

AC 2007-1393: A BA ENGINEERING AND LIBERAL STUDIES DEGREE AT A POLYTECHNIC INSTITUTION

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A BA Liberal Arts and Engineering Studies Degree at a Polytechnic Institution

Abstract

The BA in Liberal Arts and Engineering Studies provides an educational vehicle for the person who seeks a career within which a knowledge of engineering and an ability to interact with engineers is critical, but who does not want a traditional engineering career. This degree will produce more technologically literate students who understand the principles of engineering and who will apply them to the profession they choose to pursue as citizens of a deeply technological society, but will not produce more practicing engineers immediately or directly. The significance of engineering lies mainly in its relation to other societal sectors. Clearly engineers must be more aware of this interrelationship, and the leaders of other sectors must become more technologically literate. The BA in Liberal Arts and Engineering Studies graduate works at this critical interface. This paper describes a pilot effort to design and deliver a curriculum that is the fruit of a multi-college collaboration. It details the collegial effort required to distill a functional program from the ideas of an interested, variegated constituency. It treats challenges in implementation in an academic environment which is allegedly steeped in disciplinary parochialism.

Introduction

Modern society is technologically driven and technology centered. Thus, an understanding of technology, a technological literacy, is a critical prerequisite for full participation as a citizen in the 21st Century world. Indeed, government rarely characterizes the key public challenges as questions of technology, they are assumed to be socio-economic-political problems. However, key issues often intersect, and technology lies at the center of the intersections, sometimes causing the problems, but more typically offering possibilities for their solution. In its connection to human affairs, technology now defines our culture in much the same way religion or philosophy has in times past.

Engineers have too often created the technology which underpins and empowers our society in a vacuum. They are often neither fully aware of the end-uses of their creations nor participants in policy discussions defining that end-use. Similarly, users of technology and the framers of policy have employed devices and systems, often without understanding their basis, their capability or their inherent limitations. Neither of these situations is optimal, engineers must become more aware of the implications of their work, and societal leaders and citizens must become more technology - literate. It is critical that higher education reflect these complexities and provide these connections.

It is almost too fashionable to point out the shortcomings in American education. However, whether the investigator is concerned with engineering education, science and mathematics education or education in the liberal arts, it is critical to recognize that our traditional academic structure does not provide proper motivation for comprehensive learning that is appropriate for the Twenty-First Century. Engineers tend to teach science as much as engineering while

scientists often teach complex computing models of questionable relevance rather than developing and demonstrating new principles designed to enhance our understanding and predictive capability. Both scientists and engineers often carry out their work without explicit attention to societal implications and any human context. Students of the liberal arts typically discuss the implications of science and engineering without any understanding of the basic principles which underpin technology.

Engineering Education in the 21st Century

The Accreditation Board for Engineering and Technology implies that engineering education needs to become more holistic in nature.¹ It demands graduates that are integrative as well as analytical. Academia must develop programs that are capable of producing graduates who are adept at functional thinking as well as analytical thinking, alumni as capable of integrating and connecting parts as they are at reductionism. Engineering education must provide exposures that extend a student's desire to develop order into an ability to orchestrate chaos, experience which push students beyond a need to create certainty to enable them to develop a tolerance for and an understanding of risk and an attendant ability to embrace ambiguity. It requires engineers to practice problem forming as well as solving. It must stress engineering design and the ability to realize products. To be successful, engineers will need to have facility with intelligent technology to enhance creative opportunity. They will need the ability to manage complexity and uncertainty as members of productive teams rather than independent investigators. The engineer will need to be sensitive in and to interpersonal relationships. The engineer will need proficiency with language and a cosmopolitan sense of multi-cultural understanding. The engineer will need a capability to advocate and influence rather than to simply advise. Graduates must see the world as whole and sense the coupling among seemingly disparate fields of endeavor. Out of necessity, engineers will become entrepreneurs and decision-makers. In short we must create balanced attitudes of inquiry at the academic institution, finding balance between synthesis and analysis, research and design and process exposures and device centered education and theory.

Moreover, engineers will continue to move into non-traditional fields in ever greater numbers. Engineers will find their muse in business and management, finance and investment, marketing and economics, education, journalism and law, public and military service, medicine and health care delivery and architecture. Even performing arts, art and music - to paraphrase Trousseau, *there is no art without engineering, there is no engineering without art*. The connections between these two endeavors is primal and deep, arguably lying at the very core of being human. Both are uniquely human creative endeavors; one in a way limited by physical constraints, the other limited only by imagination.

Vision

The vision for developing this new program was twofold, and grew from the challenges facing engineering education outlined above. There was a need perceived for educating a new generation of students whose educational preparation was unlike that of existing disciplines. It would vary from existing engineering programs, science programs and liberal arts programs, and provide a hybrid that integrates ethics, societal issues, humanities and policy with science and engineering in a broader context. This was seen as a vehicle to address the issues of recruitment,

retention and outreach for students who do not seek a career in engineering practice, but may want to have careers in education, business, law, policy, art and design and seek this in conjunction with technological strength.

The charge to the committee was to develop a proposed plan for the BA in Engineering, including a variety of tracks and corresponding curricula which would be submitted for university review and implemented by normal processes at the university.

Process

Faculty members from every college at the university, students, industry representatives and staff joined the ad hoc committee for the proposed degree program, whose membership swelled to sixteen. As part of the effort to develop a common lexicon and a baseline knowledge the group initially:

- studied and discussed a number of reports published by the National Academy of Engineering, the National Science Foundation, and other organizations that have addressed challenges for engineering education.²⁻¹⁰
- studied existing BA Engineering programs, or similarly titled programs that have been developed and implemented by other universities by exploring their websites.
- studied the scope and mission of two new Departments of Engineering Education established at Virginia tech and Purdue University.
- sought out and studied other innovative programs that combined engineering education with studies in the humanities.

The committee was spirited in their discussion, and unstinting in their commitment to develop a BA Engineering program. Members of the group had different motivations for continuing their effort, and were evenly divided into four camps. One camp felt this was an excellent program to “plug the leaks” from the engineering pipeline, and serve as a satisfying path to completion for students who would otherwise leave engineering. However, many students who leave engineering during their first two years do so because of problems with mathematics, physics or chemistry – and these courses are retained in the BA curriculum. A second felt that this program could provide the basis for the development of a new “liberal arts” or general education scheme, more appropriate for today’s college graduate. A third group saw this simply as a vehicle to raise awareness of engineering and raise friends and supporters of engineering in the ranks of students across the university. Finally there was a fourth group that saw this as a vehicle to garner support for new curricular endeavors. Interestingly, though the motivations for each of these groups was different, all of the groups perceived of the program as having sound outcomes for students, and agreed upon a uniform curricular vehicle. The group also divided itself along five other lines, choosing to work on particular tracks associated with a “root” vehicle for the program. The first four concentrations envisioned were a Management of Technology Concentration, an Education Concentration, a public Policy Concentration and a Law and Society Concentration. The fifth concentration was essentially a venue that provided freedom

for student self-determination and a curricular flexibility that acknowledged the existence of pertinent tracks neither proscribed nor envisioned by the program developers.

Program Uniqueness

The proposed program is unique to the institution, and the general geographic area. It draws upon Cal Poly's unique character of "learn by doing," culminating in a multidisciplinary service learning or other group project. Another unique feature of the proposed program is that it has several concentrations designed to prepare students for careers in various fields, as well as a global perspectives component that encourages students to take and apply their knowledge outside of Cal Poly and the US. Programs that were examined include the following:

- Dartmouth University (A.B., Engineering)
- Harvard University (A.B., Engineering)
- Johns Hopkins University (B.A., Biomedical Engineering; B.A., Computer Science, B.A., Electrical Engineering, B.A., General Engineering)
- Lafayette College (A.B. Engineering)¹¹
- Princeton University (A.B. in Engineering and the Liberal Arts)
- Purdue University (B.S., Interdisciplinary Engineering)
- Rochester Institute of Technology (B.A., Engineering Science)
- University of Arizona (B.A., Engineering)¹²
- Worcester Polytechnic Institute (B.A., Liberal and Engineering Studies)
- Yale University (B.A., Engineering Sciences)

However, even in comparison with these other programs offered at prestigious universities, this program is unique in that Cal Poly's BA in Liberal Arts and Engineering Studies program:

- offers more specific, targeted outcomes than those at other institutions.
- includes an extended summative experience, including the opportunity to use a study abroad experience to address the global perspectives component of the program.
- is more flexible than those at other institutions, allowing students to choose a concentration in both a Liberal Arts area and an Engineering Studies area.
- better integrates its Engineering units with its Liberal Arts units as compared with other institutions.

Program Objectives

The committee defined objectives for the proposed program, that being to provide its graduates with a solid engineering and scientific appreciation that will underpin them in careers other than engineering.

To this end, the proposed concentrations:

- (1) Provide students with a unique undergraduate program unavailable anywhere in the state, and rare in the nation.

- (2) Provide students with exposure to engineering and science, as a solid underpinning for careers in other areas or as introduction to other professional endeavors.
- (3) Provide students with unprecedented flexibility, breadth and depth in curriculum.
- (4) Provide students with a pertinent core competency.
- (5) Allow students to partner in the development and design of their own curriculum.

To support the educational goal, the overarching learning objectives for students participating in the program derive from the Accreditation Board for Engineering and Technology, though there is no thought of accrediting the program. These are¹:

- (a) a working knowledge of mathematics, science, and basic engineering;
- (b) an ability to interpret data;
- (c) an ability to understand the design of a system, component, or process
- (d) an ability to function on interdisciplinary teams;
- (e) an ability to identify and help formulate, engineering problems;
- (f) an understanding of professional and ethical responsibility;
- (g) an ability to communicate effectively;
- (h) an ability to understand the impact of engineering solutions
- (i) an ability to engage in life-long learning;
- (j) participation in activities related to contemporary societal challenges;

In addition, each concentration has learning outcomes peculiar to that track:

Management of Technology Concentration

1. Ability to analyze technology oriented organizational systems and processes.
2. Ability to take into account business and technology considerations and able to make decisions based on analysis.
3. Ability to understand marketing, financial, technical, human factors and legal issues that arise in technology oriented systems.
4. Ability to manage projects and supply chain systems.

Education Concentration

1. Recruit and prepare Jr. High and High School teachers who are confident of their skills in mathematics and their understanding of the natural world and who are dedicated to helping young students to become technologically and scientifically literate citizens of the 21st Century.
2. Provide a flexible path to earn credential or gain admission to a credentialing program for students interested in pre-college science or mathematics education.
3. Provide exposure to engineering to students who will participate in pre-college science or mathematics education.

Policy Concentration

1. Increase understanding of governmental regulations and policies surrounding of various technologies.

2. Increase understanding of how government institutions respond to and assess significant social, legal, economic, and political issues at national level, state, and local levels.
3. Demonstrate increased knowledge in public policy making process and increased understanding in public policy issues, including markets and regulation, as well as various social, environmental, and political issues.

Law and Society Concentration

1. Demonstrate increased understanding and use of analytical techniques surrounding the nature of law, legal systems, liberty, and justice and understand their relevance to issues such as affirmative action, discrimination, and free speech.
2. Increased understanding of how the Supreme Court plays a role as interpreter of Constitutional rights and liberties, freedom of expression, religion and the press, search and seizure, and due process of law.
3. Increase understanding of how Supreme Court responds to issues of equality such as race, ethnic, and gender discrimination in the United States.

The group also felt that one key feature of any program was an experiential learning exposure. Experiential learning provides one powerful vehicle to embellish the abstract learning which characterizes our academic institutions with valuable learning in context and to infuse the academic environment with key features beneficial to society. This experience is seen as a culminating keystone service learning experience in which they synthesize their engineering background with knowledge from their concentration coursework into projects that meet program learning objectives and benefit society.

The Curriculum

The BA Engineering Requires 180 quarter units (120 semester units) to earn the degree, at least 60 of which must be upper division offerings. No new courses are required to initiate the program, though the project/integrative experience could develop into a new and unique offering.

Required Courses:

| | |
|---|---|
| MAJOR COURSES | |
| Introduction to Computing... .. | 3 |
| Electric Circuit Analysis..... | 2 |
| Intro to Engineering..... | 3 |
| Engineering Economics..... | 3 |
| Materials..... | 3 |
| Engineering Statics..... | 3 |
| <i>Engineering Electives.....</i> | <i>12 to 16</i> |
| <i>Summative Experience.....</i> | <i>6 to 12 (this can include, but is not limited to community service learning, internship, student teaching exposure, government service, hospital volunteering etc..., one unit must be Senior Project, units are not tied to any college a-priori)</i> |
| Concentration or individual course of study..... | 43 |
| | 80 |

| SUPPORT COURSES | |
|--|------------------|
| Introduction to Biology and Bioengineering | 2,2 |
| Gen Chem I..... | 4 |
| Gen Chem II..... | 4 |
| Technical Writing for Engineers | 4 |
| Calculus I, II | 4,4 |
| Calculus III | 4 |
| Calculus IV | 4 |
| General Physics I, II, III..... | 4,4,4 |
| <i>Science and Math Electives.....</i> | <u>16</u> |
| | 60 |

| GENERAL EDUCATION (GE) | |
|--|------------------|
| Communication (8 units) | |
| Expository Writing..... | 4 |
| Oral Communication..... | 4 |
| Reasoning, Argumentation, and Writing * | |
| Arts and Humanities (16 units) | |
| Literature..... | 4 |
| Philosophy..... | 4 |
| Fine/Performing Arts..... | 4 |
| Upper-division elective..... | 4 |
| Society and the Individual (16 units) | |
| The American Experience | 4 |
| Political Economy | 4 |
| Comparative Social Institutions..... | 4 |
| Self Development | <u>4</u> |
| | 40 |
| | Total 180 |

Student Professional Outcomes

Several Department’s Industrial Advisory Boards met to discuss the proposed BA in Engineering. Although the current version is a modified version of that proposal (focusing only on the connection between the Liberal Arts and Engineering), the feedback of the board on the two questions regarding professional uses remains relevant. Below is a list of their responses regarding 1) the types of careers they envision graduates of the program pursuing and 2) whether openings exist at their current company. Because the advisory board members do represent more technical companies, comments represent professions that more clearly emphasize the connection between engineering and the liberal arts.

To the question “What type of careers would you see graduates of this program pursuing?” respondents answered:

- Many
- Marketing
- Technical writing
- Patent law
- Management (+MBA)
- This program results in knowledge broadening that will benefit many careers.
- Program management
- Any type of support corporate activity (e.g., procurement)
- System engineering?
- Patent attorney
- Field clinical engineer
- Product manager
- Technical sales
- Training
- Facilities
- Procurement/purchasing
- You touched on several secondary teaching, lawyer, etc.
- Sales/marketing

As technology creeps into every day life more engineering expertise/orientation will be needed in traditionally non-technical areas

- Tech-savvy HR is just one of example
- Purchasing
- Business analyst

Respondents also alluded to specialized areas which are collaborative/multidisciplinary by nature such as bioengineering, science instrumentation, new media, system engineer, technical communication, systems procurement

To the question “Are there jobs at your company for which graduates of this program would be qualified?” respondents answered:

- In the company I was at, absolutely. Knowledge breadth is greatly valued. I believe it always will be, increasingly in the future.
- Program management
- Marketing
- Training
- Finance – particularly estimating
- Communications
- Procurement/purchasing
- Standards boards/consortium representation
- Are they better prepared for grad or professional schools (law, bus)?
- Yes, field clinical engineer working with high tech medical equipment

- I would like the HR people in my company to have some knowledge of engineering
- Educational outreach programs
- ITAR/export control
- Public affairs office
- Business development
- HR
- Production management

Assessing Success

Clearly defined metrics are a key for any academic program, but particularly for a program such as this. Four key areas will serve as the initial assessment of progress for the program:

- student recruitment and retention, including diversity issues
- professional outcomes for our graduates
- the catalytic value of the program for interdisciplinary faculty relations
- the internal and external perception of the program

Conclusion

The unprecedented impact of engineering on every facet of modern life demands that engineers behave in new ways. This is true not only in the context of the character of degree programs we provide for engineering graduates, but in the ways we formally connect with other disciplines at the university. We must create a cadre of informed interdisciplinary leaders, within and outside of engineering, by creating a substantive experience that leads to deep understanding of technology and its role in our society. We hope to expose students to key challenges, particularly through experiential learning, whose solutions can be found only in the meaningful integration of disciplines. This BA program is designed to provide a vehicle for students to complete a challenging academic program which offers just such opportunities.

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