Preparing for Uncertainty – Addressing Globalization in an Engineering Curriculum

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Abstract

How can an engineering curriculum more realistically prepare graduates for a changing world where global effects and events are experienced increasingly on a local scale? Globalization is a significant effect that is faced by graduates of all institutions and degree programs. Hence, the nature of this issue must be better understood to pursue an effective strategy for the curricula development needed to prepare engineering graduates for a rapidly changing world.

A central point is that engineering programs, in general, do a very good job of teaching structured problem solving, e.g., “design a system with the following specifications.” However, events such as globalization present challenges and opportunities in the form of *unstructured problems*. This is very different from problems with “open-ended” solutions, where the focus is on the end result and how it is achieved. In the case of unstructured problems, the solution again can be open-ended, but fundamentally the *problem itself is not defined in terms of specifics*.

Using globalization as a primary vehicle, the nature of unstructured problems is defined and approaches for engaging this issue in an engineering curriculum are suggested. In particular, the need for the development of strong professional skills and global awareness are identified as being essential. Increased integration of professional skills development into an engineering curriculum is detailed.

Introduction

U.S. engineering students have historically enjoyed relatively high employment rates on graduation. Recent trends in the offshore outsourcing of high technology jobs are introducing uncertainty about the long term future of U.S. engineering employment. The globalization of career competition, while well-recognized by now[1], is nevertheless an issue that is diffused and difficult to address[2].

Globalization is a well-documented phenomenon. Yet its impact on unemployment and career opportunities is being actively debated[3,4]. Some experts claim that increased productivity is the major factor influencing the availability of jobs. However, concerns are being voiced that a core assumption associated with globalization, that labor intensive and low-skill jobs can be performed more productively elsewhere while the U.S. workforce produces higher-valued goods, is a premise that “cannot be counted on to create …net gains greater than the net losses from trade.”[5]

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Whatever the correctness of that debate of how full or empty the glass of opportunities is, global career competition is a fact and will increase in intensity[6]. In a real sense, global career competition is prototypical of the problems created by globalization. The simple facts are that knowledge favors those who seek it and that knowledge is readily available to virtually everyone. Thus, engineering design will follow the historic path of manufacturing from western nations to global markets. A process of world-wide employment equalization appears to be under way that includes the migration of highly skilled jobs.

Global career competition is a disruptive event. The current generation of graduates does not have much experience in personally dealing with disruptive events. The reality is that such disruptors are common in the long term. During the course of every few generations there have been experiences ranging over economic depression, war, disease, etc. It is just a question of who, what, when, and how events play out. Textile manufacturing vanished from the northern part of East coast of the U.S., and subsequently has almost left the U.S. altogether. Similar shifts have occurred in furniture manufacturing, shoe manufacturing, television manufacturing, et al. Global competition and the role of technology as a global disruptor must be understood by engineers, the creators of such technology, since they too will have to deal with the end result, just like everyone else.

In the past, typical headlines and articles have focused on routine manufacturing jobs as departing for other parts of the world and that jobs requiring higher skill levels would be "safe" career choices. Recent economic trends[7,8] suggest that nothing is "safe." Career safety rests not on choosing a specific career but in being able *to discern and adapt* to the global market changes that are occurring and will continue to occur.

From an academic standpoint the concern for career preparation is not what the current hot skills are, but what is needed for a long-term outlook; specifically, what activities, perceptions, etc. are necessary to allow a proactive addressing of this issue?

The career decisions of future engineering graduates are such that forces of globalization are certainly to a large extent beyond the control of individuals, and even governments[9]. Economic trends will follow their own paths and it is essential for graduates to recognize the nature of the trends and prepare, not to counter the trends, but to successfully adapt to the trends. The difficulty is that the problem is unstructured but the response, the "solution," must be formulated in terms of specifics. Lynch[10] defines unstructured problems as lacking certainties regarding such factors as the validity and completeness of the data at hand, range of solution options, and range of outcomes related to various options. Unstructured problems are characterized by unknown present and/or desired states and as having ill-defined inputs, outputs, and processes.[11]

An example of an unstructured problem might be an automobile manufacturer with falling sales. The company car development team is given the assignment to design and produce a car that would cause potential customers to say "Wow, I've got to have one of those." There is no structure for the definition of what constitutes "wow," yet the problem, falling sales, is well known. The problem is further diffused in that it could even be true that the reason for the falling sales is not necessarily due to the perceived lack of appeal of the present car models. Causal effects could range from the model mix the manufacturer is trying to sell, gas mileage of the models, financing offered, and the actions of the competition.

The nature of an unstructured problem is fundamentally different from a problem where an "open-ended" solution is allowed or encouraged. In this latter case the focus is on the solution and the problem itself is capable of being well-defined. An engineering example of this is to design an audio system where no constraints are given as to the choice of technology. "Successful" engineering students are adept at open-ended type problems. But, their education fails them when it comes to unstructured problems of the type created by globalization.

When all considerations are taken into account, the suggested essentials are that graduates need a greater global awareness, to develop and maintain currency of skills, a good foundation of the basics, and, above all, professional abilities such as good communication and problem-solving skills. In the face of changing scenarios, both technical and economic, these are as close as it is possible to define lasting features that allow a graduate to add professional value for long-term survival in the workplace.

Premise/Proposal

Globalization has introduced a level of competition whereby survival, at every level, depends on the ability to address unstructured problems. Traditionally, the terms unstructured and open-ended have often been used interchangeably, but they actually have a very different meaning and implication in the context of this paper. Again, open-ended generally has been associated with the solution to a problem[12] and not with an understanding of the problem to be addressed. Examples of unstructured problems range from asking for a design for which the customer's reaction is "Wow, I've got to have one of those" to trying to define high-demand future markets that currently do not exist.

University programs and students both make choices per their perception of what the future may bring in the way of opportunities and how to prepare for those opportunities. However, the thesis of this paper is that existing long-term trends are poorly understood and that, like the general who prepares to fight future wars based upon the last war, programs and students prepare for the future based on an extrapolation of the past. In a somewhat static environment the latter can be a successful strategy, but in the current much more dynamic environment being proactive is a requirement. Things have changed and they have changed in fundamental, often unexpected, ways. Exhortations to "do things better" and simplistic improvements of past approaches will be inadequate in the future.

Objectives in Engineering Curriculum Development

Some specific objectives of an engineering curriculum that address unstructured problem solving, using a focus on globalization as a primary vehicle are:

1. Since the overall intent is primarily to foster the development of a different mindset rather than any specific knowledge, any approach should be in the context of using the entire time the student is participating in the academic program.

Unstructured problem solving, and the ability to address issues such as globalization, cannot be learned by simply offering a course. The entire curriculum must be used to connect with students in the following ways:

a. Early
b. Throughout the curriculum
c. Consistently (learned trait)
d. Using a process embedded into the structure of the curriculum
e. Experientially

2. There are major curriculum pressures to decrease the overall number of credits required for graduation, while increasing the liberal arts, economics, and business content, improving communication skills, and maintaining the strength of the math, science, and engineering part of the curriculum[13].

   Retaining traditional strength in mathematics, sciences, depth and breath in engineering, and doing so in a climate of ever increasing technical topics suggests that adding of courses, even in areas of importance, will not be possible. Rather, the integration of multiple topics within the courses is essential. But that provides a superior context for learning information and can link learning to actual experience.

3. Foster thinking in general global terms, in addition to numeric analysis and a focus on specifics.

   Mathematics is often said to be the language of engineering. If applied too literally, students may develop the impression that an answer can be calculated for any problem. Such an impression is at odds with the uncertainties of the physical domain.

   Are we "misleading," "mis-training," "mis-educating" students in our engineering curricula in some fundamental way? Not so much by curricula that gives the impression that everything can be calculated to five decimal places, but that the boundary conditions, or context, of the problems of life will always be well-defined so as to allow for a systematic approach towards finding solutions. Engineering curricula spend years inculcating the notion of a deterministic, Laplacian world. Engineering students thus tacitly operate with the fundamentally flawed notion that boundary conditions and system descriptions may be ascertained to the degree necessary for a systematic, solutions-oriented (i.e. deterministic) approach to problem solving.

4. Develop the concept of having a customer focus.

   Professional (and other) activities ultimately result in a traditional economic transfer of goods, service, or ideas in exchange for wealth of some kind. Hence, students should be encouraged to think in terms of some fundamental competitive questions such as, "who is interested (finds value) in what I am doing/making, who will be willing to pay for this, etc?" Further, there should be exploration of issues such as whether other people are doing the same activity, whether our end result will be superior to theirs?

5. Teach problem-solving beyond the confines of technical engineering problems.

   Problem solving should focus less on solutions and more on understanding and defining problems in a broad sense, with a view of the "big picture." The social and environmental impacts of technological solutions and quandaries must be understood by the designers. Solutions should be understood more in the context of being a "by-product" resulting from having achieved a deeper understanding of the problem.

6. Include regional geographical effects.

   An understanding of globalization should include the study of regional geographic idiosyncrasies. For example, the U.S. Midwest, sometimes derogatorily referred to as "flyover country," often perceives itself as having a greater "distances" between itself and the happenings of the world. This sense of mental distance may affect the interpretation of far-away events.

7. Comprehend the fluid nature of knowledge

   An often heard misconception is that while manufacturing has been outsourced, higher level skills, such as engineering design, etc., will remain within the domain of U.S. domestic activities. There appears to be an inherent assumption that a good education, especially in a technical area, will protect one from the pressures of the marketplace.

   Reality: Knowledge is neutral and cannot be captured and contained by anyone. It is impossible to contain knowledge. Knowledge can be learned by all who wish to learn and have access to the knowledge. Developments in telecommunications and the internet have assured an access to knowledge of vast proportions to anyone with access to commodity computing and communication equipment.

8. Develop the right skills.

   Globalization issues and professional skills (communications, teamwork, etc.) are intrinsically interrelated. Good communication and teamwork skills are a minimum requirement for success.

9. Teaching about the worldwide workplace.

   Engineering graduates must develop a greater awareness of and familiarity with the global world in which they are expected to function. It is highly probable that it will be the norm for U.S. graduates to have direct interaction with their counterparts in foreign lands. With companies producing for the global marketplace and manufacturing, outsourcing, and partnering globally, it is also probable that U.S. graduates may be employed by a division of an international company, travel routinely to company divisions in foreign lands, or even be employed abroad[14]. As a matter of fact, increasingly the nationality of some companies is more difficult to discern[15]. Hence, knowledge of other cultures and the ability to live and interact within them will increasingly be viewed as an essential skill required for professional success.

It could be argued that moving jobs offshore is no different than moving jobs from one state to another within the USA. The reality is that for Americans it is fundamentally different. Americans do not have any significant history of following jobs to other nations, with very limited exceptions such as Canada or other English-speaking nations. Other nations such as India do have a tradition, honed over centuries, of immigrating to find jobs over many continents. Certainly the desirability of jobs in a foreign land is viewed very differently from an American viewpoint.

10. Have students ask some basic questions of themselves

    Example question: "Why should I hire you?" This constitutes an unstructured problem where the focus is really on the person asking the question. The outcome of the answer is not within the control of the student/graduate. It requires thinking outside what one wants for oneself.

11. Convey a difficult message – in the end, it is all business

    Engineers ironically are very responsible for creating the very technology that also threatens their livelihood, as well as that the livelihood of others. Being the key creator of technology, but seldom in control of it, the engineer is captive to economic decisions made by others. Engineers have been enablers who set processes and products in motion that ultimately are subject to competitive, survival-based rules of economics. An understanding of economics and business is fundamental.

Curriculum Implementation (Some Details)

Explicit efforts are underway in the Electrical Engineering program at the Milwaukee School of Engineering to meet the objectives that were described. Some of these efforts are as follows:

- Freshman level courses – A number of courses during the freshman year are aimed at enlarging the "Weltanschauung" (the perception of the world) of the students. This begins with our orientation course for entering freshman, and to a limited extent in the introduction course to electrical engineering. A contemporary issues course and a course on economics (combination of macro and micro aimed at freshman level thinking and understanding) complete the initial course series.

- A required junior-level course, "Career and Professional Guidance," is being revised to include activities that confront students with globalization issues, particularly as they affect careers and the electrical engineering profession. Interactive sessions that focus on immediate global issues such as offshore outsourcing and company re-training are conducted with practicing engineers and managers. Human resource specialists provide students with strategies for improving their competitiveness in the labor markets.

- The year-long senior design experience is broadening its formalized critical thinking and problem-solving instruction from an "open-ended solutions" approach to an "unstructured problems" approach. The case study technique, common in business schools, is being considered as one way to introduce unstructured problem-solving[16]. An increased emphasis is being placed on professional development. Competitive advantages of U.S. graduates over offshore engineers should be their abilities to communicate effectively and to leverage diverse teamwork for increased productivity.

- Efforts by the Career Planning and Placement Center have especially focused on professional development. Students registered with the CPPC complete a Professional Development Transcript (PDT). The PDT is designed to assist students in identifying and articulating skills gained from their university experience. In addition to technical skills, seven other skills are identified as important keys to success. These skills are: critical thinking/problem solving, communication, leadership, teaming, relationships, comfort with diversity, and global interactions. The PDT allows students to: perform an ongoing self-assessment, identify their strengths and weaknesses, and develop strategies to improve in the seven skill areas. The PDT is an instrument that the student can use to prepare for an interview for employment or acceptance to graduate school and a document that may be used in a professional portfolio along with transcripts, resume, references, etc.

- A track within the electrical engineering program is being developed that incorporates courses from humanities and social sciences, business, and technical communications. The track would consist of a three course business sequence, a three course humanities and social science sequence, and a two course technical communication sequence. Topics in the humanities and social science sequence will include the philosophy of technology within the contexts of natural environment, social structures, and historical applications; ethical development in terms of professional conduct and interpersonal relations; and human factors in engineering and design. The business sequence will include management in an accelerating technological society, unstructured problems, and decision systems. Case studies will be used to develop decision-making frameworks. The technical communication sequence will include effective oral communications, group dynamics and teamwork.

Conclusion

The central conclusion is that *a relevant and proper education must have a strong non-technical component*. That non-technical component must include problem solving in the *most general sense* (problem solving is not unique to engineers), an awareness of the world and developing trends, and a focus on developing strong professional skills.

The curriculum development efforts in the electrical engineering program at MSOE are a work in progress. We feel we have identified a critical issue that requires a concerted effort, and one where the outcome is uncertain.

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