Visioning Transition: A Framework for Collaborative Change

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Abstract

Tomorrow's engineers will look nothing like the engineers of the past. Aside from a proficiency in core, technical knowledge, tomorrow's engineers will require a collection of non-engineering skills and competencies to successfully function in a dynamic, global environment. Technical competency will always be viewed as an integral skill; differential advantage however, will be gained by those individuals that can communicate effectively, and participate fully in an organization's different functional realms.

What has motivated this vision and rethinking of the engineering discipline? Where are we in the journey to prepare our students for an engineering working environment characterized by a global, integrated and multi-disciplinary nature? And finally, is it possible, or should it be necessary, for traditional engineering education systems to fundamentally change to meet corporate requirements? These are but a few of the compelling issues discussed in this paper.

1. Situational Background

During the summer of 1999, eleven individuals representing a variety of engineering disciplines and universities spent eight weeks at the Boeing Company as A.D Welliver Faculty Fellows. The primary objective of the Boeing sponsored A.D. Welliver Faculty Fellowship program is to "influence the content of engineering education in ways that will better prepare tomorrow's graduates for the practice of engineering in a world-class industrial environment." Now in its fifth year of existence, the Boeing faculty fellowship program has served as a premier, innovative example of university/industry partnership.

The summer of 1999 was a period of transition for the Boeing Company. Fellows gained invaluable experience and insight by closely observing, and participating in both the challenges and opportunities faced by the company as it continued the process of corporate reengineering. At the end of the eight-week experience, faculty fellows left their respective assignments with examples and class material unmatched by any textbook treatment. Furthermore, the engineer's cross-functional role in an organizational context, as well as the required skills needed by new engineering graduates to succeed in this environment were more fully appreciated by the Fellows.

Several conclusions are advanced from our collective experiences that form the basis of this paper. In essence, to best prepare our future engineers for success in the workplace, they must be better educated and trained in terms of:

•Having a broad working knowledge of engineering design beyond what is commonly taught in a single engineering discipline;

• Appreciating a system's perspective of the organization and how the engineer interacts and works in this cross-functional environment;

• Developing the ability to work in teams, interact successfully with co-workers and communicate effectively within and outside the engineering discipline; and

• Having the essential skills for continuous self-improvement and life-long learning.

While educators and administrators of engineering institutions have made attempts to address the above issues, few proposed initiatives have systemically affected change. It is our contention that to address both the needs of industry and the education of our students, engineering education, and its supporting systems require new and innovative agents of change. In the era of ABET 2000, the conditions and environment for enacting change are finally in place.

2. Why Change?

In recent years, a change towards lean/agile manufacturing has become a necessity for organizations to remain globally competitive. This implies that an engineering education must stress not only technical and problem solving skills, but also an understanding of how these skills are needed to interact within a larger organization model and ultimately within the global marketplace.

The current competitive business environment has also forced industry to tackle difficult issues such as cost, time-to-market, customer satisfaction, market share and shareholder value in addition to traditional issues such as quality, reliability and conformance to design standards. From a technological perspective, today’s engineering challenges have become so complex that they demand multiple skills to address. Furthermore, in these days of accountability, engineers are required to incorporate feedback measures into the decision making process to continuously improve and monitor the quality of services provided.

Change in any form or fashion is difficult to achieve. For that reason, change is often challenged, especially in a university context. Although the ABET 2000 mechanism provides a framework for wide-scale change, the reality of modifying curriculum, educational processes, and programs of study is a difficult task to actually achieve. This is not presented as an excuse for complacency, change must occur. However, for our graduates to make a worthwhile contribution to the organizations in which they eventually work, different approaches, topics, skills and philosophies must be incorporated into today's engineering education programs.

3. Our Vision for the Future of Engineering Education

Increasing competition and globalization of technology is rapidly changing the practice of engineering and challenging the educational process that must prepare future engineers. For the most part in the past, engineering education has been narrowly focused on engineering science and disconnected from the modern practice of the field. Our future engineers must be increasingly involved in the entire product development process: from the application of applied sciences to the analysis of economic and human factors involved in realization and usage of engineered products and systems.

Realization of this vision presents both challenges and opportunities in terms of modifying the "standard" engineering curriculum. In particular, it requires a comprehensive view of engineering education and an understanding of the skills and attributes that must form the core competencies of future engineers. These skills are, at least partially cited in a number of references and can be summarized as follows.[1] Engineers must:

- Possess a solid foundation in the applied sciences and be able to apply this knowledge in practice;
- Have a creative outlook while maintaining a critical attitude in the problem solving setting;
- Possess good communication skills;
- Understand the significance of organizational, scheduling, planning, and decision-making skills and are able to apply these skills in practice;
- Possess functional knowledge of business concepts and practices in a customer-driven environment/market and are mindful of the ethical, environmental, and social dimensions of engineering;
- Participate in continuous self-improvement and life-long learning;
- Have the ability to deal with open-ended problems;
- Understand the integrated nature of engineering;
- Be able to apply a systems engineering perspective in addressing engineering problems;
- Have the skills to function in multi-disciplinary and cross-functional teams;
- Be at ease with operating in an increasingly diverse and global economy and society.

In order for engineering students to develop the skills and attributes listed above, changes to the present engineering curriculum are needed. In particular, it is essential that engineering students are, from the outset, exposed to the concept of exactly what engineering entails. Furthermore, students must develop a familiarity with the methodological basis of engineering, namely the ability to develop creative, yet sound solutions to open ended problems. A significant step in this direction has already been taken by a number of engineering programs across the country by introducing engineering design at the freshman level. Indications are that such courses are both successful in terms of developing student interest in engineering, and facilitating their ability to develop the mindset that is essential to the practice of engineering.

Curriculum reform can not stop at the freshman level however, or remain limited to one or two engineering design courses. In order for engineering education to provide the rich set of skills that are necessary for a successful career in engineering, one must evaluate and potentially revise the manner in which engineering students are educated *throughout* the traditional four-year engineering program. Such reform must be, in our vision, multifaceted and will likely impact both the form and content of engineering education as discussed below.

3.1 Impact on Engineering Sciences

A key feature of our vision addresses the manner in which fundamental scientific concepts of engineering are introduced in the classroom setting. In particular, we believe that, it is desirable, if not essential that the teaching of core science, mathematics, and engineering science courses be conducted within a context of understanding. Within this context, students should understand that engineering is a creative process whereby basic scientific principles are applied in a judicious and effective manner to develop engineered products.

Such coordination can take the form of parallel teaching of applied science and engineering science courses with a focus on the *content* of these courses. In particular, it is important that engineering science and fundamental concepts of engineering such as engineering mechanics, electrical circuits, physical chemistry, or engineering thermodynamics be taught in a manner that is mindful of the application of these concepts in the practice of engineering. To this end, the teaching of engineering science courses must incorporate appropriate examples representing manageable but realistic engineering problems. Moreover, this process must enable the students to grasp the larger picture encompassing such problems so as to enable the students to make the transition to the real world practice of engineering.

3.2 Broadening Students' Horizon

One key finding shared by all Welliver fellows was the multi-dimensional nature of engineering in practice. Existing engineering curriculum does not adequately emphasize the broader issues that are increasingly involved in the practice of engineering. Future engineers must be mindful of the economic, social, and environmental impact of engineering and understand how to account for such issues in the practice of their profession. To this end, it is essential that engineering students be exposed to real-life case studies that incorporate decision making in the presence of economic, environmental and social constraints.

3.3 Cooperative Learning, Teamwork, and Communication Skills

The ability to work productively with fellow engineers, scientists and even colleagues not trained in the profession is increasingly essential for a successful career in engineering. From this perspective it is essential that engineering programs place a more significant emphasis on teamwork and cooperative learning as part of the training of future engineers. To be sure, a number of studies on cooperative learning and teamwork have taken place over the past decade with effort to incorporate these ideas into the educational setting. It is imperative however, that this aspect of engineering practice be a common feature of engineering education and be promoted throughout the traditional four-year degree program in engineering.

3.4 Lifelong Learning

Traditional approaches to engineering education often instill in the newly trained engineer, a perception that his or her education is essentially complete by the time he or she graduates. The increasingly rapid pace of technological development however, makes it imperative that engineering students be made aware of the need for lifelong learning as an essential attribute for success. To this end, it is important that educators move away from the traditional mode of teaching and encourage students to actively explore relevant subject areas and experiences to their future profession.

4. Barriers and Challenges to Curriculum Change

Admittedly, modifications and changes in engineering programs face a number of barriers and challenges. The right changes can greatly enhance a university's ability to prepare students for the dynamic industrial and global environment. Yet the wrong changes may result in wasted time and effort. In this section, we address some barriers encountered in any process involving curriculum change, and the potential facilitators for change.

There are several challenge areas for any curriculum change. They are:

- Any significant redesign of curriculum offerings requires the coordination and consensus of many faculty members, and crosses different departmental and college boundaries. At the same time, faculty members already have substantial workloads in research and teaching.

- The current university reward system does not encourage efforts in curriculum redesign. Faculty members are rewarded for individual achievements within the university and the academic community in the broadest sense. Within the university, faculty are rewarded for the number of publications, the number of graduate students advised, and the amount of funded research obtained. This is the primary basis for tenure and promotion, not curriculum innovation.

- This reward system is the result of a shift over the past 30 years in the priorities of university administrations. Their emphasis is to keep the university financially viable. As a result departments and colleges are typically rewarded for the number of credit hours they produce and the number of students they graduate. More effort is expended on recruitment and retention than on what is actually being taught.

- The lack of clearly defined planning documents that outline strategic direction, mission and methods of assessment is an additional obstacle to change. Furthermore, because of tradition and the nature of university systems, the speed with which change actually occurs in a university if often quite slow.

On the other hand, positive changes are possible given the vision and motivation for change. While faculty cherish their individualism, most faculty want to do the right thing. Individual faculty members have certain latitude within their curriculum responsibilities. The realization of the importance of curriculum redesign to students, education, and to the profession as a whole will hopefully compel faculty to realign their thinking with the needs of their various constituencies. In addition, industry has realized the need and importance for change. Industry can use their influence to effect positive changes at universities. Finally, ABET 2000 has created an opportunity for colleges and departments to redefine themselves and create the processes that enable change.

5. Agents of Change

Faculty, students, university administrators, industry and government are partners in the implementation process for the envisioned model of engineering education. Each has a vital role to play; working together as agents of change to realize this vision. Each is a stakeholder in the outcome. Each has much to gain, conversely, each has much to lose if the vision isn't realized. Achieving this vision requires a shift in the engineering education culture.

5.1 Faculty

As faculty, we must appreciate that how we act may have a greater effect on our students than what we tell them. Traditionally faculty have worked as a group of individuals rather than as teams, especially in teaching. If we are to encourage a more collaborative, teaming paradigm amongst our students, then we must behave that way in our own intra- and inter-departmental dealings. It is imperative that we serve as role models of the desired behaviors of the engineer of the future.

Rather than dealing with students as an anonymous collective, we have to engage them as unique, whole individuals. Last, faculty have to be more proactive in engaging industry on their terms, or at least with an acknowledged appreciation of the contemporary environment and demands on industry.

5.2 Students

Rather than seeking personal reward from individual effort, our students will need to be rewarded for being team players and encouraged to develop their capability for being a leader. They need to trust each other, respect each other, and treat each other with dignity and professionalism. Unavoidably, mistakes will happen in team projects and students, therefore students need to learn to give and receive criticism professionally and constructively. To this respect, surfacing problems early and seeking help, rather than hiding them and hoping they will not be found, is also crucial to the successful completion of team projects on schedule. Also important in a team environment is that students need to learn to become active listeners. Finally, as faculty, we should help students form a healthy habit of always actively seeking responsibility and expecting to be accountable.

It seems that curiosity has not been fostered in the way we approach teaching. Students should be open minded and exploratory in how they approach their learning. We have to find ways to encourage students to take risks, try different approaches, and not to be afraid of making mistakes, because mistakes are one of the most important sources of learning. Another important quality of a good learner is the ability to ask well-structured questions. To promote this skill, as faculty, we should create a classroom environment that is open to questions.

Students should be encouraged to pursue a rich selection of extracurricular activities. There are many possible activities that the students can choose from according to their individual preferences. These extracurricular activities will help students establish their own professional network and the interpersonal skills to operate within them. Another avenue for developing these skills is for students to get to know their professors on a one-on-one basis, to see them as professional colleagues rather than mere instructors.

5.3 Administration

More often than justified, administrators are perceived as roadblocks to change. However, the truth is that administrators can and often do foster and lead the much needed changes. In fact, administrators can be very effective in removing road blocks for the innovators. With the administrative power, they can create an environment that encourages and affirms new and innovative approaches to engineering education. They can also provide the infrastructure and financial and moral support necessary for the implementation of the change. Also important for administrators is to publicly recognize excellent teaching practice and to promulgate such practices through the professorate. Using their access to resources in other departments, the administrators can lead the teamwork teaching by foster, coordinate, or help establish collaborations across the departmental boundaries.

5.4 Industry

Industry must recognize that it is an important agent of change for preparing our future engineers. With this in mind, partnerships must be established early in a student's career by means of internships and co-ops. In addition, processes must be created and perpetuated which allow for frequent feedback from industry to education and vice versa. Last, industry serves as one of the best opportunities for realistic design projects and faculty internships and/or sabbaticals.

6. Potential Implementation Mechanisms for Creating the New Engineer of the Future

To implement, sustain, and continuously improve on the changes proposed in this paper a strong partnership among the university, industry, government, and students must be in place. In particular, the following items should be considered as implementation strategies for the partnership:

• Make industry a partner in identifying changes and needs in curriculum redesign and consider industry as a direct customer much the same as parents/students and state/federal governments;

• Support faculty summer fellowship (similar to the Welliver program);

• Encourage more faculty sabbatical/consulting in industry;

• Support distance education classes from universities to industry and from industry to universities;

• Participate in university-industry-government joint research programs;

• Create opportunities for industry and government in-kind support (i.e., equipment, data, etc.) to provide hands- on laboratory and practical experiences;

• Reward outstanding educators such as Boeing Outstanding Educator Award model;

• Create fellow-on-campus opportunities (bringing leading industry experts to teach on campus for a semester, creating adjunct faculty positions);

• Identify mechanisms allowing for seminars and short courses at universities taught by industry experts;

• Support university-industry-government workshops and roundtables at national level;

• Recognize the importance of broader education responsibility (K-12);

• Recruit industry participation in evaluating design projects at local and national level competitions; and

• Seek participation of industry and government in university advisory board.

7. Conclusion

Many factors lead to the realization that there exists a gap between what our engineering educational systems are teaching students, and what ultimately is expected of them in the workplace. Factors contributing to successful engineering careers are no longer solely technical in nature. Rather, a number of non-engineering skills and competencies are now required to successfully participate in an organization.

This paper has presented the collective perspective of a group of engineering faculty members who worked for Boeing during the summer of 1999 under the Welliver Faculty Fellowship Program. As a result of this hands-on experience, all faculty members participating in the program are now better equipped to bring back a more realistic perspective of the roles and responsibilities of a practicing engineer.

Notes:

1. McMasters, John H., Holt, Steven C., and Derwin, William J. Adventures in Engineering Education at Boeing (The BCAG Engineering Division Summer Intern Program.) Aerospace Design Conference, Irvine, California, AIAA Paper No. 92-1093, (1992.)

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