Engineering Globalization:

Oxymoron or Opportunity?

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Localization has always been one of the defining characteristics of the engineering ethos. The fundamental object of engineering practice is to meet a set of *specifications*, a word that explicitly acknowledges the primacy of the *specific* over the *general*, the local over the *global*. Localization manifests itself in engineering in two primary, and interrelated, ways. First, engineers routinely and intentionally engage in processes of *methodological localization*. That is, under the umbrella of engineering methodology, there exist a diversity of techniques and procedures aimed specifically at reducing the scope and complexity of a given problem to a minimum level in order to affect a practical and timely solution. These techniques, just to name a few, include making simplifying assumptions, idealizing

constraints, subdividing systems, and isolating control volumes. Methodological localization is, in large part, what allows engineers to be successful. "It is not only permissible to ignore complex subtleties," writes Mitcham [1], "but better to do so." And Bucciarelli [2], in analyzing the dynamics of the engineering design process, writes that it works "better with fewer elements; abstraction and reduction go hand in hand in this business. Sparseness characterizes a good workable model." Localization enables progress to be made despite incomplete knowledge, variable conditions, finite time and resources, and imprecision.

Second, engineering problems are themselves *objectively local*, each one comprising a unique set of requirements, constraints, and influencing factors, independent of the methods used to address the problems. For example, if engineers design a suitable drinking water distribution system for a small town, they have not solved the problem of drinking water distribution for all people everywhere. The solution for the one town is particular; it depends on the particularities of, among many other things, the nature and quality of the local water source, the geography of the locale, the size of the town, the size of the town's budget, the engineers' inherent preferences for some materials and techniques over others, and the capabilities of local construction firms. Of course there can be universal engineering knowledge [3]; that is, much of the knowledge and reasoning that went into the design of the one drinking water system can also be applied to the design of other such systems. Nevertheless, *objective localization* ensures that the application of that knowledge is always "concentrated on local conditions and their transformation," conditions "which might be absolutely unique [4]." Appropriate technology, a topic often associated with the globalization of engineering, is itself an embodiment of this fact, with its emphasis on matching engineering solutions to local conditions.

Given the prominence of these two forms of localization, engineering may be strongly characterized as an exercise in convergent, reductionist thinking applied to concrete, particular problems. On the other hand, and somewhat paradoxically, Cheong [5] writes that, "Even before the advent of globalization, the engineering profession had been the most global of all professions due to the universality of engineering science and technology." But this statement simply acknowledges what I alluded to above, that much engineering knowledge and reasoning, particularly that which is scientifically based, is universally applicable. But this statement makes the mistake, probably contrary to the author's intentions, of equating engineering with its scientific and instrumental content only. What's missing are the organizational, economic, environmental, social, and temporal elements of engineering, those things that give engineering a reason to be, that define the problems to which it is directed, that dictate which elements of the scientific and instrumental content are appropriate to use, and that determine the pace and process of the engineering enterprise. And it is this side of engineering that is fundamentally local and unique.

Taken in a normative sense, globalization, in addition to being a description of reality, can also turn out to be a prescription for a preferred reality.

Engineering Globalization – Descriptive Meaning

It is in light of these observations about the essence of engineering that *engineering globalization* can appear to be somewhat of a contradiction in terms. Can engineering, as a fundamentally localizing activity, be reconciled with the project of *globalization*? Or, is the context of what is generally meant by globalization in a socioeconomic sense completely unrelated and irrelevant to the notion of engineering localization, despite the fact that the words are nominally antonyms? To address this question, we must also address another one, posed succinctly by Lohmann [6]: "What do we mean when we say that engineers should have 'a global understanding,' 'an international perspective,' and 'a multi-cultural appreciation?'" To get at the possible meanings of globalization will be our task in this essay.

In one sense the contradiction between engineering *localization* and *engineering globalization* is nothing more than semantics. Globalization can have a purely *descriptive* meaning, one that simply recognizes the facts of the increasing interdependence of national economies, the diffusion of technology and technological activity across international borders, and the intersection and integration of cultures. "Globalization is a fact of life," writes Lohmann, "whether in the management of business enterprises, the conduct of government affairs, or the exploration of the frontiers of science and technology." And Johnston [7] writes, "Cultural diversity is a fact of professional life. Engineers are being employed in ever greater numbers by multinational and transnational corporations and are routinely working across national and cultural boundaries."

Taken in this sense, engineering globalization does not imply any

necessity for a change or shift in the fundamental character of engineering as an activity; specifically, it does not conflict with the localizing nature of engineering practice. Rather, it simply acknowledges the fact that the domain in which engineering activity occurs has been enlarged, and with that enlargement has come a concomitant expansion in the types of problems, constraints, and environments encountered. Viewed from this perspective, the globalization of engineering education comes to mean providing students with an enlarged set of knowledge and skills required to address the situations encountered in this larger domain. This includes inculcating foreign language skills, knowledge of foreign laws, practices, and customs, or knowledge of foreign environments, resources, and needs. This is likely the sense that best describes much of the current effort to globalize engineering education.

Engineering programs should take a much broader view of their responsibilities than the narrow instrumental objective of providing employees for the industries of advanced technological societies.

Within this descriptive framework, the inculcation of this new set of knowledge and skills comes to be an *instrumental* objective, one that facilitates the enhanced utility of engineers. And, quite logically, this instrumental objective for engineering education is one often promoted by engineering employers, as seen for example in Swearengen *et al.* [8], in which the authors relate how panelists representing a variety of industries "emphasized preparation for globalization." According to the authors, "Globalization of the manufacturing profession will require its practitioners to master engineering methodologies, cultures, and languages from more than one country." In addition, "In an era of globalization, people skills means knowledge and experience that permit an individual to successfully deploy science/engineering/management competencies in collaboration with any person anywhere in the world." The emphasis here is on mastering skills, methodologies, and competencies that are needed to compete in a global industrial marketplace.

Viewed from this instrumental perspective, the question for engineering education becomes, how do we shoehorn the teaching of these skills and competencies into an already overburdened curriculum? The answer is, either additional coursework (and time), or else some sort of shell game in which the humanities offerings are reshuffled to include courses in foreign languages, international studies, or similar topics. In addition, mechanisms might be developed for students to spend one or more semesters in a study abroad program and/or to pursue international internships. But all this generally takes place in the context of a relatively unaltered technical curriculum. Engineering becomes engineering-*plus*-international flavoring.

For example, Mazumder and Bean [9] describe the University of Michigan's development of a program in 'global engineering,' available to students in any traditional engineering major provided they meet the program admission standards. The program requires students to complete 24 hours of coursework in languages, general international courses, and international courses with a regional focus. Most of these hours can substitute for otherwise required humanities, social science, and free elective courses so as to minimize additional work. The majority of the course options for satisfying these requirements are drawn from already existing offerings from various departments on campus. In addition to the coursework, the students are required to have an overseas experience, which can be either a semester abroad or an internship.

The instrumental, industry-focused nature of this program is illustrated, for example, when Mazumder and Bean write, "The program will focus on interactions with China, U.K., and Mexico due to their competitive importance…" and the program goal is to produce graduates who can "deal effectively with foreign suppliers, co-workers, and clients." We can also see that the requirement that the fundamental nature of engineering education not be tampered with is stated explicitly in this case. "The success of the Program in Global Engineering depends on the support of the faculty. This support requires that it not displace technical requirements of the engineering programs." For interested readers, Mazumder and Bean also provide a brief survey of similar programs at other U.S. universities [9].

Engineering Globalization – Normative Meaning

I do not mean to convey the impression that I am necessarily critical of this instrumental type of engineering educational change, a change that is an inevitable natural reaction to the descriptive reality of globalization. On the contrary, I believe it is a good thing for engineering students to develop some depth in a non-engineering area — in this case international studies — a depth that many students probably do not get from taking the typical hodgepodge

of humanities, social science, and free electives. And, importantly, such programs presumably produce graduates who satisfy real needs within the engineering profession. Nonetheless, there is a potential concern that needs to be raised about the pursuit of 'preparation for globalization.' That concern has to do with the *normative* meaning of globalization.

Taken in a normative sense, globalization, in addition to being a description of reality, can also turn out to be a prescription for a preferred reality. This fact may lead to some ambivalence about the value of globalization, since the value to a particular individual or group will depend upon whose preferences and interests are being promoted in the globalization process. That is, in any international endeavor there will inevitably be a cultural exchange, even if not consciously orchestrated, whereby elements of one culture influence, alter, supplant, or compete with elements of another. If international endeavors are approached with respect and careful intentionality, it is possible for these cultural exchanges to be mutually enriching. If, on the other hand, international endeavors are approached indifferently or, worse, arrogantly, the result of the exchanges may be the destructive attenuation of one set of cultural values in the wake of a collision with a more aggressive set of values. "Global engineering," writes Johnston [7], is a term that "has both positive and negative connotations and potentialities."

For engineering educational programs seeking to develop a global perspective, care must be taken to develop and convey a suitable normative meaning for globalization. Of course this begs the potentially controversial question, "who gets to decide what constitutes a suitable normative meaning?" In the remainder of this essay a particular type of normative meaning will be advocated, as should quickly become apparent, but this is by no means beyond dispute.

Although some might claim that the instrumental perspective avoids the issue of normative meaning, in fact a particular set of norms are implicit in that perspective, though rarely acknowledged. The first is the value of graduate marketability. That is, if employers want graduates equipped with knowledge, skills, competencies, and experience related to international issues, particularly industrial/commerce-related issues, then the educational goal is simply to equip our graduates accordingly. This educational norm is driven more or less directly by the economic norm of engineering employers' competitive viability in the global marketplace. The reason for needing language skills, for understanding foreign customs and laws, or for gaining familiarity with foreign business capabilities and practices is to be able to better conduct business in a smooth and efficient manner, to more successfully recognize opportunities and avoid obstacles. The international portion of the curriculum is therefore about stocking a toolkit with the tools needed for successful technological business practices.

Implicit to this perspective is yet another norm, a norm which cuts to the core of cultural diversity, sensitivity, and justice. This norm is the belief or assumption that the content of engineering practice—modes of problem solving, the technological state of the art, and technologically related business and organizational practices — which had heretofore been developed in the context of practice within a single culture, can now be easily extrapolated to global practice, provided of course that practitioners have the proper toolkit of skills for interfacing with the wider world. In short, my fear is that engineers, well meaning though they might be, will sally forth into the global arena with just enough international knowledge and skills to successfully promote, though often unwittingly, an ethnocentric brand of global technological practice. This type of concern has been noted many times before, and it encompasses several specific issues, a couple of which are discussed below.

First, McGinn [10] writes that technologies — and we might add, by extension, the state of the art of engineering education and practice — are "expressions of complex social-cultural-environmental systems. As such, their designs are apt to reflect important characteristics of the societies that create them, including their values…" Engineering education in the United States and other technologically advanced nations prepares students to "work in advanced industrialized economies." Thus, and quite logically, there is an inherent bias in the repertoire of knowledge and skills imparted by an education, a bias that reflects the problems, needs, desires, capabilities, and resources of the home culture. And despite the addition of international studies courses that may serve to ameliorate this bias to some extent, the technical part of the engineering curriculum will likely remain strongly biased with respect to technologies and their applications. Ironically, as McGinn points outs, this bias is transmitted to both native and foreign students alike, which can create a dilemma for foreign students who might find it difficult to effectively apply this set of knowledge and skills at home, a fact which may contribute to a propensity for those students to remain and work abroad. The resulting "brain drain" has been noted as a significant problem in a recent report by the InterAcademy Council [11].

> "Numerous young professionals from developing nations often emigrate, or remain in the industrialized nations where they may have received some education and training, instead of applying their skills at home – where the need may often be the greatest but prospects for present-day opportunities the worst. This

> 'brain drain' actively depletes some of the developing nations' human resources, and it is being exacerbated as the populations of wealthy countries get older, more people retire, and attractive employment opportunities arise there."

Second, underlying any discussion of globalization, even one focused specifically on engineering and engineering education, is the international debate over the social, political, and economic justice of current trends in market globalization, particularly as they affect underdeveloped and developing nations. One unhelpful use of the term globalization, according to Johnston [7], is the "promise that modern technologies would make the typical Western middle-class experience universally accessible." The reality, however, is that, "for most people of the world this seems more like a cruel jest than an achievable target." The problem, according to Johnston, who writes specifically in the context of engineering, as well as according to many others writing from a much broader political and economic perspective [12]-[14], is with the mistaken belief that simply opening up economic markets and allowing technologies and goods to move freely will somehow result in the ability of everyone to acquire and benefit from these technologies and goods. But this does not seem to be an inevitable result.

> "Under the impetus of strong forces of globalization, the world is today dominated by a market-oriented economy. But many countries lack the policies or infrastructure to support market-oriented mechanisms for building their exports or the productive economic assets, not to mention their S&T (science and technology) capacity. In fact, a vicious cycle is at work whereby the developing nations (especially the S&T-lagging countries) fall farther and farther behind the industrialized nations that do have the resources — in financial, as well as human-development terms — to apply scientific advances and new technologies ever more intensively and creatively" [11].

My point is not to rehash the controversies surrounding the ongoing process of market globalization — there are numerous books and articles that do that with much more clarity and detail than I could. Rather, I raise the issues to point out that if we give credence — as I do — to the assertion that there are serious, pervasive, and persistent problems and inequities that are potentially created or exacerbated via the current process of globalization, then simply providing our students with "global skills," skills desired by employers in order to bolster their competitiveness in the global marketplace, may not be sufficient from a moral point of view.

Sustainability and social justice must be central themes.

Fortunately, many engineering faculty who work to develop "international" or "global" engineering programs are sympathetic to this point and do their best to promote a more socially conscious view of globalization. For example, Swearengen *et al.* [8] write that engineering students need to

> "…understand the controversy accompanying globalization. Advocates believe that free trade will promote human freedom, economic prosperity, and peaceful transitions to democratic government, but opponents argue that globalized companies will escape government regulations, capital will flow from developing nations to developed ones, and social institutions will erode. Clearly the global engineer must understand that in a global context, engineering solutions, whether consumer products or unintended consequences such as resource exhaustion and environmental pollution, increasingly cross or transcend international boundaries. Global sustainability, for example, may outweigh technical and other aspects of manufacturing" [8].

Mazumder and Bean [9] write, "…an engineer must possess not only technical skills but also cross-cultural skills based on knowledge of the 'other' culture and their own cultural biases." And the website describing the Global Perspective Program at Worcester Polytechnic couches the benefits of the program in terms of broader social values.

> "WPI has long recognized the need for its students to understand how their lives and work will benefit from an understanding of other cultures and other ways of doing business," and, "Projects completed at WPI's global project centers have made a real difference to individuals, organizations, and agencies around the globe." [15]

Unfortunately, other institutions convey an explicitly instrumental message with respect to the benefits of a "global" engineering education, catering squarely to the careerist instincts of students and the market-driven needs of industry by using the

rhetoric of competitiveness, and saying little or nothing about the broader needs of, or benefits to, global society. Several examples follow.

The primary motivation stated on the University of Michigan website is, "Students in the Program in Global Engineering learn about other cultures that will better prepare them to excel in a global engineering environment [16]." Clemson promotes its program by stating, "The Engineering Program for International Careers, or EPIC, is an international co-op program that prepares engineering students to be more competitive in this international arena [17]." At the University of Rhode Island, "...the IEP (International Engineering Program) was designed to meet the needs of business and industry in the rapidly evolving global workplace [18]." And the University of Connecticut states that, "Upon their graduation, EUROTECH engineers will bring not just sophisticated technical know-how to their jobs but also the foreign language skills and an international awareness that American companies are finding more and more desirable [19]."

This is not to say that in taking the requisite language and international studies courses, or through overseas work or study experiences, students in these instrumental programs might not develop a more holistic view of the meaning of globalization as a happy side effect. But the possibility of this result is likely diminished by such overt instrumentalism.

Engineering Globalization–Transformative Meaning

> "If we also agree that our generation will be judged by History for its ability to confront the two fundamental problems of our times: soul-destroying and socially destructuring poverty and increasingly worrying environmental problems… then… universities should not only adapt to 'market necessities' but also answer to the main necessities of people on the whole earth" [20].

This statement by Josep Xercavins i Valls, which is probably as succinct a plea as I can imagine for the adoption of a socially conscious normative meaning for engineering globalization, sets the stage for my discussion of a potentially *transformative* meaning for globalization. Xercavins is suggesting that universities, particularly engineering programs, should take a much broader view of their responsibilities than the narrow instrumental objective of providing employees for the industries extant in advanced industrial societies.

To achieve this, offering some "international studies" coursework to develop some "global skills" as a complement to the traditional engineering technical content will not be sufficient. Rather, we would also need to radically alter the technical content of the engineering curriculum in ways that are likely "unthinkable" given the current conventional wisdom as to what constitutes engineering education. Johnston [7] writes "For most of the four and a half billion people living in the less developed 'south,' the key design issue is to help them be more in control of their own lives, to free them from the crippling poverty and insecurity that dominate their world… While the problems commonly have a strong political dimension, the sorts of technologies that engineers develop can increase or decrease the control that poor people have over their circumstances." But the kinds of technologies needed to solve these problems in the less developed world are not necessarily the same as those needed to be "competitive in the global marketplace." And by extension, the kind of education required to prepare graduates to meet the employment needs of high-tech western industries is not the same kind of education required to prepare graduates to meet the needs of the developing world.

What kind of education is required, then? It likely must be more basic and less specialized than traditional disciplinary engineering curricula. Cheong [5] calls for "teaching engineering students to think, analyse and synthesize rather than being immersed deeper and deeper in minute technicalities." Buckeridge [21] calls for a "broader education than is currently offered," one which adopts a "systems approach" that can better incorporate cultural, environmental, and ethical considerations. Sustainability and global justice must be central themes. "System design criteria at all levels need to change," writes Johnston [7], "to take sustainability into account as a fundamental design criterion. And I see this as requiring a fundamental change of educational as well as technical focus." Topics related to basic technologies, those important in the discussion of sustainability, appropriate/intermediate technology, and the provision of basic human needs, need to be pervasive. This includes basic sciences and engineering sciences; basic environmental, ecological, and health studies; and basic energy and infrastructure technologies. And, of course, the technical curriculum needs to be integrated with a humanities and social science curriculum having a focus in international studies. Students need to understand cultures, and they also need to understand the workings of international political and economic systems. "Let us then devote time to teaching our engineering students to appreciate human history, heritage, and culture and become caring members of the community" [5].

Such a curriculum needs to be designed from the bottom up. Simply modifying an existing discipline-specific curriculum is likely problematic at most institutions. There are too many jealously guarded courses, sacred cow topics, or ossified curricular edifices to

allow the type of modification called for. We need a curriculum that takes a bold step away from traditional ways of thinking about engineering education. And I believe ABET's EC2000 criteria will allow us to get away with it. Let me be clear at this point that I am not calling for the dissolution of traditional engineering programs and disciplines. Rather, I am talking about a new type of program.

There are examples of steps in the right direction. The University of Colorado is in the process of developing a program called "Engineering for Developing Communities." According to their website, "The overall mission of the Engineering for Developing Communities (EDC) program is to educate globally responsible students who can offer sustainable and appropriate technology solutions to the endemic problems faced by developing communities worldwide [22]." The Colorado School of Mines is introducing a program in "Humanitarian Engineering," for which they provide the following description: "In the past, engineers may have asked, 'How do I generate electricity most efficiently?' The humanitarian engineer asks, 'How can I help to reduce poverty?' The answer to his question may include generating electricity, but more importantly, Humanitarian Engineers will try to balance technical excellence, economic feasibility, ethical maturity, and cultural sensitivity" [23]. Currently, these programs are in the form of minors/specializations within traditional degree programs, and I hope that they will be copied and will eventually develop into independent programs.

The stated objectives of these programs are congruent with the kind of transformation advocated here, and with the sentiments of Nobel Prize winning economist Amartya Sen, who writes, "Development can be seen, it is argued here, as a process of expanding the real freedoms that people enjoy. Focusing on human freedoms contrasts with the narrower views of development, such as identifying development with growth of gross national product, or with rise in personal incomes, or with industrialization, or with technological advance, or with social modernization" [12]. The freedoms he is talking about are freedoms from poverty, from hunger, from lack of education, and from lack of control over one's own destiny. While engineering and technology can play a significant role in the type of development Sen envisions, the pursuit of engineering and technology development is ultimately not a developmental end in its own right, as exemplified by the Colorado School of Mines statement above.

And this brings us back to the topic that initiated this essay — engineering localization, and whether it is compatible with engineering globalization. The transformation of engineering education here envisioned calls for a more divergent style of thinking, an ability to broaden one's perspective to include a greater number and diversity of factors, an ability to subserviate technical imperatives and rationalities to socially constructive ends — in short, this transformation calls for an engineering education that is about something more than engineering. It is about a type of engineering education that seeks to make good on the standard engineering organization boilerplate promise of "for the benefit of humanity."

An immediate criticism that will be levied against this idea is, who will hire these graduates? After all, they will not be specialists in anything, and many engineering purists will feel that such an education is inferior, soft, not rigorous enough, or not marketable. How can we attract students if we cannot guarantee them lucrative job offers? As conscientious educators, we certainly should make every effort to identify potential employment opportunities for our graduates, but ultimately the motivation for this type of program is not one that necessarily dovetails nicely with the interests of profit-seeking, high technology industries. But so what? Engineering education has for so long been married to the idea of producing graduates for a specific job market that we have lost sight of the fact that education *doesn't have to be that way*.

Engineers are notorious for making jokes about the uncertain career prospects of arts and humanities majors. "A science graduate asks why, an engineering graduate asks how, and a humanities graduate asks 'would you like fries with that?'" And no doubt most universities have their share of uncertain students pursing these "non-professional" majors for less than carefully considered reasons. But to condescendingly generalize this scenario unfairly depreciates the possibility of someone pursuing a particular course of study because of a sincere desire to embrace that subject matter and with a vision of applying it in fruitful ways to his or her life's goals. And not having a ready-made job description likely poses little obstacle to such motivated individuals being successful in life and work, or making positive contributions to communities large and small.

Similarly, can there not be an engineering major — just one of many, and a small one at that — which has as its primary raison d'être the acquisition of knowledge and skills potentially useful in the service of global humanity, rather than in the pursuit of a generous starting salary at a cutting-edge high-tech company? Could such a program attract people who believed in the value of such a mission, and who would find ways, perhaps unique ways, to put their education to work? And who's to say that companies seeking "global engineers" won't hire such people? And, if they do hire them, perhaps those engineers will be positive forces for promoting global social responsibility within their organizations.

Finally, this leads to another aspect of what I mean to imply by a transformative meaning for globalization. Such an engineering educational program might attract people into engineering who are not otherwise attracted, people who have the aptitude for the mathematical and scientific rigor of engineering, but who have so far been turned off by its narrow technicality, people who can transcend the localizing nature of the profession. As Yurtseven [24] writes, according to popular perception, "We are seen as predominantly male, too bright for our own good, honest to a fault, non-communicative, dull, and loners." The profession is perceived, rightly or wrongly, as being concerned more with things than with people or ideas. But this transformation seeks to put people and ideas squarely back on center stage, demoting the technical to the position of means to an end, similar to the way in which medical science is a means to the end of providing healthcare to humans.

Despite nearly constant predictions of looming shortages of engineers nationally, and despite a relatively booming engineering job market through much of the 1990's, the number of engineering graduates has been on the decline in the U.S. for nearly twenty years [24]. Many possible reasons for a lack of interest in engineering have been suggested [25], and many of those are related to the perceived lack of diversity and narrow technicality of the field. One group that has obviously avoided engineering in representative numbers is women. Domenico Grasso [26] notes that, "many college bound students, notably women, are unwilling to sign on for educational programs that promise such a narrow role in society." But, "in engineering disciplines where social relevance is manifest, such as environmental or biomedical, women are well-represented." In their study of student persistence in science, math, and engineering majors, Seymour and Hewitt [27] find that, "Altruistic reasons for choosing S.M.E. majors are predominantly expressed by woman and students of color." If this is accurate, then perhaps the type of program proposed herein will benefit from that inclination on the part of women and minorities toward social relevance, with obvious collateral benefits for the profession overall. "An influx of adventurers," writes Engineer-author Samuel Florman [28] of women, "hailing from different cultural landscapes and bringing with them a humanistic view of the technology, is just what our somewhat insular profession needs."

But perhaps the attraction will not be limited to women.

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Acknowledgment

This article is based on a paper presented at ISTAS`04 in Worcester, MA, June 2004.

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