2006-1755: CREATING A “GLOBAL ALGORITHM” FOR ENGINEERING EDUCATION

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Creating a "Global Algorithm" for Engineering Education

Abstract

For five generations American engineering education has rested upon a practical model of drawing a broad range of students with certain mathematical skills and wide technological interests into a large-mouthed pedagogic funnel, gradually compressing their training into ever-narrower frames of specific, skill-sets and acumens. The result has been to standardize the end-products emerging from the apex of the educational funnel. Examinations and re-toolings of engineering education have usually merely redirected the funnel with recommendations of new methods and protocols for fine-tuning the relevance of contemporary technology to the classroom and laboratory. One canon remains constant: engineering education has maintained an approximately 80/20[1] curricular equilibrium between technical/non-technical requirements and emphases. Conventional wisdom and practical experience stress that this emphasis upon technical proficiency has assured American domination of engineering education for most of the last century.

A seismic shift in technology, manufacturing, and economics is occurring as we enter the new millennium. Global currents once far removed from the engineering classroom have become irrevocably intertwined with both the process and product of engineering education. A paradigmatic readjustment equal in impact is necessary to meet the global challenges faced by today's engineering students.

The Challenge: The core competencies, created and honed in the 80/20 funnel of engineering education, must be retained to assure technical competency. Simultaneously, engineering education must introduce more of a 50/50 balance in the final educational outcomes of the graduate between the technical and nontechnical competencies. i.e., the educational process must embrace much broader parameters of global/professional/personal competencies without compromising up-to-date technical expertise. This can only be accomplished by adopting creative concurrencies in curricular development. The personal and professional skills necessary to compete on the global stage of 21st century engineering must be included as aggregates (packet aggregation) to technical skill development. The tube of the funnel must be widened.

If the fundamental principle of the first five years of the millennium was multi-tasking in a lean manufacturing and professional environment, multi-identity competence (in the surge rather than in the wake) of globalization must be the foundation of the coming years. Preparing the next generation of engineers to enter this world with a competitive advantage requires inventive, resourceful, and continuously evolving methods to instill parallel intercultural communication, global resource management, and interpersonal professional training alongside the requisite and non-negotiable technically related subjects of the discipline.[2]

Introduction

One overarching reality demonstrated beyond reasonable doubt in the initial decade of the 21st century is that globalization is not "coming," it is already here.[3] The discussions and debates regarding the probabilities and vicissitudes of globalization that dominated engineering pedagogy in the 1990's are moot. From Inner Mongolia to Milwaukee, Wisconsin, globalization is an established fact of life**.** The critical realities of globalization and the unique pressures imposed on the nation's present and future security, economy, and stability create an educational imperative for engineering educators – *the paradigm for preparing engineering students must expand to include essential survival skills for a rapidly changing, increasingly globalized world*.

The minimum definition of a successful graduate from an undergraduate engineering program can no longer rest upon existing standards of technical acumen, an adequate completion of a traditional senior design project, and prompt job placement. With the rapid expansion of technologies, market forces, and even social movements fostered by globalization, the pragmatic standards of technical acumen are moving at the pace of Hubble's Law, leaving the elements that appeared so innovative in last semester's senior designs teetering on the edge of obsolescence while the seemingly perfect position secured in Boston following graduation may in all probability will transfer to Beijing.[4]

While engineering educators cannot hope to address every challenge posed by globalization, it is within the province of the profession, however, to meet the most acute problems arising from this inevitability. By creatively shifting foci and drawing upon resources already available to most engineering faculties, American engineering education can be a force that drives the engine of international integration and global cohesion rather than become a victim left in its wake.

The Scope of the Challenge

In a very real sense, American engineering education is a victim of its own success. A century of world leadership in science and technology is a tempting apologia for "business as usual." Four generations of engineering educators can take just pride in the world-changing achievements of their students and thus, argue forcibly for maintaining the same tracks that have driven the intellectual and technological engine of the Republic so successfully in the 20th century. If the recent past has taught us anything, it would appear that is has instructed us to "stay the course."[5]

Thus, it is with good cause that engineering education has been pedagogically conservative. Transitory fads and well-intentioned, but ultimately doomed educational experiments that have afflicted other disciplines have been defeated with the doubled edged sword of highly focused faculty curriculum committees and accreditation requirements. It is often, and not inaccurately, assumed that while other departments squandered time and valuable resources pursuing "relevance," the faculty of engineering continued with single-minded doggedness to train students that would change the world.

On the other hand, success can truly be its own worst enemy. While allowances are made in all engineering curricula for emerging technologies, little attention is paid to emerging global economic and cultural realities.[6] Encouraged by decades of past success, the American engineering pedagogical paradigm has become extraordinarily standardized: attract very intelligent students with widely diverse skills, interests, and abilities and "funnel" them into a standard "engineering outcome."[7]

While this approach produces graduates with excellent technical skills, the funneling process works diametrically against the flexibility (and even malleability) demanded by a globalized world.[8] The specialization that is inherent in engineering must make room for some diversity and even (the heresy of) ambiguity.[9] Global phenomena once far removed from the experiences of most engineers are now irrevocably intertwined with the essential elements of the profession. To prepare globally competitive graduates, engineering faculty must be as conscious of cultural changes as they are of technological advances.[10]

Producing global leaders in the 21st century involves a seismic shift in the approach to educating engineers.[11] Alongside technical acuity and accuracy, the curriculum must inculcate the skills of open ended problem solving,[12] critical thinking,[13] and cultural awareness.[14] In other words, expanding the apex of the funnel.[15]

While this pedagogical modification is consummately reasonable in theory, the reality in most engineering programs is counterintuitive to such changes. [16] The equilibrium of most curricula is maintained on an 80/20 balance between the "hard skills" of technical expertise and associated emphases and the "soft skills" of communication and social science.[17,18] Furthermore, program chairpersons and faculty curriculum committees face the dual pressures of maintaining the 80/20 balance while facing the imperative to reduce rather than expand credit requirements from the competitive reality of the academic marketplace.[19]

The changes being wrought by globalization at every level of industry and society, however, require immediate attention in the engineering classroom and laboratory. Global competitiveness alone creates a critical necessity for engineering faculty to prepare their students to succeed in a very different world from their parents. To succeed, creative solutions to the inherent dilemmas posed by this challenge must come from within the engineering departments rather than from external dicta.[20]

Premise/Proposal

Any hope of carrying over America's international preeminence in industry and technology from the 20th to the 21st centuries requires that the elementary realities of globalization be addressed with an intelligent, innovative, and aggressive response in the engineering classroom and laboratory. An ability to recognize, analyze, approach, and amalgamate issues and ideas crucial to global awareness must be treated as core competencies of an engineering degree. At absolute minimum, the stasis often present in the "20" of the "80/20" curricular formula must be granted the same dynamic kinesis that has kept the technological "80" evolving for an hundred years. Continuous curriculum review in the light of shifting international and domestic exigencies on the "soft" side of the Bachelor of Science degree must demand the same attention that adjustments due to technological advancement inspire on the "hard" side of the curriculum track. Cultural education cannot be treated as the last remaining curricular cathode in a digitalized world.

A more aggressive and ultimately more efficient approach requires a new model of engineering education. The requisite "80" of the curriculum is non-negotiable. The negotiable "20" can be utilized to its fullest extent with a global emphasis in intercultural communication, international resource use, and interpersonal professional training as keystones of the curricular construct. The innovation comes in the creation of a global composite or aggregate throughout the entire educational experience – the fostering of a global mindset rather than just he addition of another skill-set.[21]

The overarching goal of this model is to inculcate a flexible archetype or worldview in every undergraduate engineering student that includes:

- ✓ Critical thinking based upon unstructured problem solving
- ✓ Regarding the engineering professor as a mentor rather than a conduit
- ✓ Instilling a global focus in every course
- ✓ Utilizing local and regional issues to expand student worldview
- ✓ Encouraging international engineering education

The Model: The 80/20 and 50/50 Rules

Paradigmatically, the model rests upon the creation of a heuristic algorithm for global engineering education. The input is the 80/20 based system of American undergraduate engineering education. Vector elements include faculty engagement, the phenomenology of critical analysis, and the necessity of a shift to a global worldview. The outcome is expected to be a set of creative concurrencies – approaching an 80/20 reality (80% technical emphasis; 20% humanities) with a 50/50 mindset (50% technical acumen; 50% human interaction and critical thinking). The output is designed to expand an engineering undergraduate's world and life view, not the number of credit hours necessary for graduation.

Critical thinking based upon unstructured problem solving

At every level of student engagement and every "teaching moment," engineering students must be reminded that the world cannot be engaged strictly as a formula. One of the unintended consequences of the 80/20 necessities of a technical education is the communication of a subliminal belief that all "real" problems can be addressed either through modeling and differential equations. If 80% of "life" for an 18-22 year old involves the calculator or the calibrator, it is a facile leap to a black and white worldview that allows little room for diversity and no quarter for deviancy.

With little disruption and no damage to the integrity of the transfer of technical knowledge from professor to student, an environment can be encouraged wherein a 50/50 (at least) worldview may be nurtured in an 80/20 framework. Posing questions about the environmental impact of technology consumes very little time or energy but may open a window of positive reflection to a student trained to look only at efficiency of heat transference. A faculty member does not have to join Green Peace in order to raise elementary questions about global environmental responsibility. No harm is done to the 80/20 integrity of the engineering degree, but an element of 50/50 balance is skillfully introduced to the students' mindset. This is creative concurrency. If this "unstructured problems approach" is characteristic throughout the department, then true educational progress towards responsible global citizenship can be accomplished. [22]

Much of the challenge in a globalized world deals with cultural, social, and human issues that are so deeply intertwined with technical and scientific projects as to make them functionally inseparable. Culture is an algorithm with multiple preconditions, paths, and variables rather than an equation. An engineering graduate with even a modicum of unstructured problem solving competency stands a far better chance of success in the face of globalization than those focused solely on binary solutions. [23]

The engineering professor as mentor rather than conduit

A primary goal of education remains the conveyance of knowledge. This is especially true in the education of technical specialists and scientists. During the last century the industrial might and scientific preeminence of the United States allowed engineering departments to mass produce legions of highly focused, well-trained graduates with almost Orwellian efficiency. The fact that the "products" of this mass production might have developed Orwellian humanity in the process was not seen as problematic. American engineers knew their material, secured well-compensated positions, and dominated the industrial and scientific world.

The system worked as long as the competition followed similar protocols and professional standards were set by the same experts that created engineering curricula. As long as Terre Haute and Milwaukee synchronized their expectations and employers from Peoria and Memphis competed vigorously for graduates, the system continued to flourish.

In the second semi-decade of the new millennium, however, expectations for engineering graduates are being set more frequently in Bangalore than Terra Haute and employers are just as apt to seek applicants prepared for duty in Guangzhou as Peoria. Expertise in the Navier-Stokes equations alone does not prepare a student for this brave new world.

The equipment for re-tooling the engineering education process to meet the challenge of globalization at this point, however, is already in the hands of engineering faculties. Like polytrophic processes, the dilemma is internally reversible.

While education does involve the transfer of information, the instructors is not *ipso facto* required to serve solely as a factual conduit.[24] Sorely needed attention is now turning toward the integration of engineering curricula with other disciplines in order to adjust the process and, ultimately, the product of American engineering education.[25] Concomitant attention must be paid to the ethos of the classroom. With the whole world now setting the standards of, and providing the competition for, the American engineering student, the approach to the transfer of information in the classroom must reposition toward holism.

The task is not as daunting as it may appear. Engineering professors are also professionals in their field. While not necessarily actively engaged in industry, most instructors have valid, practical experience – the one element missing from even the brightest student's resume. Almost by definition, an instructor is a living case study of the human element in engineering.[26]

Without further education or time commitments, the average engineering faculty member can transform the function of conduit into the role of mentor.[27] Creating a human dynamic in engineering (the springboard to a global dynamic in engineering) begins with faculty/student interaction on the realities of the profession, "real time" problem-solving, failures communicated alongside successes, and positive responses to non-technical questions.[28]

Traditionally, this "side" of a nascent engineer's training has been abdicated to the instructors on the "soft" side of the curriculum – if a student wants to know about life they can ask their sociology professor. This dichotomy (like closed-set vs. open ended problem solving) implies that engineering does not address humanity – and by extension – does not address the issues and challenges of human communication critical to global citizenship. A pedagogical duality that artificially separates categories of learning and experience (either explicitly or implicitly) ensures that synthesis of ideas and actions, a critical component of coping with a globalization, is absent from the student's educational experience.[29]

The greatest single factor in globalization is humanity.[30] While an engineering faculty cannot be expected to master the intricacies of world trade policy or cultural anthropology and conceptually integrate these fields into the nuances of electromechanical energy conversion, every professor of engineering is human. It is the conveyance of the promise and pitfalls of humans practicing engineering as an integral element in every classroom that can provide a giant leap forward in meeting the challenges of a globalized world. The destruction of the artificial dichotomy between engineering and humanity engendered by a "mentor-focused" pedagogy will, by definition, produce more holistic graduates.[31]

Every course should have a global focus

While the shibboleth of interdisciplinary cooperation has already been broached, it is incumbent upon faculty and curriculum committees to expand their focus on this subject if the challenge of globalization is going to be met by this generation.[32] The time for offering an olive branch to the Social Sciences Department, and likeminded colleagues, is long past – engineering departments must be willing to throw them a tow line and haul them into the boat.

Integration, however, is not an act of sacrifice. Synthesis of globally-focused disciplines into engineering curriculum does not necessitate an offense against the 80/20 balance. Outside the United States engineering faculties are developing innovative and creative project-based interdisciplinary cooperation in such unlikely combinations as mechanical engineering senior design/cultural anthropology and electrical engineering/international development. The integrity of engineering projects does not appear to suffer loss when combined with humanistic disciplines. The end result, however, is an engineering student with technical acumen and global awareness.[33]

Synthesized engineering/social science projects are creative concurrency at its best. The 80/20 equilibrium is maintained while infusing a 50/50 approach to the skills necessary to thrive in a globalized world. On a less ambitious plain, however, is the need to remind all students in every course that they are facing issues, challenges, and possibilities of an international magnitude in their engineering careers.

Focus locally to think globally

Creative concurrency in the engineering curriculum does not demand an exclusively international focus. All global phenomena begin locally. The use of local and regional issues as affective points of discussion in the engineering classroom is an efficient and effective way of broadening students' worldview. [34]

Environmental, social, and cultural impacts of technology and industry at the regional level are easier for the average student to comprehend and more likely to generate genuine interest than trade policy in Southeast Asia. Even the most basic local issues when collocated to the pragmatic lessons of the engineering classroom can generate a paradigmatic shift in a student's approach to the profession. [35] Using practical, local problems as the impetus for discussion fulfills a 50/50 mindset to problem solving while maintaining the academic necessity of an 80/20 curriculum. [36]

Encourage international engineering education

Citing the need for "the next generation of United States' leaders to be engaged globally," a special committee of the United States Congress has requested funding to support the goal of one million American students studying abroad by 2017. [37] This decision underscores the recognition that international educational experiences have passed from the realm of luxury to the reality of necessity. [38]

The rigor and (please let me put *mortis* here) inflexibility of many engineering tracks (pursuing the 80/20 goal) make long-term study abroad (one semester or a full-year) impractical. This should not discourage the engineering faculty from pursuing short-tem opportunities.

Short-term study abroad programs have demonstrated quantifiable benefits for technology and science students including "increased perception of their perceptions of the costs and benefits of globalization."[39] Both the financial and time commitments of a short-term study abroad program fit more readily into existing engineering programs.

Study abroad programs do not have to focus on the "20" of the 80/20 balance. International travel is not the sole property of the Department of Foreign Language and the School of Fine Arts. Programs ranging from Industrial Development to Comparative Manufacturing have been offered with great success by universities and corporations with the professional engineer or engineering student in mind. Cooperative summer programs and international internships in Europe, Asia, and Latin America are readily available to the engineering faculty prepared to focus upon global citizenship.

Conclusion

Eras of historic transition require bold action. As the "American Century" passes into the "Age of Globalization," the maintenance of America's industrial and technological leadership rests to a substantial extent in the hands of engineering faculty. Central to the future is the understanding that the stunning successes of the past cannot be the single determinant of how to approach that future.

Engineering schools exist to guide and produce the future. There can be no doubt that this future will either drive, or be driven by, globalization. With very little disruption to existing programs and careful maintenance of the 80/20 curricular balance, engineering departments can create a new pedagogic composite that nurtures the global education of engineering students. These creative concurrencies interweave existing institutional and faculty resources with steady and consistent innovation to form a solid foundation for global education.

Integrating a 50/50 mindset (technical/human) into a dynamic technical education with a strong element of open ended problem solving lays the foundation creating a regional and international perspective in engineering students. This perspective, if combined with relevant cross-cultural education and critical thinking skills, will create global professionals prepared to compete on a worldwide scale.

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[1] The numerical numbers of 80/20 should only be taken as broadly based numbers intending to show a relative emphasis.

[2] An 80/20 reality must flow concurrently through the funnel with a 50/50 phenomenology.

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