

**TOWARD THE “INTEGRATED LIBERAL ARTS”:
RECONCEPTUALIZING THE ROLE OF THE LIBERAL ARTS
IN ENGINEERING EDUCATION**

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INTRODUCTION

While working a few years ago on a university-wide committee to redesign Clarkson’s first-year curricula, we considered a proposal to adopt a core problem that would “reverberate” through all freshman courses as a unifying and integrating theme (e.g., global warming or the Three Gorges Project in China). While debating the details of this idea, an engineering colleague turned to me and said, “We can bring the problem into all of the disciplinary courses during the first semester--math, physics, chemistry, introduction to engineering, and so on--and show students how these disciplines deal with various aspects of these complex problems, and then you can put it all together for them in your second semester liberal arts course.” I have been preaching the integration of the liberal and technical in engineering education for several years, and this appears to have hit the nail on the head; however, instead of being exhilarated over finally having my ideas understood and accepted, I was dismayed. I replied, none too politely, “We can put the liberal arts course in the first semester and bring our disciplinary perspectives to bear on the core problem, and the introduction to engineering course can be switched to the second semester and put everything together for the students.” My engineering colleague smiled and tried to mollify me with the observation, “Well, I guess the devil is in the details.” My concern was not about the details. Not only did my engineering colleague not understand that the liberal arts have perspectives that illuminate technical problems in important ways, he did not

see that his proposal failed to integrate the liberal and technical. Indeed, it would not be too strong to say that he had absolutely no general idea about integrated liberal learning for engineers, and all of my preaching about this integration had simply failed to take root.

This anecdote sets the problem for this essay: What constitutes an integration of the liberal and technical in engineering education? And, why is it so hard to communicate and understand this?

FRAMING THE PROBLEM

While going through some old books shortly after the conversation reported above, I chanced across a copy of the minutes from the Punderson Conference. Held in 1970 and funded by the National Science Foundation (NSF) and the American Society for Engineering Education (ASEE), this conference drew together thirty-five engineering, humanities, and social sciences faculty from twenty leading engineering schools. I had been given these minutes many years ago by my department chairman at Clarkson, but I had not read them. As I began glancing through them, I discovered that the question before the conferees had been how to achieve greater coherence between the technical and liberal components of engineering curricula and, consequently, to make the humanities and social sciences courses that all engineering students are required to take more relevant to their lived and professional concerns. The conferees' answer was the "applied humanities," that is, an integration of the liberal and technical in engineering education, and they also developed a set of curricular, organizational, and funding recommendations for accomplishing this goal.

I had come to similar conclusions early in my career, which coincidentally began the year of the Punderson conference, but I had not reached them without struggle. And I had been publishing, presenting, and preaching this view of engineering education for many years, but

with little sense that my audience understood and accepted it. I was at once surprised that so many of my ideas about the role of the liberal arts in engineering education had been anticipated at a conference three decades ago, and I was astonished that these recommendations from such a high-profile conference had achieved so little effect. Why do my engineering colleagues, both at Clarkson and elsewhere, many of whom have been engineering faculty members for twenty and thirty years, apparently not understand a major perspective on engineering education that has been in the air for their entire careers? Why do I feel like a voice crying in the wilderness, when most engineering educators with whom I am speaking have probably heard about the integrated liberal arts and might even say they endorse this approach to engineering education? I believe the answer is that an understanding of the integrated liberal arts rests on a fundamental reconceptualization of the role of the liberal arts in engineering education, and this has become possible for the engineering education community in general only recently because of a revolutionary transformation of engineering education that is being driven by new accreditation criteria that became effective in 2000. Thus, in this essay I will sketch the general outline of this reconceptualization.

WHAT ARE THE “INTEGRATED LIBERAL ARTS”?

What are the “integrated liberal arts,” when they are placed within the context of an engineering education? I will approach this question through a brief history of the role of the liberal arts in engineering education. This account identifies the four general models of the relationship between liberal and technical education that have shaped the history of engineering education - ones, moreover, that I have experienced in my personal history as an engineering educator. These four models will help me clarify what the “integrated liberal arts” are, and what makes them revolutionary within engineering education. I should note at the outset that these

models are not substitutive, although they historically have emerged sequentially. These models should be understood as aggregative, and my strong belief is that an exemplary integrated liberal arts program within engineering education will draw upon all four.

The First Model: The Liberal Arts as a Supplement

From the outset, engineering education has recognized that it is important for engineers to encounter the liberal arts while they are students. For example, the *First Circular of Information*, which announced the opening of my institution, Clarkson University, in the late 1890s, states that one of Clarkson’s curricular objectives was “to add to the scientific and technical studies, which tend to make one resolute, exact and strong, at least a moderate amount of those cultural studies which tend to make one broad and liberal.” This view was still alive and well at Clarkson when I arrived in 1976 and my department chairman told me that a major portion of my job would be to “couth up” the engineering students. He was saying in his inimical way that the Humanities Department existed to “educate the whole person”—that our job was to help our students understand that while it is important to know how to make a living, it is even more important to know how to live life. Note that this view makes the liberal arts a *supplement* to students’ technical studies. In terms of this model, the liberal arts could be eliminated from the engineering curriculum, and it would not affect the quality of students’ eventual work as engineers.

The Second Model: The Liberal Arts as a Complement

Also from the outset, engineering education has recognized that the liberal arts contribute to engineers’ ability to practice engineering as a profession after graduation; because engineering practice occurs in a professional context, more than technical knowledge is required for success. Consequently, engineering curricula have long included courses directed toward preparing

engineers to cope with the non-technical aspects of engineering practice. This curricular policy has been examined and reinforced by a series of reports commissioned by ASEE: the Mann Report in 1918, the Wickendon Report in 1930, the Hammond Reports in 1940 and 1944, the Grinter Report in 1955, the Burdell Report in 1956, and the “Goals of Engineering” Report in 1968.¹ These studies formalized the “second stem” concept of the liberal arts for engineers that dominates engineering curricula today. If engineers need to communicate well in the practice of their profession, then the students should take technical writing or speech courses. If engineering practice requires engineers to work with people, then the students should take a psychology or organizational behavior course. As an engineering student at the Illinois Institute of Technology in the early 1960s, I had a liberal arts experience that certainly appears to have been structured on this model: two English composition courses, the second of which was actually technical writing, two economics courses, two psychology courses, including business and industrial psychology, and an introductory sociology course. In the later reports, the importance of the social and political context of engineering practice was also recognized. If engineers’ monopoly of a body of powerful knowledge and technique confers on them a special obligation to advance the welfare of society, then the students should take engineering ethics courses. If engineers play a role in the solution of complex social problems such as energy, then the students should take courses that promote social awareness and an understanding of society so that they will be better able to address the social and political processes they will encounter as they work on these problems. In general terms, this view holds that engineering education will not prepare students for the full range of activities that constitute engineering practice unless the “main stem” of technical engineering courses is complemented by a “second stem” of courses drawn from the liberal arts. Note, however, that this is not an integration of the liberal arts into engineering per

se. In terms of this model, the liberal arts could be removed from the engineering curriculum, and even though engineers would become less effective practitioners, the quality of their technical engineering solutions would not be compromised.

Third Model: The Liberal Arts as Practice for the “Real World”

During the past three or four decades, engineering educators have begun to recognize that the methods and concepts of the liberal arts increase the quality of technical engineering solutions themselves. In 1976, the ASEE Annual Meeting was held at the University of Tennessee, where I was a young assistant professor of philosophy. I was electrified by the plenary address of Arthur G. Hansen, President of Purdue University, in which he stated that the engineering design process consists of a series of socially binding value judgments and that, consequently, these judgments must be made an explicit part of engineering. Hansen concluded that engineering students will be prepared to make such judgments only if there is an integration of values and the humanistic perspective with technical know-how in their curricula. I had become involved in some interdisciplinary teaching and research activities with faculty from engineering and the sciences, and I had come to believe that applications of technology in the real world could be successful only if they were based on an integration of the methods and knowledge of experts from many disciplines. Hansen had cast this view into educational terms. Engineering students need to learn about the economic, social, political, and human valuational dimensions of technology, as well as the ways in which these can be integrated with the technical considerations to design technologies that can truly advance human welfare. I came to discover that this view had been articulated in two more reports commissioned by ASEE: the Olmsted Report of 1968 and the Gianinny Report of 1975.² As already noted, the Punderson Conference was dedicated to exploring the implications of this view, and numerous articles in ASEE’s

various publications since the early 1970s, as well as numerous presentations at ASEE annual meetings during the same period, have also clearly articulated this theme. If the concepts and methods of inquiry of the liberal arts are essential and integral components of engineering problem-solving, the liberal arts must be integrated with the technical content of the engineering curriculum. Here, finally, is an integration of the liberal and technical. In terms of this model, if the liberal arts were removed from the engineering curriculum, this would decrease the quality of the technical engineering solutions that eventually would be produced by the students.

The Fourth Model: The Liberal Arts as a Common Core

The central notion underwriting this model is that the essential features of humanistic and social scientific inquiry are structurally similar to--perhaps even identical with--the central features of engineering design, so that liberal education is also simultaneously technical engineering education in an important and fundamental sense. When I first wrote about this model in the late 1970s,³ supporting citations were few. Today there are more. For example, in 1984 Billy V. Koen published an article in *Engineering Education* that won ASEE’s William Elgin Wickenden Best Paper Award for 1986, and led the Liberal Education Division of ASEE to award him its annual Sterling Olmsted Award for contributions to the liberal education of engineers. A major point in this article was that the analytical philosophical method developed by René Descartes in *Discourse on Method* is essentially the same as the engineering design process, with the consequence that when engineering students are studying Descartes in their philosophy class, they simultaneously are studying the central features of engineering design method.⁴ Or, a more recent example is an article in the *Journal of Engineering Education* by John A. Robinson that is titled, “Engineering Thinking and Rhetoric.”⁵ The article’s thesis is that “analogical thinking” is at the heart of engineering thinking and, moreover, that engineering is

not the only discipline that relies on “analogical thinking.” The liberal arts include several of these other disciplines. Consequently, when students learn the methods and patterns of thinking and problem solving they encounter in their liberal arts courses, they are also learning engineering methods. This model certainly represents an integration of the liberal and technical; if the liberal arts were removed from the seamless fabric that the model envisions engineering education to be, students would not be as thoroughly grounded in the basics of engineering as they could have been. Indeed, it would be the same as a student graduating as an environmental engineer without having studied fluid mechanics.

The meaning of the Latin root for *integrate* is: “to make whole, renew.” The first meaning listed in the dictionary for *integrate* is “to form into whole: unite.”⁶ Creating and implementing the “integrated liberal arts” within the engineering curriculum, then, consists of achieving a wholeness, a completeness within the curriculum that currently does not exist by unifying the liberal and technical together into a single educational enterprise. Both the “real world” model and the “common core” model do this, and I believe there can be a powerful synergy between them. What are the “integrated liberal arts?” They are a liberal arts presence in the engineering curriculum in which the liberal arts are both shot through technical engineering courses and projects and relied upon as a front-line vehicle for teaching students about methods and patterns of thought and problem-solving that are central to engineering.

Against the background of this history of the role of the liberal arts in engineering education, the central question of this essay emerges in a slightly different form: Why has the “real world” model—a model of engineering education that embraces the integrated liberal arts—been extant for thirty years without becoming prevalent in engineering educators’ thinking about the role of the liberal arts in engineering education, and why has the more recent “common core”

model attracted so little attention? The answer is two-fold. First, only recently has a decade-old revolution in engineering education created the conditions under which the “real world” and “common core” models could possibly become prevalent, and, second, transition from the “second stem” metaphor to “integration” requires a fundamental reconceptualization of engineering education that has yet to be completed. I will consider each of these in turn in the next two sections.

A REVOLUTION OF INTEGRATION

Engineering education has been undergoing revolutionary transformation over the past decade, and the “integrated curriculum” is one of its major themes. The September 1996 issue of *Prism*, ASEE’s non-archival periodical magazine, contains a progress report on the Engineering Education Coalitions. These coalitions, which currently enroll 60 institutions, were created by NSF with millions of dollars in funding to be instruments for major reform of the educational system for engineering students, and at least two of the Coalitions have adopted integration of the curriculum as a primary theme. The September 1997 issue of *Prism* contains a lead article that is titled, “The Integrated Curriculum.” The opening paragraph states,

To produce more competent engineers and increase student retention, some engineering schools are experimenting with versions of...[an integrated] curriculum design. The theory behind these integrated curricula is that by connecting engineering, math, science, and other subjects, students will gain a richer, more holistic view of their coursework and what it means to be an engineer.

Note the “other subjects,” which the article makes clear ought to include at least English as a representative of the liberal arts. The May-June 1998 issue of *Prism* includes an opinion piece by Lyle Feisel, ASEE’s President at the time, that is titled, “The Scholarship of

Integration.” The article explores the implications for engineering education of Ernest Boyer’s concept of the scholarship of integration, which Feisel depicts as “making connections across the disciplines, placing the specialities in larger context, illuminating data in a revealing way, often educating nonspecialists, too.” Feisel calls on the engineering education community to take up this scholarship of integration, and, most importantly from the perspective of this essay, all of his examples of possible integrations link engineering with the humanities and social sciences. The current reform movement in engineering education advocates the integration of liberal education with engineering students’ technical education as part of a broader integration of disciplines within engineering curricula.

The culmination of this revolution in engineering education is a fundamental revision of the criteria by which the Accreditation Board for Engineering and Technology (ABET) evaluates engineering curricula and confers accreditation. The new criteria, titled “Engineering Criteria 2000,”⁷ include two components relating to the liberal arts in engineering education. Criterion 3, “Program Outcomes and Assessment,” stipulates that engineering graduates must demonstrate several outcomes that traditionally have been associated with a liberal education. These include:⁸

- 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
- j) a knowledge of contemporary issues

Moreover, Criterion 4, "Professional Component," stipulates that:

"Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating . . . the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political."

Given the clear assumption in Criterion 4 that engineering design should demonstrate a wholeness or integration of parts, rather than being a collection of disparate elements that are cobbled together, I see this Criterion as calling for an integration of liberal learning - the humanities and social sciences - with the technical components of the curriculum. Moreover, since students cannot integrate knowledge they do not have and cannot integrate it successfully without practice, I see this criterion as also calling for course work and educational experiences throughout the four years that ground students in the concepts and methods of the humanities and social sciences and also develop their ability to integrate these with technical considerations. This is no small task; indeed, Criterion 4 allows up to one and one-half years of the curriculum to be devoted to a liberal education component that would accomplish this.

Consider future accreditation reviews based on "Engineering Criteria 2000." How will engineering schools demonstrate, for example, that their graduates understand their professional and ethical responsibility and, moreover, have appropriately and successfully integrated ethical considerations in their capstone design experience? I believe the answer that will emerge-- indeed, the only possible answer--will be to establish ethics-across-the-curriculum programs that will integrate ethical considerations in multiple engineering courses throughout the four years of the curriculum, including a capstone design experience that is truly "real world" in its ambiguity, open-endedness, and interdisciplinary messiness. The same will be true for the other liberal arts

elements mentioned in Criteria 3 and 4; liberal learning and technical considerations will have to be integrated across a variety of liberal arts and engineering courses and interdisciplinary projects. In other words, the “real world” model of engineering education with its central notion of the “integrated liberal arts” will have to be generally adopted within engineering curricula in order to meet the requirements of “Engineering Criteria 2000.” Not only has the recent revolution in engineering education created the conditions under which an integration of the liberal and technical can occur, but “Engineering Criteria 2000” is an engine that can drive this integration.

TOWARD RECONCEPTUALIZING THE ROLE OF THE LIBERAL ARTS IN ENGINEERING EDUCATION

I think it is fair to say that my view about the profoundly revolutionary character of “Engineering Criteria 2000” regarding the integration of the liberal and technical is not generally shared by the engineering education community, nor is my concept as to what this integration will involve. The necessary preconditions exist for reconceptualizing the role of the liberal arts in engineering education, but most engineering educators have not yet made this reconceptualization. In the remainder of this essay, I will illuminate this new concept of integrated liberal learning for engineers. The lens that I will use is a set of metaphors that should be considered as replacements for the “second stem” metaphor that grounds the prevailing concept of the role of the liberal arts in engineering education.

As noted earlier in this essay, the prevailing metaphor today for liberal learning in engineering education is that liberal education is a “second stem” that supplements and complements the technical component. What students learn in this second stem is good for their souls, and it might even be useful in certain professional contexts (e.g., communicating your results, interacting with public agencies and bodies). However, it has nothing to do with

technical competence. In terms of the “second stem” metaphor, the humanities and social sciences could be eliminated from engineers’ education without affecting the technical adequacy of their work. Oh, engineers might be more nerdy, and their reports might be somewhat illiterate, and a company might never send them to negotiate with a city council, but their designs would still be satisfactory.

However, I am seeking fundamental reconceptualization, and so I invite you to participate in a thought experiment to try out some new metaphors. I know that it is somewhat dangerous to ask academic readers to do a thought experiment or to brainstorm--it asks us to suspend judgment in ways we have been trained not to--but here we go.

The core experience of the type of reconceptualization I am seeking is the “well, of course,” experience in which the puzzles associated with the old concepts are rendered non-puzzling, the problematic in the old concepts becomes unproblematic, and the common wisdom built on the old concepts becomes revolutionized and transformed. The quintessential reconceptualization is the one involved in the Copernican Revolution. Not only were a variety of puzzles and problems dissolved when our solar system became understood as sun-centered rather than geocentric, but people literally came to live in a different reality because of the revolution.⁹ I am going to suggest three metaphors that could possibly ground a revolutionary reconceptualization of this type for engineering education, one that I have been calling “integrated liberal learning for engineers.”

First, what if liberal learning were seen as the primary--indeed, the only—“stem” in engineering education, and technical courses were seen as the “leaves”? Imagine engineering students and faculty not only believing that humanities and social sciences were necessary prerequisites for engineering courses, but they actually were because the engineering courses

were structured according to the “real world” model. Imagine how those engineering courses would differ from those under the “second stem” metaphor. Imagine humanities and social sciences faculty believing that engineering education at its core is liberal education, and that liberal education at its core is engineering education, as the “common core” model holds. Imagine how their humanities and social sciences courses would differ from those under the “second stem” metaphor.

Second, what if C. P. Snow was wrong? Imagine there are not two, unbridgeable cultures, with neither giving credence or ascribing value to what the other holds dear and on which it grounds its view of reality. Imagine there is instead only one culture in which each element illuminates all of the others, and one can never know prior to an inquiry upon which elements of the culture one will draw. After all, there is only one, complex, inextricably interconnected world. Imagine an educational process structured on this metaphor. I believe that it would require literally an everything-across-every-curriculum approach. An engineering curriculum would have ethics, communication, and other elements of liberal learning shot through all of its technical courses, but its liberal arts courses also would have technical elements shot through them. Similarly, a humanities curriculum would have technical considerations shot through the humanities courses in the major, and its science and mathematics general education courses would be shot through with elements of liberal learning. Indeed, the difference between a civil engineering curriculum, say, and a philosophy curriculum, would be a difference primarily of emphasis, rather than a difference in kind as at present.

Third, in the Seventeenth Century, a distinction was drawn between the natural and moral branches of philosophy, with the former becoming science over time and the latter becoming philosophy per se. Imagine that engineering had existed as a field when this distinction was

drawn and that it was placed in the moral branch of philosophy, with the consequence that engineering would today be seen as a type of applied philosophy. For example, in my professional ethics course, student teams explore famous technological disasters. They not only must determine all of the factors that led to the disaster - technical, ethical, managerial, communicative, political, and so on - but they must produce an alternate design for the technology in question that alters all of these factors and, more importantly, demonstrably would escape failure. Through the vehicle of this project, the students come to see that every real technology rests on a set of complex value-laden judgments. At Clarkson we count this course as moral philosophy, or ethics in modern parlance, and rightfully so, but it could equally be counted as an engineering course. What if all engineering courses were also equally an experience in moral philosophy?

Let these metaphors roll around in your minds a while. Do you see the curricular differences they would make? Do you see the integration of liberal learning and technical learning that they would engender? Do you see the disappearance of current barriers to interdisciplinary courses--no time in the curriculum, not my thing, not my job, and so on? Do you see the enriched and expanded interactions between engineering faculty and faculty in the humanities and social sciences? Because if you do, if the reality of your engineering educational enterprise has been transformed by a reconceptualization of the role of the liberal arts in engineering education, then there are many exemplary practices to adopt or adapt. Although the engineering community in general is still caught up in the “second stem” metaphor, since the early 1970s a steady stream of both engineering and liberal arts faculty have created courses, curricular structures, and educational experiences that successfully capture the “real world” model by integrating the liberal and technical, and these exemplary practices have appeared over

the years in the various publications of ASEE, as well as the proceedings of ASEE national and regional conferences. There are also on our campuses isolated believers in the "common core" model--I discovered one in Clarkson's Mechanical and Aeronautical Engineering Department just last year--with whom we can share the goal of a truly integrated engineering education enterprise. These educators are the visionaries, the harbingers of a revolution in the making. Let us follow in their footsteps and move forward to complete this revolution of integration of the liberal and technical in engineering education.

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- ³. See, for example, Gravander, Jerry, “L. S. M. F. T. (Liberal Studies Means Finer Technology),” *Journal for the Humanities and Technology*, vol. I, no. 1, 1979, pp. 20-29.
- ⁴. Koen, B. V. "Toward a Definition of the Engineering Method," *Engineering Education*, December 1984, pp. 150-155.
- ⁵. Vol. 87, No. 3, July 1998.
- ⁶. *Webster’s Seventh New Collegiate Dictionary*.
- ⁷. Available as a download from the ABET Web site: www.abet.org. The new criteria were phased in over a transitional period from 1998-2001, but with a 6-year accreditation cycle, all accredited engineering curricula will have been evaluated by “Engineering Criteria 2000” the late 2000s. Note that with the implementation of the new accreditation criteria in 2000, ABET has begun including the current academic year in the title of the Engineering Criteria; thus, the criteria are presently titled “2004-05 Engineering Criteria.” (Accessed July 28, 2004, at www.abet.org.) The content of Criterion 3 and 4 as cited in the paper has remained invariant since 2000.
- ⁸. The numbering and wording are quoted from “Engineering Criteria 2000.”
- ⁹. One of the puzzles facing astronomers before the Copernican Revolution was why all of the planets except Venus and Mercury were seen at angular separations from the sun that ranged from 0° to 180°, but Venus and Mercury were seen in only a narrow range of angular separation from the sun. There simply was no reason for this in a geocentric conception of the solar system, although ad hoc manipulations of orbital parameters could be made so that predicted positions of Venus and Mercury fairly closely matched observed positions. Under a sun-centered conception of the solar system in which the orbits of Venus and Mercury are closer to the sun than the Earth’s orbit and the orbits of the other planets are all further away than the Earth’s, the observed facts about angular separation could not be other than they are. The Copernican Revolution dissolved the problem and replaced astronomers’ puzzlement with a sense of, “well, of course.” As for the different reality in which the Copernican Revolution situated people, it removed us from the physical center of a finite universe and placed us on one planet among many, in one solar system among many, in an infinitely extended universe, a reality so inimical to the religious beliefs of the time that people were burned at the stake for advocating it.