering*

## INTRODUCTION

Sweet Briar College (SBC) is particularly well-positioned to create a successful engineering program within the context of a liberal arts culture. SBC is a selective four-year liberal arts and sciences college for women with approximately 600 students in residence from 42 states and 21 foreign countries. The average class size is twelve and the student to faculty ratio is eight to one. *Yahoo Internet Life* magazine has ranked SBC as one of the most wired liberal arts campuses (as high as sixth) in the last three years on its ranking of liberal arts colleges, standing first (two times) or second among women's colleges. In the inaugural *National Survey of Student Engagement*, SBC was one of only four colleges and universities in the country to rank in the top quintile in each category. In its only subsequent survey, SBC scored even better, placing in the top 10 percent in each category.

An important aspect of SBC is that it has particularly strong science departments. The natural sciences at SBC include

the departments of Biology, Chemistry, Environmental Studies, Mathematical Sciences, Physics, and Psychology. In addition to eponymous majors, these departments offer majors in biochemistry-molecular biology, computer science, environmental science, and mathematics-physics. Over the past decade, SBC has implemented extensive science curricula revisions and has initiated a new program of summer faculty/student research. The combined impact of these efforts has been striking: since 1992, the number of students with a major in the natural sciences has increased by 50% to fully one-third of the graduating class of 2003. These results are particularly compelling considering that:

- approximately 25 to 30% of students entering college in the United States intend to major in natural science or engineering [1];
- attrition of natural science and engineering majors is greater than 50% [1];
- research has shown that women are often discouraged from pursuing a career in the sciences [2] because of "bad" experiences during science laboratories [3]; and
- women also frequently are intimidated by careers in applied sciences [4].

To put it succinctly, SBC graduates natural science majors in excess of twice the national average of liberal arts colleges in spite of being a women's college, whose clientele are traditionally predisposed against these fields of study. In particular, five to ten percent of our students graduate with degrees in physics or chemistry, compared to about one percent for all colleges and universities [1]. Based on these statistics, SBC is an ideal environment for creating a successful women's engineering program at a liberal arts institution.

## THE PROGRAM

The recently renamed Department of Physics and Engineering will initially have four faculty members including a new faculty member with a specialty in engineering. The core of the Engineering Studies Program at SBC is the establishment of seven new engineering courses and four physics and environmental studies courses

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upgraded to include more applied science and engineering, which, together with elective courses, will lead to a B.S. degree in Engineering Science (ES). The ES major will leverage the strong sciences curriculum at SBC with the addition of a new engineering curriculum to create a broad, flexible, and rigorous major preparing students for employment or graduate school in engineering.

Students will also have the option to combine a subset of the engineering curriculum with SBC's new Business Management courses to earn a B.A. degree in Integrated Engineering and Management (IEM). This interdisciplinary degree meets emerging workforce needs for technically literate business leaders in the private and public sector. The IEM major evolved from a logical use of resources to create a second marketable degree that will help expose even more women to engineering courses and careers. The IEM major is an adaptation of models of Accreditation Board for Engineering and Technology (ABET)-accredited Engineering Management degrees such as the one found at University of Missouri-Rolla, and the Integration of Science and Technology degree at James Madison University [5-7]. The IEM major will incorporate the strong liberal arts and science programs and the new Business Management major at SBC, along with a portion of the new engineering curriculum, to create a cross-disciplinary degree with career opportunities for graduates in business, government, and industry

The two majors, ES and IEM, share an early curriculum before a student must choose a track. At SBC, students are not required to declare a major until their fourth semester. We believe that the proposed two-track program will help encourage women to explore engineering; students will have two years to "test the waters," after which they can choose either a science-based or liberal arts/business-based engineering major. In addition to a supportive all-women educational climate, this "test the waters" approach helps eliminate an intimidating situation, often encountered at large institutions, of having to commit, from day one, to an engineering curriculum and culture dominated by male students that is often perceived by women as unpleasant, uninteresting, and too difficult [8].

To further encourage women to explore engineering, a minor in engineering science will also be available. Students combining the minor in engineering with a major in the sciences will increase their employment opportunities in technical fields and facilitate their acceptance into graduate engineering programs. Students combining the minor in engineering with a major in a liberal arts field will gain a substantially greater degree of "technical literacy" not traditionally obtained by students in these fields. In addition to the two major and minor options, a further novel aspect of the program is that *introductory engineering courses will*

*satisfy general education requirements, and therefore be offered to students of all majors as stand alone courses.* In this manner, SBC is parlaying the new engineering program to promote social change by facilitating some level of technical education for all SBC students.

The development efforts of the engineering program at this point in time have included some initial ground work for recruiting and retaining a diverse student population. Funding opportunities for engineering scholarships for underrepresented women students have been investigated, and future recruiting plans to focus on target high schools and community colleges have been discussed. The authors believe that SBC's supportive environment will initially also be conducive to attracting and retaining a diverse student population, and 20% of the students in the first engineering class offered at SBC in the spring semester of 2004 were women of color.

## THE CURRICULUM

The heart of SBC's Engineering Studies Program is the creation of the new engineering curriculum. What is novel about the SBC approach is that the engineering courses are developed from a "clean-slate", based on best practices from existing engineering programs and education coalition findings. For example, SBC is using the course requirements from the Engineering Science major at the Picker Engineering Program at Smith College [9-11,13] and the engineering program at Harvey Mudd College as a general basis for the SBC Engineering Science major [14,15]. Harvey Mudd awards an undesignated engineering BS rather than a specialized degree and their college policy requires a curriculum including 30% humanities and social sciences [14,15]. As part of the curriculum development effort, SBC has also looked for guidance from Virginia Tech [12], and the University of Michigan's "Curriculum 2000" program whose goals consist of teamwork, communication, computing, dealing with uncertainty, ethics, and environmental awareness [16].

The actual new engineering courses are still being finalized but they generally consist of two early courses, Introduction to Engineering and Introduction to Engineering Design, which also qualify as general education courses for all SBC students. Upper level courses currently include Issues in Engineering and Society, Continuum Mechanics, Engineering Topics Course (to be determined by the research area of the new faculty member), Engineering Circuit Analysis, and a senior year Design Capstone course. In addition, upgraded existing courses include Optics, Materials Science, Instrumental Analysis, and Environmental Technology. Regardless of the actual courses determined, the new engineering curriculum at SBC will be focused on investigative-based learning, technical skills competency, and mastery of underlying scientific

concepts. Four important touchstones of the new curriculum are that it is being developed with *course integration focused across disciplines*, that it has *strong design components starting in the freshman year that utilize a new Engineering Design Studio (EDS)*, that it has an *environmental module*, and that it has a *required research or internship component*. Each of these is described briefly here.

**Culture of Course Integration.** The Engineering Studies Program is being created with a focus on developing a culture of integration. That is, all new engineering courses will be designed to incorporate topics from other required courses and faculty research to create an integrated experience for the students throughout their studies at SBC. The new Engineering Studies Program culture will be facilitated by periodically holding an open forum for all SBC faculty to meet and discuss how disciplinary boundaries can be permeated and how individuals can affect the incorporation of technological issues across departments. Ideally, self-determined teams of faculty will emerge to contribute to this endeavor, as was the case in the Drexel model [17]. In order to facilitate this, SBC has included a curriculum development budget item for summer stipends that will be determined through an internal proposal process. The goal is to engage non-engineering faculty in creating courses and/or course modules that tie into the engineering curriculum, and also to support other novel approaches to facilitate course integration.

There has already been “buy-in” from a number of science and liberal arts faculty to integrate engineering components into existing courses and new interdisciplinary courses. One example of this aspect of the program is a course proposed by one of the authors, Dr. Lynn Laufenberg in the Department of History. This course will be on engineering, history, and society in the west from antiquity to the Renaissance. This course will encompass the mathematical/aesthetic theories of the ancient Greeks, the engineering achievements of ancient Rome, the preservation of ancient engineering knowledge by the Byzantine Greeks and the medieval Muslims, and the rediscovery of advanced Roman engineering and its application to architecture and urban planning in the Renaissance by figures such as da Vinci, Brunelleschi, etc. Through collaborative efforts across disciplines, such as the course just described, the new Engineering Studies Program fully utilizes the liberal arts resources at SBC to benefit all students.

**Design-Based Approach and the Engineering Design Studio (EDS).** SBC is committed to utilizing the engineering design process as a pedagogical tool in the engineering curriculum. For example, Harvey Mudd’s engineering program is based on the premise that design is the distinguishing feature of the engineering profession, and they have structured much of their curriculum around practice-oriented team experiences [12,15]. Another model

that SBC turned to for guidance was Drexel’s NSF-funded project, “An Enhanced Educational Experience for Engineering Students” and the Gateway Engineering Education Coalition [17, 18]. This group also recognized engineering design as the critical essence of the profession and therefore, used it as a context for learning scientific principles. Based on these models, we have incorporated design-based pedagogy throughout our engineering curriculum. SBC will also implement another important finding in the Drexel study: that creating more engineering experiences in lower-level courses is key to retention of students to matriculation in an engineering major [17].

An integral part of the new design courses will be the use of the Engineering Design Studio (EDS). This studio will be adapted from an architecture studio approach (both physical and pedagogical) which is an ideal utilization of the liberal arts culture to create an enhanced design experience for students. This concept is elegantly described by Kuhn in her work supporting project-based pedagogy in engineering education “[the architecture studio] offers us a teaching model from a design discipline in which the functional and the structural, the social and the technical, must be successfully blended...”[19]. From a physical standpoint, the studio will be an open environment with large workspaces, an abundance and variety of supplies and materials, and with student access to tools and machines. From a pedagogical approach, student work is organized into open-ended projects where designs undergo rapid iterations with frequent critique from faculty, peers, and visiting experts. Students are encouraged to look at historical references and think of the big picture. Faculty advisors and mentors will help students put reasonable constraints on their designs. The EDS space and approach will be integral to the new design courses and projects throughout the engineering curriculum.

**Environmental Component.** SBC has created the new engineering studies program so that it has a strong green engineering component by utilizing existing strengths from SBC’s Environmental Sciences Program. Since practicing environmental scientists frequently interact with engineers, one of the goals of the Environmental Sciences Program is to expose students to both environmental science and environmental engineering. Students are taught both process-based and iterative approaches to environmental problem solving and the importance of quantitative solutions is stressed. In particular, SBC’s existing environmental technology and environmental risk assessment courses will be upgraded to include engineering components. In these courses, teams of engineering and science students will address real world environmental problems. Past projects have been conducted with the Virginia Department of Transportation and the County of Amherst. This approach tends to integrate the disciplines with their different approaches and assists students once they transition to the

“real world” where engineers and scientists work together to solve problems.

**Research/Internship Component.** The novel requirement of a research or internship component in an undergraduate engineering degree program is facilitated by the size and climate at SBC. SBC has a strong history of engaging students in research. All biology, chemistry, and physics majors are required to complete a research experience. Most of these students are involved in on-campus or off-campus faculty research during the summers. We believe this integration of research and education is critical to both prepare students for the real world of open-ended problems, and to get them excited about graduate studies. Therefore, SBC has included a research requirement for students in the ES track where students will be required to engage in research or internship opportunities with SBC faculty, industry, or faculty at other institutions in order to complete this requirement.

## CONCLUSION

The new Engineering Studies Program at all-women’s Sweet Briar College has been designed to give students the opportunity to learn about engineering in a variety of ways and levels. The core of the project establishes a two-track approach leading to a B.S. degree in Engineering Science (ES) or a B.A. in Integrated Engineering and Management (IEM). The two majors share an early curriculum before a student must choose between the ES and IEM options. This two-track approach will help encourage women to explore engineering knowing that they can choose either a liberal arts- or science-based degree.

Another novel aspect of the SBC program is that *introductory engineering courses that satisfy general education requirements and an Engineering Studies minor will be offered to all students.* Students combining the minor in engineering with a major in the sciences will increase their employment opportunities in technical fields and facilitate their acceptance into graduate engineering programs. Students combining the minor in engineering with a major in arts, humanities or social sciences will gain a substantially greater degree of “technical literacy” than is traditionally available to women majoring in these fields. Through the development of the new Engineering Studies Program, SBC is expanding the definition of “liberal arts” to include a technical component in order to provide women the well-rounded education required of citizens in the 21<sup>st</sup> century.

## ACKNOWLEDGMENT

The authors would like to acknowledge the National Science Foundation Division of Engineering Education and Centers

for support of the new Engineering Program at Sweet Briar College through a planning grant (#0230542) and implementation grant (#0343071) in their program for Department-Level Reform of Undergraduate Engineering Education.

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