Obstacles to a Liberal Engineering Education

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I. Introduction

> *"I ponder the grim fact that Greece, for all its art and philosophy, and Rome, for all its wealth and technology, both in the end toppled and fell. Perhaps a culture that weds competence to grace, and wisdom to know-how, would persevere and flourish where others have failed. Such a culture would have at its core a cadre of civilized engineers."*[1]

A civilized engineer would understand and appreciate the interrelationships between engineering and society, technology and history, and art and science - an understanding derived from a liberal education.

The recognition of the importance of liberal studies in engineering education goes back to the passage of the Morrill Act in 1862.[2] Since that time there has been concern that engineering education is not successfully incorporating liberal studies into the curriculum, beginning with the first major study of American engineering education directed by Dr. Charles Mann of the University of Chicago.[3] Among its recommendations was that students be taught so as to develop character, and surveys of 7000 members of professional engineering societies ranked "character" at the top of a list of 6 attributes while "technique" came in last place. The results of this study, completed in 1918, are echoed in other studies that followed over the next 50 years, including the Wickenden Studies (1930), the Jackson report (1939), the Grinter report (1955), and the Olmstead report (1968), all indicating concern for the lack of integration of liberal arts into engineering education.[4]

In spite of the importance of a liberal engineering education, the issue is still debated today, as it has been for the past 100 years. This may be due, in part, to the continual "crises" that portray the state of higher education. According to Lucas, "If there is an authentic crisis at present . . . it is that the wrangling and contention, the endless disputations and hand-wringing, over the state of undergraduate education in America have become so routine as to obscure rather than to reveal what has actually taken place over the span of the last quarter century or so in academe."[5]

Although the liberal education of engineers may not be perceived as a crisis, it has always been an issue in engineering education, and is growing in importance as society embraces the "business paradigm". The purpose of this paper is to discuss how higher education has adopted the business paradigm in response to reduced public funding, and to provide examples of how this change has created obstacles to a liberal engineering education. The paper concludes with a discussion of ABET 2000 and recommendations for improving the liberal education of engineers. First, however, the benefits of a liberal engineering education are presented in the next section.

II. Benefits of a Liberal Engineering Education

Before extolling the benefits of a liberal engineering education, the term will first be defined. "Liberal education", as it's used in this paper, relates not only to education in the traditional arts and sciences, but also to the students' potential to think broadly, and to tolerate the ideas and behavior of others through exposure to the arts, humanities, and social sciences. A liberal engineering education is defined as engineering education that incorporates liberal studies, requiring both depth and breadth in the arts, humanities, and social sciences.

Engineering arose out of the useful arts, eventually gaining professional status when science formed the basis of its theories and ideas. As engineering has risen in status and importance, so have its consequences which today are far greater than ever before. The world is becoming more technologically complex and globally connected. Events which occur throughout the world can affect all of us – fallout from the Chernobyl nuclear power plant, the catastrophic failures of the Challenger, and the proliferation of nuclear weapons, for example. Other less spectacular events also illustrate the connection, the importance, and the dependence between engineering and the world – automation, bioengineering, and artificial intelligence, for example.

The rise of the multinational corporation, the advancement in computer technology, and the expansion of capitalism have resulted in a global interdependence between business, science, technology, and society. The global economy affects everyone's life, and the engineer is in a position to ensure the well-being, the quality and the safety of each of our lives.

Societal Benefits

An engineer with a broad education, a liberal education, understands that the relationship between engineering and society is interdependent, and is in a position to better understand the engineer's role in serving, improving, and protecting the society. This important role is recognized by the American Society for Engineering Education:

> "In teaching sustainable design, faculty should ask their students to consider the impacts of design upon U.S. society, and upon other nations and cultures. Engineering faculty should use systems approaches, including interdisciplinary teams, to teach pollution prevention techniques, life cycle analysis, industrial ecology, and other sustainable engineering concepts."[6]

Engineers who understand how their profession influences society are in a better position to consider the policy implications of engineering creations. Engineers have had considerable influence in public policy. The Office of Science and Technology resides in the executive branch of the government, and the Office of Technology Assessment serves Congress. Engineers help explain technical concepts in order to better understand impacts on peoples' health and the environment, thereby assisting regulatory policy and compliance.

Engineers build transportation systems, water and sewer systems, buildings, and defense systems. They build power plants and maintain the power grid. They build health care products

using cutting edge technology in bioengineering and plastics. They build the products we use in our homes and our workplaces. The products, the structures, and the ideas created by the engineers can be seen throughout our society, in the public and the private realm. An engineer who can incorporate aesthetics into the design of structures and products contributes more to our lives than the value embedded in the utility of a product. They are creating value beyond the "use value", a contribution borne out of exposure to the liberal arts. Being educated in the liberal arts provides benefits within another sector of society as well: the corporation.

Corporate Benefits

The corporation reaps benefits when engineers are prepared to think beyond their specific job and consider how the engineering function relates to other parts of the organization. They can then understand the constraints and opportunities with which they are faced within the context of the organization. They are more capable of working with other people and more opportunities to socialize can also be created. Engineers who advance into the ranks of upper management in an organization are able to conceptualize problems, understand the full range of implications of engineering and business decisions, and provide leadership and managerial support for the organization. The engineer who has not achieved career goals due to the lack of these types of abilities can become disenchanted, unhappy, and unproductive. This “career ceiling” was recognized by the Colorado School of Mines and, in the late 70s, they embarked upon an undergraduate honors program in the arts and humanities to address, in part, the career limitations faced by their engineering graduates. This undertaking has proven to be successful, and the Colorado School of Mines continues to promote this program, as well as others which are aimed at improving undergraduate engineering education.[7]

Employers need engineers who can communicate and present ideas. According to a Deere & Company executive, “we’ll need engineers who are articulate and can write and speak concisely, effectively and persuasively [and who will] not be subjected to cultural shock if involved in projects in the Middle East, the countries of the East Bloc, or even the people’s Republic of China”.[8]

Michael Useem reinforces the corporate benefits of a liberal education:

> “ . . . the call by executives for more liberal education is predicated on the belief . . . that the next generation of corporate leadership must be educated as broadly as possible if the short-term vision so prevalent today is to be overcome, and if we are to remain creative and innovative in both product and workplace design.”[9]

Engineers must learn to disseminate technical information, assessing impacts on the corporation and consumers. The ability to think beyond engineering, reinforced by a liberal education, is essential for the welfare of the corporation. It is also essential for the welfare of the individual engineer.

Individual Benefits

Perhaps the individual benefit of a liberal education is best expressed by Samual Florman:

> "More important than any specific connection between liberal culture and technical creativity is the overall effect on character and personality that can be observed in those engineers whose education was liberally enriched and whose interests were not limited to their everyday work."[10]

The individual whose personality and character extend beyond engineering are able to embrace opportunities that occur outside the realm of engineering, enhancing not only their personal lives through exposure to the arts and the humanities, but also their ability to interact with non-engineers in business and society. This "engineering charisma" has played "a crucial - and fascinating - role in the success of many engineering projects . . ."[11]

The engineer also derives benefits of a liberal education by "exercising" other areas of intelligence. The notion of emotional intelligence has been popularized in the media, but other areas of intelligence exist. A liberal education taps into these other areas of intelligence which help to create a well-rounded individual. Whereas science, math, and engineering courses emphasize analytical and logical abilities, the liberal arts address other aspects of the "whole person" - musical, inter-personal, intra-personal, language, artistic, and physical abilities. Taken as a whole, these areas of learning comprise a balanced individual with the ability to function in numerous environments and enjoy other artistic and creative activities.

In spite of the numerous benefits of a liberal engineering education which are garnered by society, the corporation, and the individual, the ascendancy of business can overshadow these benefits. The business credo focuses on private costs and private benefits, as opposed to public costs and public benefits, shifting our focus away from benefits that fall outside the arena of easily measured outcomes.

III. The Privatization Challenge

Declining Public Funding and the Rise of Privatization

Since 1980, the distribution of the sources of revenue received by public institutions of higher education has shifted away from public funding and toward private funding sources. Between 1980 and 1996, the most dramatic changes occurred in tuition and fees, increasing from 12.9% to 18.8%; and state government contributions, declining from 45.6% to 35.8%. This trend is also reflected in reduced federal funding, and increased reliance on private gifts, grants, contracts, and endowments.[12]

Although universities have, to some extent, always relied on the contribution of private individuals and corporations, this dependence has grown deeper. In accordance with the paradigm of privatization, emphasis has shifted toward the private, and away from the public benefits of higher education.

As the business paradigm gained ascendancy during the 1980's so did its metaphors, expressions, and culture. Education has become a market-driven pursuit, with the intent of attracting and satisfying customers through total quality management and continuous improvement programs. Schools with the best programs may even win the Malcolm Baldridge Award, whose administrators have created a new educational category along side the original categories for private businesses. In order to achieve customer satisfaction and measure quality, universities are developing models to assess teaching and research productivity, value-added activities, and learning outcomes, establishing benchmarks to assess the return on investment. Education has become a marketing endeavor, competing for customers.

Students: The New Education "Customer"

In viewing the student as the consumer of education, the student's role is shifted and his relationship with the professor is no longer a "student-teacher" relationship; the student is now a "consumer" of education who plans or demands a course of study suited to the their needs. These needs are frequently expressed in terms of career potential, without the input of the greater society which contributes financially (to a lesser and lesser extent) to the student's education. In short, the student is in a position to shape their own education according to their own needs, perceptions, and values.

One form of expressing student perceptions is through the use of student evaluations, intended also as a tool for assessing learning and the instructor's teaching effectiveness. Although it makes sense to survey customers who purchase washing machines to determine how the product can be improved, the analogy to education is a poor one. Education is a lifelong process, and cannot be measured on the basis of one course. Furthermore, the students are not always in the best position to determine what they need to know in order to succeed in the early stages of their career, let alone as they mature. Students may not realize the value of a course until after they have begun to use those basic ideas, theories and principles in higher level courses where they are applied, after mastering elementary concepts. Without mastery at the lower level, it is not possible to rise to a higher level of competence. Students do not always understand, at the time they are taking a course, its relevance to their education and ultimately, to their career and life.

Student evaluations can, if used inappropriately, undermine the educational process and impede student learning, particularly in the required general education curriculum (which includes liberal studies), where the intent is not to provide the student with the immediate acquisition of work skills.

A study conducted at the University of Washington and another study published in *Change* reported that "professors who want high ratings have learned that they must dumb down material, inflate grades, and keep students entertained."[13] Although this claim is refuted by other studies, it should provide pause not only for professors who are teaching engineering classes, but especially for those who are teaching the liberal arts courses to engineering students. First of all, engineers need to be challenged in their liberal arts courses, especially since they take so few in the engineering curriculum. Second, grade inflation may serve as a mechanism for students to choose some liberal arts courses over others, where they are not particularly challenged.[14]

Third, evaluations can reflect how much a student likes the professor, not necessarily how much the student learned, reflecting the entertainment, not the educational value of a course.

According to Peter Sacks, "a culture that allows students to determine what is good teaching does not lend itself to the kind of critical messy thinking that we need to be encouraging in higher education."[15] Liberal arts lends itself to critical messy thinking. If we, as faculty, are not promoting this type of thinking among ourselves, how can we demonstrate its usefulness to our students?

This is not to say that student evaluations are not useful or undesirable; too much emphasis placed on student evaluations can occur if the student is viewed only as a customer, and not as a *student* who needs guidance, challenge, criticism, encouragement, and honest assessment of their abilities. Student evaluations can undermine the educational process when they are viewed solely as instruments for quality assessment in the educational market place.

Another avenue for expressing student needs and demands is through their tuition costs. In the "student as customer" paradigm, the private benefits to the student are paramount, and become more relevant as tuition rises. If education changes to suit the student consumer, then it should be changing in accordance with student values and perceptions. According to a 1992 and a 1994 follow-up survey of high school seniors, approximately 90% rated four life values as "very important". In descending order they are: "being successful in work", "finding steady work", "providing better opportunities for my children" and "having strong friendships".[16] Other life values that received very important ratings were "having lots of money" (approximately 37%) and "correcting inequalities" (approximately 20%).

Two of these values, "being successful in work" and "having lots of money" have both increased in importance since the 1970s. Although limited in its analysis, this survey reflects the values students place on work and money. The ascendancy of business in the 1980s has diminished the role of liberal education in general, contributing to the challenge of educating engineers in the liberal traditions.

With the emphasis on successful work, the student customers can choose a university that provides them with those skills that will help them to best achieve these goals. Liberal studies are not usually viewed by student customers as providing them with the skills which will place them in a competitive employment position. Samuel Florman has written:

> "I take little satisfaction in knowing that engineering enrollment has doubled when I learn that young people are entering the profession mainly because it promises steady employment. It is depressing to learn that college students in general are far less concerned than they used to be with helping others or developing a meaningful philosophy of life. . .A melancholy paradox: in its moment of ascendance, engineering is faced with the trivialization of its purpose and the debasement of its practice."[17]

Engineering is trivialized and debased when it is viewed solely as an avenue for making money, and not in its proper context within the society. This trivialization is due, in part, to the university itself.

The University

There has been a trend in higher education to model the university after the corporation. According to Lucas,

> "As the interests of the market economy infiltrate and penetrate ever deeper into the academy, the pressure to focus the curriculum on vocational concerns increases. The time and space given over to liberal education correspondingly shrivels, and the value assigned to it is diminished."[18]

In addition to pressure on the curriculum, there is also pressure to increase productivity, decrease costs, increase the return on investment, and improve quality. These are just a few examples of the new educational metrics, but each can impact the quality of the liberal education of engineers.

First consider teaching productivity. Productivity could be measured in several ways, but usually is applied in terms of student to teacher ratio or credit hour generation. Although it is generally agreed upon that lower student teacher ratios result in greater learning, a lower ratio may also increase the number of sections of a course that must be offered, lowering the capacity utilization of the facility and the productivity of the faculty. In this model there is ever increasing pressure to increase class size and diminish the quality of education. "No one should nurture the illusion that authentic liberal learning can be had 'on the cheap' via mass lectures".[19]

Second, consider cost reduction strategies. Distance learning and part-time faculty are two strategies aimed at reducing costs. Although an entire engineering degree cannot be earned via computer technology (including asynchronous, web-based, and televised live courses), students can elect to take some courses in the curriculum with an alternative delivery system. These other methods of delivery can present barriers for communication, debate, and discourse, the essential elements of "liberal learning". Other elements of liberal learning may also be lost in this medium, including those associated with the institutional environment.

> " . . . liberal and general education must be recognized as something more than the product of formal classroom learning alone. The institutional environment, the totality of experiences that contribute to undergraduate life as a whole, may serve to impede or to encourage the intellectual, moral, spiritual, and aesthetic development institutions of higher learning ostensibly encourage and foster. If the climate is cold, uninviting, and impersonal; if bureaucratic routines serve chiefly to alienate students; if faculty-student interaction outside the classroom is infrequent or perfunctory; and if cocurricular involvements are not actively encouraged, authentic learning suffers."[20]

Although some research has indicated that there is no difference in learning between distance education and traditional on-campus courses, surely learning in isolation undermines a student's ability to assimilate those aspects of education gained in a classroom: discourse, atmosphere, and interpersonal relationships.

Another strategy to reduce costs is to hire part-time teaching faculty. This is particularly true in the arts and sciences where the number of Ph.D. graduates has exceeded the number of tenure-track positions for years, placing short-term financial gains ahead of job security, teaching quality, and student learning.[21] It is no surprise, then, that liberal arts faculty consider the liberal education of engineers to be the least of their problems.

Third, consider the "return on investment". First of all, this is a financial term, so returns are generally perceived in terms of economic benefits. Second, the notion of return on investment becomes very messy because returns accrue to different groups of people. From the student's perspective, this could measure the entry level salary; from the taxpayer's perspective it could measure the increased tax revenues as a result of the student's increased earning power; from the faculty's perspective it could measure the "level of learning". The university's perspective, however, could be quite fragmented or jaded. In addition to the possibilities just presented, it could also refer to measures which attempt to gage the university's image, including revenue generation, capital expansion, and cost containment. If we consider the role of the university as one of education, then it seems apparent that the "return on investment" should measure learning and understanding. In spite of the attention and efforts to assess learning, it's tough to measure and too often we fall back on pseudo-measures: career success, performance on standardized testing, employer surveys, and college rankings. How do we assess the contribution of the liberal arts to an engineering education when assessment measures are steeped in the language of business performance?

Lastly, consider total quality management (TQM) programs. According to Kohn, "What is striking about the articles and books on the application of TQM to education is their failure to address any fundamental questions about learning, per se, or even more remarkably, curriculum."[22] Quality management programs were created to increase the quality of manufactured goods through a systematic process that would reduce the variation in process output. Applying this concept to education is nonsense. One basic tenet of quality improvement is the control of process inputs: material. Would we then abandon the argument, promoted by Thomas Jefferson, of education's purpose as an equalizing role in society, in favor of homogenous inputs? This interpretation of quality, based on its original meaning, would prohibit groups of people from pursuing education, due to special needs which place them outside the "tolerance bands of educational capability". This notion is diametrically opposed to liberal education.

Universities and corporations have different goals, purposes, and reasons for existence. Applying business performance measures to academe serve to undermine the academy's purpose. Even Deming understood the pitfalls of measurement within the corporation when he said, "The most important things we need to manage can't be measured."[23]

The Engineering Program

In conjunction with the trend toward more specialized coursework and less general education, there is also a concern that engineering students are taking coursework in the humanities and social sciences that lack balance and coherence, undermining the intent of the liberal education curriculum. According to a report by the American Association of Colleges, course selection strategies which undermine coherence include choosing as many "practical" course in social sciences as possible; choosing a more or less random set of introductory courses; and choosing courses by times, locations, and ease of instructor grading. These strategies "lead to liberal arts coursework that fails to serve any notion of general education or indeed add up to any meaningful educational experience at all."[24] The same report is also quick to point out that this problem is due in part to the failure of the engineering programs to demand structure or coherence of the student's coursework. Additionally, engineering faculty "tend to know little about the liberal arts. . . think of it as a trivial and unnecessary part of the engineering program".[25]

There is also pressure on engineering departments to create engineering graduates who can "hit the ground running", requiring limited on-the-job training.[26] The engineering program may have partnerships with regional or local industries who hire their graduates, furnish "real world" cases for class use, provide consulting opportunities for faculty, and make financial contributions to the program. Liberal studies are not a high priority, often viewed as a general education requirement unrelated to the engineer's career potential.

Although research indicate that corporations want to hire people with the skills that can be attributed to a liberal education, there is a dichotomy between the skills required as engineers climb the corporate ladder and those skills which gain them entry into the corporation. Because a B.S. degree is an entry level requirement, the engineering program is largely concerned with placing students in jobs with the skills and knowledge to ensure initial success as an engineer. With the rapidly changing advancements in technology, it is challenging for faculty to keep up with the changes in the engineering profession, let alone the role of liberal arts in the engineering curriculum.

IV. ABET 2000: Help or Hindrance?

Criteria (f) through (j) of ABET 2000 that "engineering programs must demonstrate that their graduates have:

(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/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

These represent nearly half of the criteria, and all are directly associated with liberal education. In this context, it seems promising that the liberal education component of engineering curricula will have a large role to play. This will depend on how institutions organize the liberal education courses, and the level of importance ABET will place on these criterion compared to the other criteria which reflect disciplinary competence.

If an institution has a strong liberal arts component, then the ABET criteria will support this strength and perhaps help to lend balance between the liberal and engineering studies. On the other hand, if an institution simply follows the "old" ABET criteria of a half a year of humanities and social science courses, with the minimum depth and breadth requirements, these criteria could serve to maintain the status quo, guiding students to take courses (5 or 6 total) which specifically address each criterion. This latter possibility would undermine the liberal education component of engineering, and impede the attainment of an engineering education which is broad-based. Nevertheless, it could still fall within the ABET guidelines.

Several engineering schools do recognize the importance of a liberal education for engineers, and these programs could serve as models for other schools to follow.[27] Adoption of the new ABET 2000 Criteria provides an excellent opportunity for engineering programs to assess the liberal component of the engineering curriculum, and to determine to what extent it serves to meet the needs of the engineers AND society. This will require effort on the part of both the engineering and the liberal arts faculty, and it could be a very exciting undertaking. Visionary institutions could develop liberal engineering education programs which provide models for all of us.

In short, the extent to which the liberal education component of an engineering program will suffer or excel depends in large part on the importance the institution places on liberal learning.

V. Conclusion

It is rare that anyone involved in engineering education would suggest that there is no role for liberal education in the engineering curriculum. The question becomes one of how much liberal education. This question, however, should extend further, and ask also how to achieve balance within liberal studies between the social sciences and the humanities. As Criterion d of ABET 2000 suggests, engineering and liberal arts faculty should function as a multi-disciplinary team to establish a liberal arts curriculum which is structured and coherent, and reflects the vision of the engineering program and the institution.

The new ABET 2000 criteria provide an excellent opportunity for revising the liberal arts curriculum. Only by recognizing all the benefits – both public and private - of liberally educated engineers, can this opportunity be seized. If engineering education is viewed only through the lens of private business, then this challenge cannot be met because we are incapable of seeing "the big picture". This larger world view acknowledges the private and public benefits and costs that accrue to all the people involved in higher education, a recognition borne out of a liberal arts education.

The business paradigm focuses on private benefits and costs, too easily ignoring non-quantifiable benefits that accrue to society, the individual, and the corporation. It is important that, as educators, we question the relevance of applying corporate metrics and programs to higher education. Profit centers do not have the same goals as centers of learning. Vice presidents work in corporations, not universities. And students can never really become customers in the university. They are and should remain "students" – a term which reflects the multifaceted and rich relationship between the students, the professors, and the institution. A term whose meaning is lost without the benefit of a liberal education.

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