Too Liberal or Not Liberal Enough: Liberal Arts, Electives, and Professional Skills

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Introduction

A well conceived liberal arts education is essential to developing the professional skills needed for 21st century engineering practice. Currently, the liberal arts comprise a component of most undergraduate engineering curricula, though as a recent study indicates, not necessarily a significant or well-integrated component. Moreover, it has become increasingly common for liberal arts courses to be offered via electives. This paper presents findings from a national survey of civil engineering curricula that helps clarify the liberal arts content of engineering programs, as well as addresses the ramifications of the current configuration. Ninety of the nation's 218 accredited undergraduate civil engineering programs (41.3%) participated in this survey, including the majority (81%) of the top undergraduate programs at schools that have a corresponding graduate program, and 50% of the top programs without a graduate program, as identified by *US News and World Report* (2002).

What are the Liberal Arts?

The liberal arts are a constellation of academic fields united by a common interest in developing the intellectual capacity of the individual. Sometimes referred to as arts and sciences or general education, sometimes housed within liberal studies or letters and sciences colleges, the liberal arts teach one *how* to think, not necessarily *what* to think. Since the Middle Ages the liberal arts have been the cornerstone of higher education. The liberal arts were so named because, quite literally, the "liber" or "free" arts were intended to free one's intellectual capacity from the toils of manual labor (Schachterle 1997). Guilds instructed tradesmen such as masons and shipwrights through apprenticeships, while liberal arts colleges instructed civil servants, clerics, and the ruling class in the knowledge considered essential to polite society. From the Renaissance up to the present, the liberal arts have grown from the original lower division trivium (grammar, logic, and rhetoric) and the upper division quadrivium (arithmetic, astronomy, geometry, and music) to encompass fine arts, economics, history, language, mathematics, philosophy, political science, sociology, and abstract science. While the precise definition of the liberal arts varies by institution, the purpose of a liberal education, whether in art history or the philosophy of science, remains the general development of the intellect in reason, judgment, and communication. All liberal arts are united in the respect that clear thinking, critical analysis, and concise communication are paramount to understanding and interacting in the greater world.

Today, most engineering degrees are offered at colleges and universities that also offer liberal arts courses and majors. By and large, however, engineering education is offered in *parallel* to a liberal arts education, meaning that technical engineering courses supplant traditional liberal arts courses. Engineering education in this country has long been based on the French polytechique tradition, which grew outside of, and in reaction to, traditional "liberal arts" colleges. Accordingly, the majority of an engineering student's time is spent on science, math, and specialized technical courses. The minimum Accreditation Board for Engineering and Technology (ABET) requirements for engineering programs are one year of math and science and one and one-half year of engineering topics; there is no minimum length requirement for the liberal arts (ABET 2001). Compared to medicine and law students who typically earn an undergraduate degree in liberal arts or basic science before they enter graduate-level professional programs, engineers typically take few liberal arts courses outside of science and math and stop their education at the baccalaureate level (Russell et al. 2000; Russell and Stouffer 2003b).

Why Do Engineers Need the Liberal Arts?

Cultural critics such as Neil Postman and Allen Bloom have written poignantly and persuasively on the need for a well-rounded education in the liberal arts in order to think creatively, critically, and responsibly (Bloom 1987; Postman 1992). In his book *The Civilized Engineer*, Samuel Florman cites countless examples of scientists and engineers whose education in, and passion for, the liberal arts led to breakthrough discoveries and world-changing ideas (Florman 1987). From Isaac Newton to Albert Einstein to Thomas Edison to Washington Roebling, Florman recounts the ways in which the forms of music, painting, and philosophy have helped structure thought and enhance an individual's problem solving abilities. In his article "How Creative Engineers Think," Tom Peters explores the creative problem solving of leading engineers such as Gustave Eiffel (Peters 1998). Based on archival data, Peters determines that groundbreaking design concepts often stem from simple, even sublime reformulations of current thinking and practice, and that these breakthroughs are often fueled by study and observation *outside* of engineering paradigms.

A broad, holistic education has been shown to increase creativity and the ability to solve complex problems. Such an education can also strengthen leadership and management skills by teaching such valuable lessons as cultural sensitivity, ethical relativity, and opportunity costs of operating in the real world. Such appreciation and understanding can be taught to undergraduates, and is being taught in many literature, philosophy, history, language, math, music, and social science courses. But in general, civil engineering students have little exposure to the liberal arts or important professional skills. How little, and in what sequence and proportion, is the focus of this paper.

Professional Skills

In recent years there have been no less than 39 separate studies conducted into engineering education by organizations such as ASEE, ASCE, the National Research Council, and the National Science Foundation (Ernst 2001). Many of these studies point to deficiencies in non-technical areas, including the engineering graduate's inability to communicate, work on teams, and understand systems-level parameters and consequences. These skill areas, of which engineering graduates seem to be in short supply, are commonly called professional skills. ABET defines professional skills as leadership, management, teamwork, communication, and knowledge of contemporary issues (ABET 2001). While the liberal arts do not have a corner on the market of teaching professional skills, liberal arts courses and methods of inquiry are essential for developing the fundamentals of clear thinking, critical analysis, and concise communication. A liberal arts education helps cultivate an appreciation for the ambiguities that confront virtually every relationship—business, engineering, and personal. That is why leading undergraduate institutions such as Stanford University "aim to strike a balance between the technical sophistication and the social and cultural breadth demanded of engineers in modern society" (http://soe.stanford.edu/programs/undergrad/undergrad.html).

Analysis Methodology

The authors recently conducted a statistical analysis of the nation's accredited civil engineering programs based on uniform data compiled from recent Accreditation Board for Engineering and Technology (ABET) accreditation visits. In total, 90 of the nation's 218 accredited programs (41%) participated in this analysis, including the majority (81%) of the top undergraduate programs at schools that have a corresponding graduate program, and 50% of the top undergraduate programs without a graduate program, as identified by *US News and World Report* (2002). Measured by the number of graduates, this analysis accounts for nearly 50% of the national student body, since in 2001 the participating schools graduated 4,035 of the 8,219 total civil engineering graduates.

The average distribution of required courses for all civil engineering programs is presented in Figure 1. The analysis focused on three general categories of courses: 1) math and science; 2) general education; and 3) engineering topics. These categories, plus a fourth "other" category, are based on the general classes identified by ABET. For the purposes of this paper, the liberal arts include language, communications, economics, literature, history, philosophy, and social science courses—the core of most general education components. As such, the ABET category "general education" will be used synonymously with the term "liberal arts." While basic science is sometimes considered a liberal art, this study follows ABET and counts all "hard" sciences such as physics, chemistry, biology, and geology in the "math and science" grouping.

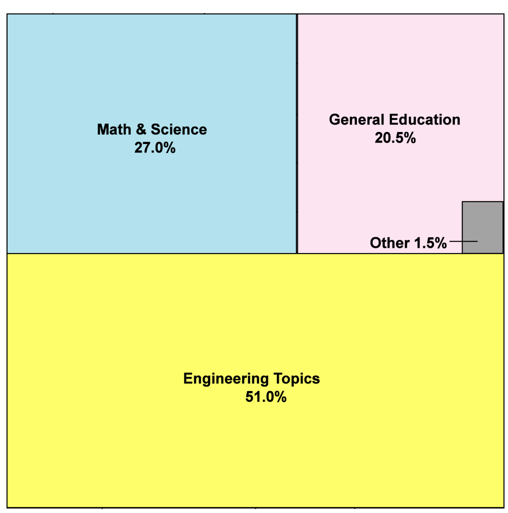

Figure 1. Percentage of Average Curriculum Allocated to ABET Subject Categories

To become accredited, engineering programs are requested to distribute curricula into the four subject categories and report the results in Table I-1 of an institutional self-study. ABET recently reformulated its accreditation criteria to an outcome-based system. In a move away from prescriptive requirements of the past, schools must now demonstrate that their graduates are meeting a series of 11 outcomes, in addition to discipline-specific criteria. A few programs included in this study reported data from an accreditation visit under the prior system on the analog to Table I-1, called Table XII. While these two tables are very similar, what was called "humanities and social sciences" under the former system has been changed to "general education."

For the purposes of this study, similar courses were grouped regardless of the categories individual programs placed them in. Universities have leeway in how to organize and present their curricula to ABET, and it is common for universities to place similar courses in different categories. To normalize the data, comparable courses were counted as one of the four categories. For example, different programs counted economics as a general education, math and science, and engineering topics course. Traditionally, economics is a liberal arts course, and as such, all basic or introductory courses in economics were counted in this study in the general education category.

There are two basic types of academic periods: 1) semesters and 2) quarters. In this study, 74 schools offered semester programs, and 16 offered quarter programs. Semester and quarter programs did not differ in significant respects regarding general education course distribution or overall content, and as such data from the two types of schools has been combined. A more detailed report of this analysis, including the slight ways in which quarter and semester programs differentiated, has been published elsewhere (Russell and Stouffer 2003a).

Liberal Requirements

One of the more interesting findings of this analysis involves the distribution and concentration of liberal arts courses. The total number of required liberal arts credits varies between 18 and 58 semester credits. Some schools require what amounts to a liberal arts education, while others, with barely a semester of liberal arts, require significantly less.

Of the 26.7 average semester credits devoted to general education, Figure 2 presents the proportions of leading subject areas. The values presented do not represent individual courses, but rather the total percentage of the liberal arts/general education curriculum devoted to these subjects. Since institutions can require more than one course in a particular area, Figure 3 helps clarify the most commonly required individual courses (x-axis) and the percentage of schools requiring those courses (y-axis). The numbers following the "Liberal Arts Electives" and "Open Electives" listed in Figure 3 indicate a sequence of required electives, with higher values signifying a greater number of required electives. For example, almost 30% of programs require Liberal Arts Elective 6, or at least six Liberal Arts Electives. Therefore, no program requires Liberal Arts Elective 4 without also requiring Liberal Arts Elective 3, 2, and 1, respectively.

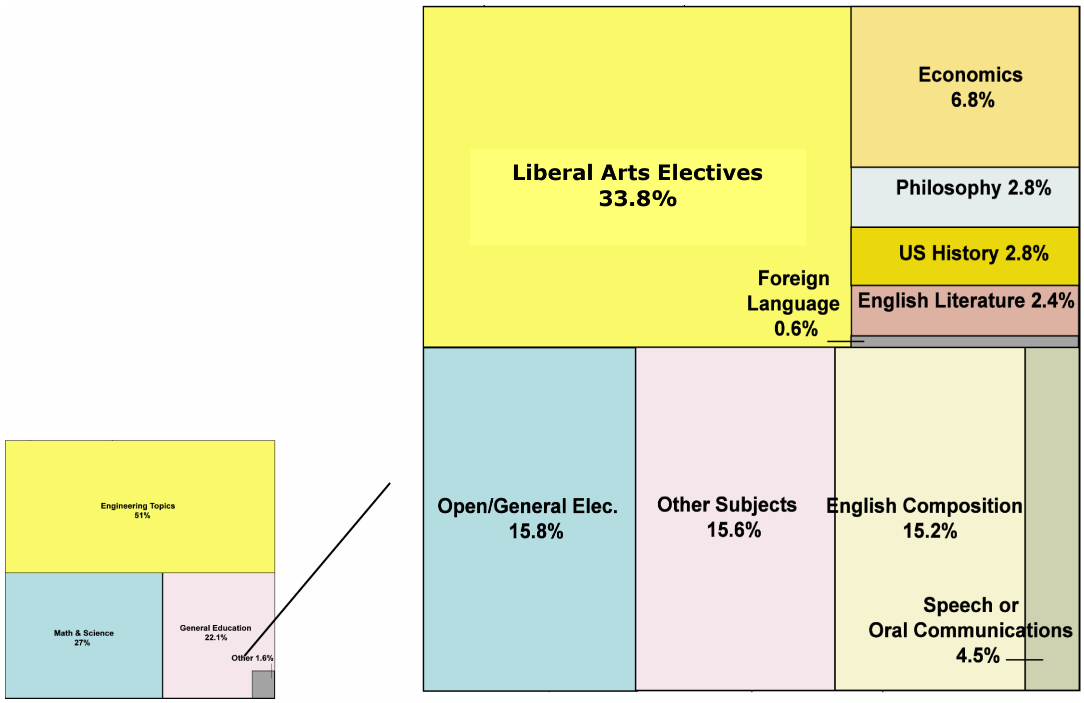

Figure 2. Percentage of Average Curriculum Allocated to Liberal Arts Topics

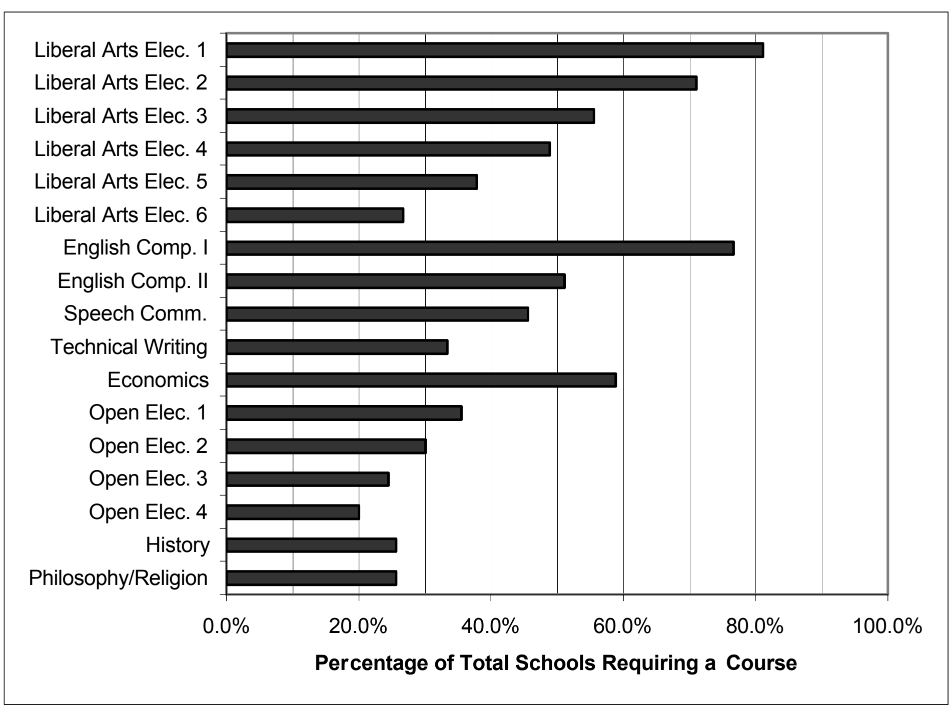

Figure 3. Most Commonly Required Liberal Arts Courses

Sixty-nine, or 76.7% of programs require a course in English composition ("English composition," "Freshman composition"). Over half of all programs (51.1%) require a second English composition course. One-third of programs require a course in technical writing, often in addition to English composition. Just under half of surveyed programs (45.6%) require a basic speech or oral communications course, almost always in the first few semesters or quarters of college. Economics is required by 58.9% of programs, while 25% require a single course in history or philosophy. Less than 20% require a course in literature (17.8%), political science (17.8%), fine arts (14.4%), world civilization (12.2%), or foreign language (3.3%). Collectively, traditional liberal arts courses not including English composition, speech, and economics, make up about 3% of average undergraduate requirements.

Independent Confirmation

The US Department of Education (USDE) and The National Institute for Science Education recently performed a joint study on engineering education, entitled *Women and Men of the Engineering Path: A Model Analyses of Undergraduate Careers*. This study confirms the relative scarcity of liberal arts courses in the undergraduate experience: "only four courses outside of science, mathematics, and technology—introduction to economics, English composition, general psychology, and introduction to management—turn up frequently on transcripts" (Adelman 1998). The authors' study confirms these findings, except the presence of a psychology course, of which only two civil engineering schools specifically require. This is likely a difference between civil and other branches of engineering. The USDE study went on to report that although "all branches [of engineering] encounter problems brimming with ambiguities and conditional situations," engineering students are not typically exposed "to the ways in which culture and personality enter design criteria for real world solutions to engineering problems." One of the reasons for this lack of exposure is that liberal arts courses, especially communications courses, are not traditionally integrated with technical subject matter.

Right Subject, Wrong Time

Even though English composition and speech communications, liberal arts courses tracing back to the classical trivium (rhetoric and grammar), are common undergraduate requirements, it is unclear how well these courses prepare students for professional communication. The timing and lack of integration with technical subject matter is partly to blame. Both composition and speech courses are generally required in the first years of college, well before the student has developed a technical vocabulary or facility. It is unusual for a civil engineering program to require a technical presentation course or technical writing course in the junior or senior years. Even if the student takes that course later in his or her academic career, courses are generally designed and offered at the freshman or sophomore level. As such, students generally learn the rudiments of presentation outside the context of complex engineering subject matter. While the skills they learn in Speech 101 could translate into stellar business proposals and client presentations, somehow this is not the case, and engineers continue to struggle with public speaking and presentations.

Engineering students are not often required to present complex ideas to technical and non-technical audiences that mirror the design meetings and public information meetings that real engineers must participate in. Many students make presentations in upper division design courses, often as part of group work, but it remains unclear how much class time is devoted to developing presentation skills in the average capstone or senior design course. Instead of reinforcing the professional skills absolutely vital to practice, and then documenting and assessing these efforts, a disconnect between lessons and application can be found between separate courses, and between engineering education and practice as a whole.

Too Much Choice or Not Enough Direction?

In our designer culture where custom-order is included on most everybody's consumer bill of rights, engineering education seems to have followed suit. Electives, especially technical electives, reflect the opinion that the wealth of information "out there" necessities the need for specialization. Student-determined electives comprise a much larger percentage of the total civil engineering curriculum today (21.5%) than was the case in the 1920s (4.5%) (Wickenden 1930). This holds true for liberal arts as well as engineering courses.

As Figures 2 and 3 convey, much liberal arts content is required through electives. Electives sometimes constitute the entire general education curriculum, while on average 15.7 semester credits in the curriculum are liberal arts electives—well over half the average general education total of 26.7 semester credits. In fact, the single most commonly required general education course is a liberal arts elective, which over 80% of schools require. Each institution regulates the distribution of electives in a unique way, though there are two primary types of general education electives: 1) liberal arts, and 2) open. For liberal arts electives, some programs require concentrations in specific areas such as fine arts or humanities. For open electives, programs often prohibit certain classes of courses, such as civil engineering courses. Both liberal arts and open electives are distinct from math, science, and technical electives. Seventy-three schools require at least one liberal arts elective, while over one-third (37.8%) require five, with one program requiring 12 electives. Added to that, 35.6% of schools (32) require at least one open elective, while 20% require four.

Professional Skills and the Liberal Arts

The minimum ABET accreditation requirements for all engineering programs are one year of math and science, one and one-half year of engineering topics, and "a general education component that complements the technical content of the curriculum" (ABET 2001). In addition, all engineering programs must demonstrate that their graduates have achieved the following 11 outcomes:

a) An ability to apply knowledge of mathematics, science, and engineering;
b) An ability to design and conduct experiments, as well as to analyze and interpret data;
c) An ability to design a system, component, or process to meet desired needs;
d) An ability to function on multi-disciplinary teams;
e) An ability to identify, formulate, and solve engineering problems;
f) An understanding of professional and ethical responsibility;
g) An ability to communicate effectively;

- **h) The broad education necessary to understand the impact of engineering solutions in a global and societal context;**
- **i) A recognition of the need for, and an ability to engage in life-long learning;**
- **j) A knowledge of contemporary issues**; and
- k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The six outcomes that relate to professional skills are listed in boldface above. Though professional skills comprise over half of the outcomes, they do not constitute over half of the required curriculum as currently offered by the nation's engineering programs. On average, civil engineering students take less than a single course devoted to professional skills (2.8 credits), not including basic oral and written communication. Students are unquestionably exposed to professional skills as components of engineering and liberal arts courses; if not, then every program in the nation would fall short of ABET outcomes. Advanced design courses may include a lecture on leadership, but this is very different from requiring, or even offering, an entire course in that subject. When a subject has an entire course devoted to it, or a series of courses as with calculus and physics, the course and the topic are imbued with a sense of importance. These courses and subjects are important, the logic goes, or why else devote a whole semester (or two) to studying them? With the exception of communications and project management, professional skill courses are not generally taught in self-contained courses, but are rather folded into other courses, if covered at all. Moreover, the liberal arts courses that are required are generally vague electives with no clear bearing on either technical education or professional skills.

Missed Opportunities

Liberal arts courses are important in developing professional skills and an integrated outlook necessary to perform engineering in a global context. However, many programs do not take advantage of the liberal arts resources at their institutions, and as such, students—and engineering—suffer. Engineering schools have adopted a "stovepipe" approach to education, which in many respects mirrors specialized professional practice. Engineering education tends to be black and white, with textbook-oriented solutions, taught in distinct units. Specialists teach their specialized areas to students, and students go to other specialized departments to learn math, science, and the liberal arts, with missed opportunities for integration between calculus and physics or between the history of western civilization and the rise of the engineered environment. To be sure, some programs offer joint calculus and physics courses, and a handful of schools offer history of science and technology courses that help place engineering and science within a larger cultural context, but based on this analysis of civil engineering curricula, neither of these forms of integration are common.

In 1990, D.A. Bella, professor emeritus at Oregon State University, addressed the pernicious issue of the liberal arts and engineering education:

> Despite our best intentions, we may be producing functionaries rather than educating human beings to serve higher ideals. We like to believe that education addresses such concerns by requiring engineering students to take a minimum number of courses in the

> liberal arts. By sending students across campus we, in practice, tell them that someone else deals with such concerns. We wash our hands (Bella 1990).

This comment seems especially relevant in the light of the findings in this study that the majority of liberal arts courses are taken through electives. Students select courses based on a number of subjective criteria, including distribution requirements, personal appeal, recommendations from friends, and offering logistics and convenience (time, location, etc). Undergraduate students cannot be expected to select the courses most germane to their professional practice as engineers, nor should every course necessarily relate directly to professional practice objectives. One of the joys of the liberal arts is learning to challenge accepted wisdom in the search for the answers and solutions most relevant for you, your community, or your culture. Choices, in courses and in life, are a central theme. Liberal arts courses instill the importance of context and circumstance in understanding problems. They challenge students to explore the world and, perhaps most importantly, to turn within to determine what and how to think, what their personal limitations and prejudices are, and how they can overcome their shortcomings to become better people, better citizens, and better engineers.

The Big Gray Picture

In his book *The Contrarian's Guide to Leadership*, Steven M. Sample, president of the University of Southern California, discusses the concept of "thinking gray" (2001). This approach to dealing with problems in the real world consists of not being afraid to reserve judgment and to accept situations as complex, and sometimes unsolvable. As opposed to the binary approach that is commonly taught to technical people, especially engineers, where something is either right or wrong, "thinking gray" forces one to be of two, or even multiple minds regarding a problem or situation, and to pay attention to external factors, or "the context." Sample makes a compelling case that "thinking gray" is an essential quality to becoming a dynamic leader, but "thinking gray" is also an important skill to becoming a successful engineer. However, current engineering education does not always entertain the notion that the world is complex and must be appreciated from multiple perspectives. This lack of a broad focus hurts the profession and sends the wrong message to students. A limited appreciation for the "grayness" of the world can be a career limiter, as well as prevent full participation in society and in the engineering profession.

To successfully blend the liberal arts with technical education to cultivate a broad, holistic appreciation of engineering practice in the modern world, departments must take an active hand in assembling a series of courses, offered at the correct time and at the correct depth, that help address the issues most pertinent to becoming a well-rounded professional engineer. The exact courses are not as important as the structure that goes behind the courses and the relative and implicit importance placed on them by faculty and the profession. If students are told again and again how important it is to study the laws of harmonics or the sketches of Da Vinci, many of them will catch on. But it they are told to take some liberal arts courses, and get back to their engineering, most of them will do exactly that because it seems easier and more "serious" than all of that (perceived) touchy-feely stuff that goes on across campus. The current lack of emphasis on and integration with the liberal arts is far from ideal, but fortunately there are some inspiring examples out there.

The Bright Spots

A few schools and programs are doing an excellent job of integrating the liberal arts with a sound technical education. The University of San Diego, a liberal arts institution, offers the only nine-course ABET-accredited program leading to a joint Bachelor of Arts (BA) and Bachelor of Science (BS) degree in electrical engineering (Schubert 1997). The program includes 43 to 54 semester units of liberal arts content. The Georgia Institute of Technology has established a School of Literature, Communication, and Culture offering liberal arts degrees and courses for engineering majors with significant technology components (Hill 2001). North Carolina State University has established the Ben Franklin Scholars Program, a five-year course of study that results in a BS in engineering or computer science and a BA/BS in a multidisciplinary study. Students develop customized majors by working with faculty in engineering and liberal arts departments, and take a three-course interdisciplinary core sequence (Porter and Herkert 1996). The Colorado School of Mines has established a unique program that addresses leadership and engineering from a liberal arts as opposed to a business school perspective (Olds and Miller 1996). The program melds engineering with public policy, and is administered by engineers, physical scientists, social scientists, and humanists.

All these programs demonstrate meaningful, curriculum-wide interaction between the liberal arts and engineering. As an intermediate step, many programs offer innovative integrative courses. The American University is experimenting with pairing physics for non-majors with an introductory college writing course that has met with success. Preliminary findings reveal that "writing has proven to be an effective way to assist students in articulating their thoughts and their understanding about a topic," a finding that "has enormous potential within both science and engineering communities" (Larkin-Hein and Joyner 2001). Ashraf M. Ghaly, an Egyptian national and associate professor at Union College, developed a course examining how building design is "influenced by environmental conditions, and by religious, historical, and cultural traditions" ("Construction for Humanity" 2000). The course examines the system behind large public structures such as temples, castles, and skyscrapers, and is team-taught by Professor Ghaly and Professor Steven D. Sargent, a historian.

ASCE Policy Statement 465

There has been much discussion about whether current education is sufficient for the practice of engineering, especially civil engineering, at the professional level. ASCE Policy Statement 465, Academic Prerequisites for Licensure and Professional Practice, has spurred much of this discussion through a call for additional education beyond the BS degree. The call for additional education has in many ways shifted the focus away from what the policy is intended to accomplish: building a new curriculum from the ground up. The committee in charge of implementing Policy Statement 465 is approaching the plan by addressing the body of knowledge necessary for practice for the next generation of professional civil engineers. This includes an undergraduate base and advanced graduate-level courses, not necessarily leading to an advanced degree. The focus is on acquiring a body of knowledge, whether through a practice-oriented MS or an approved set of advanced courses that do not lead to an advanced degree. For more information on the status of Policy Statement 465, please consult the website www.asce.org/raisethebar.

ASCE has determined that an integral part of the body of knowledge for professional practice includes the ability to communicate technical information to non-specialists; an appreciation for culture, environment, history, and human behavior; knowledge of the relationship of engineering to critical contemporary issues; and an understanding of sustainable design concepts and principles. In order to prepare students for the professional challenges ahead and to become leaders of the built environment, civil engineering departments need to integrate the liberal arts into their programs to help develop such systems-level perspective.

Towards Meaningful Integration of the Liberal Arts

As this study found, less than 20% of civil engineering programs require a specific course in literature (17.8%), political science (17.8%), fine arts (14.4%), world civilization (12.2%), or foreign language (3.3%). Students may choose to take any of these courses through electives, but they may elect not to. Colleges and universities generally have distribution requirements for electives, but even so, engineering students can be overwhelmed with the vast offering from foreign departments and opt to take courses based on their offering time and peer-recommendations, not necessarily based on tie-ins with their civil engineering course.

But how to educate contrarian leaders and thinkers, and how to incorporate the right amount of "gray" into a jam-packed curriculum? Engineering students are taking, on average, fewer engineering courses at a time when by almost universal estimation the complexity of the modern engineering project continues to mount (Allenby 2000/2001; Bordogna 1998; Clough 2000; TCFPD 2001). To confront the challenges of the 21st century, engineers need to polish their non-technical repertoire, and this includes developing closer ties with the liberal arts. As programs reform their curricula in response to ABET's new outcome-oriented criteria, and as civil engineering departments respond to Policy Statement 465, it is hoped that the liberal arts will not be left out as an afterthought, but will instead move to the forefront of the on-going challenge of continuing to be the global leaders in engineering education.

If the goal of a liberal arts education for engineering students is an appreciation of a wider context, ambiguity, and the lingual and logical foundation for developing professional skills, then the liberal arts component should attempt to address these issues in a way that students can understand and relate to. Perhaps a smattering of unrelated electives is not the best means to instill an appreciation for the liberal arts and how they relate to engineering education and practice. Programs may consider:

- Compiling and circulating recommended course lists that help explain how specific liberal arts offerings relate to the engineering curriculum. For example, students might be interested to know that history of science, history of technology, and science, technology, and society (STS) courses place science and technology within a larger social context. These courses help explain the complex historical background for how technology and science are created and discovered, as well as address current viewpoints that may be critical to the consequences of technological development. These courses are offered through literature, history, sociology, anthropology, and dedicated departments. For example, the University of Wisconsin-Madison has a history of science and technology department, as well as an inter-departmental STS program. Even small colleges often have a social scientist who teaches a course that examines science from a perspective that might be interesting and informative to engineering students.

- Limiting the number of choices available for any liberal arts elective, in the same way that many technical electives are regulated. Engineering professors know technical courses, and as such, can help select the most important courses for their undergraduates to select from to satisfy technical electives. By investing some time in exploring the liberal arts offerings by reading course descriptions, contacting department chairs and individual professors, and even visiting a class or two, a faculty committee could pretty quickly assemble a series of relevant courses for their undergraduates. This should be viewed as an on-going, iterative initiative, not an ad hoc endeavor.

- Holding a 1 or 0 credit seminar for undergraduates that addresses engineering from a broad cultural context with guest lectures from liberal arts departments. This forum could introduce students to a wide variety of fields and methodologies, as well as help establish ties between liberal arts and engineering faculty and departments.

- Offering a course (or courses) to liberal arts students that attempts to explain what engineers do to a wider audience. This sends a message to engineering students that interaction with other majors is worthwhile and possible. It may also help in recruitment (Bolding and Bauman 1999).

A Brighter Future

This paper concludes with a quote from a chemical engineering professor at Iowa State University that appeared in the editorial section of the *New York Times* in response to another professor's efforts to teach computer science to liberal arts students.

> Compression of curricula in technical fields has reduced the need for undergraduates to sample the liberal and fine arts, and the rush to turn the best and brightest into research engines has removed these topics from agendas that might otherwise include them. Beyond the breadth one gains from dabbling in new areas, an awareness of art can benefit the technologist by encountering alternate modes of thinking. Science and engineering students too often lead with their left brains and look for rules and equations when more subjective approaches can yield more global and lasting results (Jolls 2002).

The liberal arts help "humanize" the technical focus of engineering education. They also teach engineers to understand and be sensitive to the people they will work for and with on a regular basis. Taking liberal arts courses forces students to discuss, debate, and defend assumptions and opinions about the wider world for which there are no textbook solutions. Through giving students a solid foundation in and appreciation for the liberal arts, educators can spark an interest in history, philosophy, drama, or music that will enrich the student's life and professional career. As students build on their education base with real world experience, life long learning, and personal study, hopefully they will become engineers who appreciate and further culture in their everyday engineering. The lasting legacy of engineering reform in the 21st century can be to finally cement formal ties with the liberal arts. In so doing, engineering education will better prepare future generations to safely and effectively practice in the complex, ever-changing 21st century global economy.

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