Why Does Engineering Fit into a Liberal Education?

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1. Some Background

When President Ainlay called me a couple of months ago and asked me to speak at your symposium, frankly I had mixed feelings in responding favorably. As a professor of English at WPI and also for the last twenty years or so in academic administration, I had been concentrating about a decade ago on the kinds of issues which we are addressing at this gathering. My concerns then were primarily the fate of the kind of liberal education (which I had enjoyed as an undergraduate) at technological universities like WPI that were facing a major change in the way in which the liberal arts (more specifically humanities, arts and social sciences) were presented within the engineering curriculum.

My concerns focused on the changes in the policies and procedures for our professional accrediting organization, the Accreditation Board for Engineering and Technology (perhaps sardonically to some, known by the acronym of ABET). In the late 1990's, ABET replaced the requirements for engineering accreditation based on demonstrating through transcripts that students had passed certain numbers of courses in engineering, science, math, humanities and social sciences, with a set of undergraduate learning outcomes which institutions seeking accreditation would need to define for themselves and then demonstrate how they measured those outcomes. My concerns then were more with what would be the role of the liberal arts within an engineering curriculum rather than the inverse question which I am trying to address today, why does engineering fit into a liberal education.

2. The Argument

In the course of my comments, I will draw on what we have learned about student learning outcomes in general, and in liberal education within engineering education. But let me begin by saying that to me *engineering fits into a liberal education because without some sense of both the specific "life of the mind" engineers live-- as well as with the products of that life-- I do not believe it will be possible for anyone to call him or herself liberally educated.*

Let me start with a simple anecdote which really sticks in my mind here. Five years ago, Ioannis Miaoulis, then dean of engineering at Tufts University and now president of the Museum of Science in Boston, began a campaign to persuade the legislators and people of Massachusetts that engineering should be an option within the state K-12 public education and assessment system. He made the distinction, as many do, that science explains *how the world as it is functions*, but that engineering *changes* the world better to address human needs.

[1] http://www.union.edu/integration

Scientists understand the world; engineers change the world. Miaoulis argued both are necessary in public education. He developed into a mantra the image of all of those elementary and high school science projects describing how a volcano works, but (in the absence of either a curriculum or outcomes expectations in engineering) no students ever discussed how cars work or can be improved. Surely, he asked with rhetorical certainty, we all daily experience cars more frequently than volcanoes. Further, now more than ever as our energy resources shrink, we need to be better informed about increasing the efficiency of our transportation system and identifying alternative energy sources. Volcanoes heat no houses, at least in New England.

Miaoulis's point applies equally well to college education. But at the college level, I think we can do much more to show that as highly-creative people, engineers enjoy a vigorous "life of the mind." I have seized on the phrase "life of the mind' because pursuing such a life is often part of the rhetoric in support of liberal education, but often such mental lives are supposed only to live within the College of Arts and Sciences. If challenged, most people, even Liberal Arts faculty, would I suspect grant that successful engineers demonstrate creativity; that engineers exercise critical thinking skills, work in teams, communicate across disciplinary boundaries, and make decisions based on their personal ethics. Yet perhaps because the products of their work are embodied in the material world, we think of engineers less as living the lonely life of the mind than as practitioners of vocations, most often within a corporate structure in which their position in the hierarchy may be middling at best, tenuous at worst. And I think many practicing engineers and not a few engineering faculty think this way too.

But my argument is that engineers do live the life of the mind, and that the evidences of that living are the ways in which they solve problems. And I argue that a—if not the--cornerstone of any undergraduate education is <u>learning how to solve problems.</u> Thus my main argument is that engineering education, as a form of liberal education, liberal knowing, and liberal action, is learning how to solve problems. The "ways of knowing the world" –another shibboleth from liberal education—which engineering distinctively uses to solve problems, involve the follow steps:

1. Defining with as much precision as possible exactly what the problem is that requires a solution.
2. Based on the *art and practice* of solving such problems in the past, defining what experiments and resources will be needed to model typically several potential solutions to the problem at hand.
3. Fleshing out competing solutions, paying particular attention to the inevitable trade offs among such crucial issues in solving the problem as financial costs, human impact, aesthetics, environmental consequences and the like.
4. Making a successful case for your solution to whoever has requested a possible solution to the problem; and
5. Carrying out the solution agreed upon after inevitable discussion and probable compromise, in a way that is *efficient* in human and material resources, *ethical* in addressing relevant laws and codes, and *practical* within the span of time allotted for its conclusion.

It seems to me courses could be designed for students who are not engineering majors that could take one or more case studies of how engineers solve problems in different disciplines, using the ways of thought described above. Such courses would serve the students far better if they actually challenged them to carry out an appropriate small project of actual value to the campus or the community in which they reside. (Example: heating oil in New England will apparently soon be over $4.00 a gallon. Find ways to address this problem in your residence hall room.)

In engineering education, we have seen a proliferation of such projects. I would argue as a WPI faculty member that WPI began this requirement with its interactive project in the early 1970's (about which I will speak tomorrow), and that other organizations such as Purdue University's program EPICS (Engineering Projects in Community Service) have devised similar curricula which have been adopted at a number of universities that enable students to understand the impact of engineering problem solving. Such curricula have played a significant role in moving the perception, at least among some educators and students, that engineering is a discipline by which humans learn how to solve problems for other humans – that engineering is in fact a helping profession.

Finally I note that if something like the five steps I have suggested above constitutes an "engineering method," then why are we not presenting it all the appropriate levels of education in parallel with the "scientific method" which is widely discussed?

3. Problems with the word "Liberal"

As professor of English, I often look to the history of words for guidance on the kinds of social and pedagogical issues that we are concerned with today. As I have commented before (and I am far from being alone in this), the term "liberal education" or "liberal arts" derive the defining adjective "liberal" from the Latin word "*liber*," or free. Pushing the etymology even further back, the Latin *liber* derives from the Indo-European, "*leudhero,"* "belonging to the people, free." [[These and further word histories are from the *Webster's New World Dictionary of the American Language*, Second College Edition, 1972.]]

It is the touchstone of such historical commentary that the defining characteristic of being free was the ability to read and write; literacy brought freedom from manual labor. Mastering the key elements of communications enabled those learned in the arts of grammar, rhetoric, and logic both to record the history of their culture and to define and communicate its current concerns and debates. (One notes with amusement that Ben Jonson, Shakespeare's greatest dramatic contemporary, escaped the death penalty for killing a fellow actor in a duel by demonstrating he was a member of the clerisy—liberal education had some real privileges then.)

In the last ten years it has grown more difficult to talk about liberal education because of the political overtones many hear in the word "liberal." As used within the academic community, liberal education (along with liberal politics) connotes being open to new ideas, enjoying a critical debate even over fundamental values, valuing knowledge for its own sake rather than its applications, and generally, privileging vigorous intellectual inquiry and research over other forms of human activity. All good things, at least to academics.

But, again looking at word history in a source like Raymond Williams's book *Keywords* or in the *Oxford English Dictionary*, one finds that historically the word "liberal" also has meant freedom from proper constraints, looseness of thought and behavior, and even licentiousness. In politics, "liberal" took a body blow when the Monica Lewinsky scandal broke.

Liberal education encountered another difficulty in the last decade as the paradigm shift to redefine education in terms of measuring what learners acquire and use, began to replace education conceived as what the faculty member delivered in front of the classroom. It is comparatively easy to define learning outcomes within a professional curriculum. In the profession I knew best, engineering, WPI and other engineering programs had no great conceptual difficulty in adapting the ABET learning outcomes to indicate how, for example, students in a senior-year capstone design project would be challenged to demonstrate how well they could pull together their math, science and engineering courses in order to solve a problem at a level they could reasonably anticipate encountering in the first year of graduate school or in the first year of professional practice. Articulating and measuring such conceptual frameworks for liberal arts programs which define themselves not in terms of problem solving but in terms of nurturing the life of the mind is notoriously far more difficult. (But not impossible, which I would be glad to talk about in the break-out sessions.)

Perhaps it is not sufficiently observed, however, in such historical references that the classes of people who achieved the freedom granted by liberal education were always significantly restricted. Only men – and at that only men not slaves (a large population in all ancient societies) – could achieve the status of liberal education, even though of course many slaves were highly educated not only in the disciplines of communication but in the areas of the professions and arts today. Until the 18th century in Europe, the concept that women could be liberally educated was essentially never entertained. I mention these restrictions because I'm struck now how increasingly in the 21st century we face similar class if not also gender restrictions on who can—or want to be—liberally educated. The statistics on those who are pursuing a liberal education are striking and they are grim. I refer now to a study of liberal and professional education, funded by the Teagle Foundation and being conducted at five universities (WPI, Smith College, Cornell College, Warren Wilson College, and Hampshire College) where WPI is represented by my colleague Dean Rick Vaz.

In a recent survey of 1,000 adults, 64% indicated that the purpose of a college education is to prepare graduates for their careers. (Center for Survey Research and Analysis, Univ. of CT, cited in Semuels, 2005). From 1970 to 2006, the percentage of college freshmen who consider "being well off financially" to be an essential or very important goal has increased from 36.2% to 73.6% while the percentage of freshmen who consider "acquiring a meaningful philosophy of life" to be essential or very important has decreased from 79% to 39%. Perhaps reflecting these shifts in college purposes and goals, by the year 2000, *only 4% of baccalaureate degrees were earned at residential liberal arts colleges.*

Later, this study makes the case that "there will be a smaller pool of white, middle-class, non first generation, bicoastally-located, college-going students, and more Latino and other minority students in the Sunbelt who come from lower socio-economic strata and who are first

generation." (p. 33). This demographic forms the pool for our future undergraduates, and these will be students who traditionally have not sought out conventional liberal education; they are much more likely to wish to pursue two- or four-year programs which they perceive to enable them to secure professional employment at a socio-economic level higher than their parents enjoy.

In short, a traditional liberal education has historically freed only a small percentage of the population, even the population that has availed themselves of whatever opportunities exist within their culture for advanced study. And that percentage will continue to shrink in our lifetime. These observations bring me to a crucial point that has struck me in preparing my present talk: to achieve the conventional definition given above of a liberal education—that is, to achieve a perceived sense of being in control of one's life within one's culture--such an education must confer upon its possessor the freedom both to secure a productive role within society and to contribute productively to the welfare of that society. To be wholly free, one cannot be wholly dependant economically or psychologically on others. Part of the life of the mind a liberal education nurtures must be how to solve problems of importance to oneself and others in some domain—artistic, social, humanistic, political, scientific, or technological. Fewer and fewer families will consider the four college years as an extended, carefree adolescence, free from developing mature commitments to society including a vocation.

(In the discussion session, I will be happy to provide examples of how, in my teaching at WPI and working with my colleagues in our Humanities and Arts department, I have tried to reframe our teaching and learning in the humanities and arts in terms of solving problems.)

4. Problems with the word "Engineer"

The stereotype of an engineer as a geek exists because the stereotype captures enough of the specific characteristics of the engineer to distinguish that type from other groups of humans. Like, sadly, increasing numbers of younger people, engineering students prefer to communicate in electronically-mediated environments rather than face to face. They are often better with things, science, and numbers than with people, arts and words. (But I note that, judging from profiles submitted by WPI applicants, interestingly, women applicants are more secure in their social skills than the males, perhaps because only applicants with this security would be likely to want to compete in a field so male-dominated.)

Recently, a friendlier spin has been put on this geek image, and not only with the "rent-a-geek" concept for those whose PC's have mysteriously expired. Increasingly, geeks with the meek are ruling the earth. Regionally Dean Kamen and, nationally, Bill Gates have emerged as very positive examples of how the "life of the mind" of the engineer can lead to new products we all use regularly and to fortunes which these innovators have dedicated to socially admirable causes. (I note as a topic for another session that neither graduated from the college where they began, WPI and Harvard respectively.)

To some degree the perception that engineering is not a liberal art is reinforced by the history of higher-education institutions in this country. The "ivy-league colleges" are often placed at the top of the educational heap, with references to the likes of Princeton, Harvard and

Yale as *colleges* dedicated to the non-vocational pursuit of the life of the mind. (This construct of course ignores two historical facts: 1) until the mid nineteenth-century such colleges were vocational schools preparing young men for the vocation of the ministry, and 2) since World War II, such "colleges" no longer exist solely for undergraduate education but are subsumed within much-larger research universities.)

In contrast to these elite colleges are those institutions like WPI and MIT where the words "polytechnic," "institute" and "technology" figure in the name to signify objectives different from the traditional colleges. At an even further distance, in mission and geography, from the east coast ivy leagues are the "A&M'S"—Agriculture and Mechanical—institutions set up in part in response to the Morrill Act of 1862. Without question, in the 19th C. young men went to these A&M's and institutes for vocational education leading to immediate employment. (Union College, I note, has the rare distinction of an 18th c. foundation along with a long tradition of a substantial undergraduate engineering program.)
The situation has grown more complex as the distinction between vocational schools for workers with their hands and liberal arts institutions for workers with their heads began to collapse. The world of work increasingly demands "knowledge workers" and cares less where they come from. But "knowledge workers" must, upon graduation, be prepared to begin to work.

Etymology is at the root of yet another problem facing engineers, a most curious—and serious—one. In English, the root for "engineering" comes from the Old French "*engin,"* which has taken on connotations sharply different in Anglo-American and in European practice. In America "engin" is associated with engines and the term "engineer" (certainly in my generation) perhaps most commonly associated with someone who ran a steam locomotive. I think in this country that this association is shrinking steadily, but those of us involved in engineering education still far too often encounter – most painfully at conferences of engineering education – statements from the hotel that if anything goes wrong within the room, an engineer is always on call to fix the problem at extension XXX. (Ironically, according to the American Society of Engineering Education's monthly magazine *Prism*, this linguistic association is even more problematic in the United Kingdom, where the modern professional of engineering developed most robustly in the 19th C. The January 2008 article "Too Little Respect," articulates the continuing problem of the sharp drop in students in the United Kingdom who wish to pursue engineering because those graduates rarely are able to achieve high-end managerial roles in even high-tech and globalized companies.[2])

The case is different in Europe. By a fateful linguistic quirk, "engin," in both French and German usage, became associated not with grimy, greasy 19th C. engines, but with ingenuity—going back to the Old French source of "engin" in the Latin "*ingenium*," "natural ability or genius." The French or German "*ingeneur*" is highly regarded and often sought out for having learned the problem-solving skills that high end management requires. French and German polytechniques enjoy often the prestige of being the most highly regarded university of their countries, in American terms, MIT and Harvard rolled together.

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[2] Engineers seem to fare better in the US in terms of being tapped for the highest managerial positions. The March 2008 *Prism* announced in "A Route to the Top" (46-50) that "a fifth of the top executives in America's biggest companies are engineers. One reason: their hard-nosed problem solving skills help the bottom line." But 20% seems low to me, and I suspect is significantly lower than the graduates of French and German polytechniques.

5. The Problems with Us.

I proposed earlier that we could take a major step in showing how engineering educating nurtures "the life of the mind" by designing and offering courses that demonstrate to engineering and non-engineering students alike how engineers solve problems that matter, that indeed "engineering is a helping profession." Significant barriers exist even within vibrant engineering educational communities, however, to engage engineering faculty in creating such courses. Chief among them is probably an always-increasing emphasis placed in engineering education on specialized disciplinary research. The emphasis on research in and of itself is a relatively new expectation in engineering education, originating according to many commentators in the post World War II Vannevar Bush regime of drawing engineers and scientists much more closely to the military-industrial complex. To many engineers and engineering educators today, the essence of engineering is not disciplinary research but appropriate design. This debate goes on at my university, probably at yours, and probably most places where engineering education takes place, with respect to the relative importance of science-like disciplinary research as opposed to learning and practicing the art of successful design.

And-- stressing the engineering side of design aligns the profession more with the arts than with sciences, a useful way to think about including engineering within the liberal arts curriculum.[3]

Engineering faculty are no different from faculty in any other discipline in terms of the need to place in perspective, if they enter the teaching profession, the specialized disciplinary work they conducted for their doctorate. Many faculty at all institutions, I speculate, consciously or unconsciously regard the highest professional result of their teaching to be the replication in their students of the passion that drove them to solve the high-level problem embodied within their dissertation, and in many cases, continued in their funded research. However, the hard reality is that most of their students will not follow this path. (I sometimes tease my colleagues by reminding them that the A students will get the top research jobs, the B students will get the good teaching jobs, and the C students will make enough money to pay for the work of the A's and B's.)

I think as an external observer of engineering that the "ways of knowing the world" by which I characterized engineering problem solving above could be enormously important and helpful as the template for organizing courses that would make both engineering and non-engineering students better aware of what the practice of engineering is all about. The problem, however, is that most engineering faculty (like most faculty in all disciplines) are eager to develop their teaching careers in such ways that increasingly they teach upper level and graduate courses, better enabling them to link their ongoing research with the instruction of students who can assist them in these goals. The engineering faculty that I have talked with to get a reality check on my model of engineering problem-solving generally agreed that something like it makes sense in terms of how engineers work, but don't really see any need to detach such a general template from the way in which they teach or do their research in their disciplines. And that's entirely understandable – the rewards in an increasingly large percentage of technological

[3] Authors worth reading on engineering as design include David Billington, Samuel Florman,and Henry Petroski.

universities go to those faculty who combine their specialized teaching and research with identifying ever shrinking opportunities for funded research.

However, it does strike me that the goal often cited for a liberal education (and here I'll quote again from the Teagle paper to which I have referred several times before) should not be restricted only to the narrow conventional meaning of such an education such as this one (which the Teagle authors offer as conventional but not desirable wisdom):

> Liberal education is devoted to the cultivation of "the life of the mind" - an essentially intellectual pursuit carried out through a program of personal development that provides "intellectual, cultural, and emotional experience which is neither a mere continuation of what went before [grade school] *nor* a mere foretaste of what is to follow [career or professional training]. What matters is the material should engage the student's intellect and sensibility, that he [*sic*] should be held to the highest possible standards of thought, and that his activities be free of extraneous career consequences of a professional school. (Teagle, p. 6)

In my 38 years of experience with colleagues in science and engineering, I believe strongly that every attribute of this quotation with the exception of the last one (the reference to the alleged "extraneous career consequences of a professional school") can be carried out every bit as well in engineering education as in the traditional areas of the liberal arts. It is simply not the case in my experience that nurturing "the life of the mind" – either in the faculty member or in the student – is a skill limited to liberal arts faculty. I've known—and I am sure you have--many engineering faculty who are every bit as knowledgeable and engaged in social and cultural issues as my colleagues on and off campus in my own discipline. Indeed, it is a well known truism – at least within technological universities, that the probability of finding an engineer really interested in and knowledgeable about any area of the arts or humanities is much higher than finding a colleague in the humanities or arts even mildly interested in technology, or even the sciences.

The same may be argued for other areas of learning associated with liberal learning, such as helping to develop a sense of ethics—and applying those principles. "Engaging the student's intellect and sensibility" and holding him or her to "the highest possible standards of thought" clearly should occur in all academic programs, not just the liberal arts. And teaching <u>critical thinking</u> is certainly every bit a part of engineering education as it is of liberal arts education. So, according to this cardboard definition of the liberal arts, the only substantial difference between a liberal arts education and an engineering education is that the former "should be free of extraneous career consequences." My whole point in this discussion is that this claim is losing all rational support, and should be rejected.

Perhaps the only difference is that engineering faculty have to date been less challenged than humanities faculty specifically to articulate how they cultivate the life of the mind of their students, and to provide evidence of learning outcomes from their classroom to demonstrate such broad student intellectual growth. Thus I think that in many introductory-level engineering courses – and I suggest here introductory level so as to make the intellectual content of those courses available to students from all disciplines, and not needing extensive prerequisite

knowledge – engineering faculty could (if properly prepared and rewarded) provide learning opportunities for students in such areas as critical inquiry, teamwork, developing a personal ethics, and communications (especially to the non technologically adept).

One possible solution to overcoming the specialization that prevents teachers and learners from getting at the fundamentals of problem-solving in any one established discipline is to develop more inter-disciplinary courses and programs. Interdisciplinary programs in my experience have worked best when they set expectations for both students and faculty to integrate knowledge from different, sometimes quite different, fields, when there is a purpose in mind. WPI was one of the first undergraduate institutions to create a program in interactive media and game design, the faculty for which draws equally from the computer science department and from the arts division of the humanities & arts department. Those faculty who were at WPI and decided to enter the program, as well as those faculty newly recruited to it, made a commitment to learn enough about the other field to be able to be successful. The program even managed to bridge significantly different professional expectations, with the computer science faculty all having research-driven Ph.D.s and the humanities faculty, in contrast, having as their terminal degrees MFAs and with expectations for showing their professional work in venues such as art exhibits, not giving papers at professional conferences.

Humanities faculty, of course, are in many cases as specialized as engineering faculty. Moreover, humanities faculty in my experience, often (<u>not always</u>) tend to be more interested in defining, expanding, or even (dare I say it) luxuriating (liberally?) in problems rather than solving them. There is certainly a lot to be said within the diversity of professional interests of any university culture to have a faculty group that counters the dominant culture. However, I have always been concerned at institutions like WPI that if faculty view their roles as providing through the humanities and arts an antidote to the poison of engineering (which admittedly too often is a very real poison with respect to the way engineering is used to harm the environment and other humans), those faculty, if strident and blinkered, may lose any credibility with their colleagues and students. We all need to remember that while Hamlet may be one of the greatest figures in Western literature, his inability to solve his problems led to a stage full of dead bodies at the end of Act V. In contrast, an equally troubled Shakespearean hero – Prospero in *the Tempest* – did manage to sort out the problems by the end of his play, including foregoing the special magic that made his manipulating a happy outcome possible.

I share the views of the Teagle research team that setting at odds to each other a liberal and a vocational education will result in a dead end for both individuals and for the civic fabric. My Teagle colleagues here argue that the

> …conclusion that the values of higher education are disjoint from those associated with vocation, profession and life success only becomes inevitable if we construe the range of liberal values too narrowly. To the extent that liberal learning places value on teaching students to develop a calling, to positively impact their world, and to develop an integrative, reflective stance on their education and their purposes in life, we will find a more seamless connection between the values of liberal learning, and many of the values associated with professional studies, vocation and career. (Teagle, p. 51)

No less a paladin of liberal education than Derek Bok has written the following in his 2006 book *Our Underachieving Colleges: A Critical Look at How Much Students Learn and Why They Should be Learning More*.

> Denying vocational concerns any place in the curriculum will diminish the chance to help undergraduates think about their careers in terms broader than simply making money….The question then is not whether to banish all vocational courses but whether to join in giving students a larger view of the professions than goes beyond mere skills training. (Bok, 282; as quoted in Teagle, 19).[4]

To be free, then, in the 21st century, a student must cultivate the mental independence required both to begin to learn how to formulate and carry out mature critical decisions and to "get a calling," to have a job, professional or otherwise, which provides the income necessary to ensure individuals are not a burden on society as well as to be in a position to contribute productively to the commonwealth. For example, art historians or art students – even the proverbial basket weaver – need to know something about how the materials used in the craft are made, what the history of the product is, what models have been particularly vibrant and aesthetically pleasing in the past – and what potential market for the product may exist. By the same measure, students of engineering or computer science need to understand what the societal or even political impacts of their work will be, to ensure that they will have a chance to play a key role in the production of the products they design. Otherwise, they will be relegated to a replaceable commodity in a Dilbert's cubicle.

A recent article which appeared in the *NY Times* about a month ago, on Sunday April 6 (A 25), "More College Students Opt for the Life Examined," provides a useful insight into the role of liberal education in a world of higher education increasingly concerned with students preparing for a life of work as well as of thought. The article, if you saw it, carried as its subtitle "New appreciation for a practical value in studying philosophy." Quote: "Nationwide there are more colleges offering undergraduate philosophy programs today than a decade ago (817, up from 765, according to the College Board." Four universities—indeed, one of them an A&M (Texas)—have doubled the number of majors. The article attributes this growth to students seeking the intellectual richness of a discipline whose content is remote from vocational training but whose methods of teaching, as several students state in the article, provide excellent preparation for competitive professions. The ways of examining life these students are learning balances the intellectual content and the intellectual tools one needs to solve such problems as those arising from globalization. But to me, the most telling information in the article were the student references to why they were studying philosophy, even changing from something like political science to a philosophy major. With one exception, the students gave as their rationale the sharpness of the tools they were mastering to use in problem solving. But in Socrates' terms, they were training as sophists not truth-seekers.

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[4] Bok also notes that liberal arts faculty see the acquisition of knowledge as "an end in itself—indeed, the principle end of academic life." He commends such an end but reminds liberal arts faculty that many of their students and their families "look upon knowledge and ideas less as ends in themselves, and more as means towards accomplishing other goals, such as becoming better, more mature human beings or achieving sucess in their careers." (Bok, 2006, as quote in Teagle, 13.)

Let me conclude with a few words on the questions raised by the symposium organizers concerning designing effective curricula at those institutions with both strong liberal arts and engineering programs. For anyone to advise the Union College faculty on this matter is presumptuous; founded in 1795, Union in 1845 (according to the college history on its website) "became the first liberal arts college to offer engineering."

Fully to succeed in offering effective learning opportunities to liberal arts and engineering students—a distinction here I regret but will use for purposes of discussion—faculties from both areas must not only be engaged but have equal decision-making power. This is easier to say than to do. At large universities, deans of respective schools can either mediate or ignore such discussions. The evidence I have seen from the American Society of Engineering Education conferences I have attended is that engineering deans too often choose to ignore these issues, as discussed in the 2004 collection of essays *Liberal Education in Twenty-First Century Engineering Education* (edited by David F. Ollis, Kathryn A. Neeley and Heinz C. Luegenbiehl, NY: Peter Lang.) The movement towards assessing engineering curricula based on learning outcomes and not courses, to which I referred at the outset of this talk, culminated in Engineering Criteria 2000. EC 2000 removed the long-standing requirement of at least a half year of study in humanities and social sciences (while retaining a mandate for a year and half of engineering science and design, and a year of mathematics and science.) [5] Engineering programs are now required to show what they know about student learning in eleven outcomes, six of which rely on preparation in the humanities and social sciences.

These outcomes involve demonstrations of learning in such areas as ethics, communications, social awareness, and team work—process skills often rather than content. But the engineering profession still calls such skills "soft skills," from which you may reasonably infer they are accorded a lower place in resource allocation. Indeed, dissatisfied with how well their students acquire such skills in a college of arts and sciences, engineering deans and faculty increasingly are hiring their own faculty (adjuncts, usually) to offer the appropriate H/A/SS classes within the College of Engineering. And they are stressing those courses which most directly meet the needs of nurturing the soft skills for engineering students. Ethics, for example, is frequently presented through case studies, often of "whistle-blowers"; history through the history of technology; and communications through technical writing. Often as not, the instructors have backgrounds in engineering rather than the liberal arts. To limit the study of the humanities exclusively to such subjects, because they relate most closely to the core interests of engineering, is to risk providing only feeble opportunities for engineering students to grapple with the life of the creative mind in many areas of the humanities, with cultures new to them, as well as with the creative arts.

This approach to a liberal education for engineering students emphasizes the utilitarian over the conceptual, and reduces the opportunities of engineering students not only to exchange ideas with liberal arts faculty but with liberal arts students. Thus I commend those engineering programs with histories and traditions like Union (and similarly long-established programs at

[5] It should be noted that the New England Association of Schools and Colleges, our regional accrediting agency, does mandate an amount of time in the notional four-year curriculum required for the study of general education, thus maintaining some minimal block of time for these studies in engineering, at least in New England.

several ivy league institutions) as well as at numerous technological universities, large and small, who have resisted this co-option of liberal learning into the college of engineering.

The debate C. P. Snow started in the 1950's on the "Two Cultures—which quickly went beyond even his facile and opportunist pen—remains with us as a warning that we who seek to educate future generations must always scrutinize our own limitations and blinders. If we want to enable our students to prepare for lives and careers which will take directions none of us can predict, we must ensure the educational enterprise we engage them and us in is truly liberal, that is, liberating.

I have argued that engineering can contribute most helpfully to such a liberal education by articulating a structured way of solving problems through defining the issues, gathering the facts and/or conducting relevant experiments, modeling different solutions to illuminate the inevitable strengths and weaknesses of different approaches, and then executing the solution with the fewest problems. If more engineering courses, especially at the introductory level, can abstract this problem-solving model from the rich and complex knowledge of the specific discipline, then I suggest such an approach to solving problems can be used across many domains, including the arts and sciences. Such an approach to solving problems then would well exemplify the most cogent definition I have ever heard of a worthwhile education: "what you use after you have forgotten everything you've learned."

I commend such an education to us all.