THE LINK BETWEEN INDUSTRIAL AND ACADEMIC ENGINEERING

Anne E. Mohan[a], Enrique Sola[a], and James Patrick Abulencia[a]
[a] Department of Chemical Engineering, Manhattan College, Riverdale, NY 10471 USA

Session: Industrial Partnering for Preparing Engineers for the 21st Century Global Economy

Abstract

The transition from the academic to the industrial setting is often a trying one for most engineering students. Many graduating seniors are unsure of which industry they would like to work in, how to balance 40 (and often 50) hour work weeks and a social life, or how to function in an industrial culture that is oftentimes less well defined than an academic culture. For undergraduate engineering majors, the senior design project is the most comparative experience to that of the industrial workplace. During this project, students are given the opportunity, usually as a team, to utilize all of their previous coursework to accomplish a common technical goal. However, this project only covers one year. Industrial partnering can be used to prepare engineering students throughout their scholastic career for an ever-growing industrial setting. A partnership between a college or university and a company can give students exposure to a variety of industries, allowing them to make well-informed decisions when actively seeking employment. Such a relationship also has the potential to blossom into a recruiting process for the college involved. There are an infinite number of ways to incorporate industrial partners into academic coursework. Some examples are pairing senior design groups with an industrial "consulter," who would be able to lend some real-world insight to the project, or forming research projects based on specific company idiosyncrasies. Engineering educators play a central role in fostering these company/college relationships, and are imperative to their success and longevity. By remaining present and active throughout the interactions between students and professionals, an educator can ensure that graduates are well-equipped for their future careers in engineering.

I. Introduction

The nature of engineering education in America has morphed throughout history to meet the requirements of the country at any point in time. This modulation has been defined by the tug-of-war between practical training and academic training. Terry Reynolds provides a comprehensive view of the American engineer throughout history in his book, "The Engineer in America: A Historical Anthology from Technology and Culture." [1]

The appearance of engineering in America is associated with the emergence of the military during the American Revolution. The large-scale projects necessary during this time such as conducting sieges, constructing fortifications, and building bridges, required the knowledge of technical military engineers. Prior to the Revolution, the level of capital investment and risk in American society was never high enough to justify the expense of full-time technical experts.

Most American engineers during the 19th century were practically trained through apprenticeships or similar on-the-job training systems. This method of instruction was comparable to the British engineering tradition. During the construction of the Erie Canal, New York developed the most widely used on-the-job training system for civil engineers.

Formal engineering education began to appear in the mid-19th century at a handful of colleges such as the University of Michigan, Harvard, and Dartmouth. However, academic engineering did not become the prominent method of training until the Industrial Revolution during the late 19th century. The rapid expansion of industry led to the "ultimate triumph of academic engineering education over apprenticeship and related on-the-job training methods." [1]

Edwin T. Layton Jr. points out in his essay, "Mirror-Image Twins: The Communities of Science and Technology in 19th Century America," that by the 20th century, the systems of knowledge, institutions, and values developed by the engineering community had become a mirror image of those in the scientific community. For example, in science the highest status was accorded to mathematical theorists working on universal laws and lowest status to scientists working on practical matters like improved experimental apparatus. In engineering, highest status went to the practical designer and builder, lowest to the academic theorist.

In the 20th century, there was a shift in engineering education from practical training to academic training due to the nature of the projects during World War I, II, and the Cold War. It was observed during these times that those proficient in the fundamental sciences such as physics and chemistry were more apt to complete the projects required. The new disciplines of engineering that appeared as a result (e.g. electrical and chemical engineering) were built more heavily on basic science and often required more theoretical approaches.

As Lawrence Grayson comments in his book, "The Making of an Engineer – An Illustrated History of Engineering Education in the United States and Canada," this movement toward science continued until recent problems in the competitive position of many American companies in global markets has shown the disadvantage of neglecting industrial applications. [2]

Already a decade into the 21st century, the engineering community must address the differences and correlations that exist between engineering science and engineering practice. Shifting the focus of engineering education from one to the other is no longer sufficient if American engineering wishes to remain a prominent force in the global market. Forming a comprehensive undergraduate engineering curriculum through the marriage of industry and academia will ensure the fortitude of American engineering. Industrial partnerships are one method of enhancing the engineering curriculum.

II. The Gap between Academia and Practice

Many engineering graduates are unprepared for the working environment when they enter it. This can be due to any combination of reasons. Some have a difficult time applying the technical knowledge gained in schooling to the projects at work. Others find achieving the appropriate work/life balance while working 40 hour (and often longer) work weeks exhausting. But there are some common threads which unite entrant engineers in the work force.

There are major differences between the projects and assignments given in school and those given in industry. In school, students are typically given one assignment or project at a time to perform from start to finish, whereas in industry, an engineer will often be handed multiple projects at various stages of completion. An engineering practitioner must be able to multi-task and prioritize projects in order to be successful.

Another major difficulty that entry-level engineers struggle with is the lack of definitive feedback given in industry. While in college, an engineering student "knows" exactly how well they are performing based on the grades they are given. At work, no grades are given, and recent graduates consequently find it difficult to assess their performance. Young engineers must learn to be proactive and seek feedback if none is offered.

Finally, while most engineering students do some amount of group work while in college, the group usually consists of other engineering students of the same discipline. In the industrial setting, engineers will be required to work on multi-disciplinary teams. Graduating engineering students must be willing and able to communicate and work effectively with others in order to complete a project.

III. A Possible Remedy: Industrial Partnerships

One possible remedy to this disconnect between academia and industry is the implementation of industrial partnerships between colleges and industrial affiliates. Because industry is the primary "consumer" of recent graduate engineers, it follows that industry should be closely associated with the engineering curriculum. Most students, after receiving a B.S. in engineering from their undergraduate institution, begin their professional careers in industry immediately after graduation. However, most degree programs focus on engineering science fundamentals, which better prepare students for graduate study rather than industrial practice. [3] An industrial partnership can provide the necessary insight to the engineering work force that so many students need.

An "industrial partnership" can cover a wide range of interactions between a collegiate institution and an industrial company. One such interaction is the involvement of industry in the development and execution of senior design projects. Because of its direct and immediate benefits to both parties, this is one of the more widely used methods of partnering. However, there are many other ways in which industry can be incorporated into the undergraduate curriculum. Some examples of these incorporations are: [4]

- Engineering professionals providing lectures in the classroom about engineering practice
- Industrial donations and/or loans of equipment to the institution
- Plant tours of engineering facilities for students and faculty
- Advice and feedback on undergraduate curriculum

These types of industry-college relationships benefit both the industry and the university involved. Industry benefits by: (1) increasing the number and availability of well-prepared engineering graduates who are ready for real-world problems, (2) improving the traditional interview process by "interviewing" prospective hires over the duration of the partnership through internships, senior design projects, and/or independent research projects, and (3) receiving relatively cheap assistance on a company project that might otherwise be costly and time-consuming. Similarly, universities benefit by: (1) being able to provide more engineering graduates that are prepared and confident in facing industrial problems, (2) indirectly obtaining a recruitment pathway for graduating seniors whose impressive actions during the partnership result in job offers, (3) motivating engineering students by emphasizing the significance of their work on a real-world project.

In addition to these advantages, projects from industry can be the most influential and satisfying part of an undergraduate engineering student's career. [5] As Dr. John Lamancusa of the Learning Factory elaborates, "The industry involvement makes a real difference…It is an opportunity to innovate and design. Most importantly, there is a ‘customer’ and someone who really cares – the sponsor.”

Partnerships also clearly foster communication between engineering programs and industrial groups. Feedback from industry keeps the university up-to-date on the industrial climate, and the knowledge and skills required of a 21st century engineer. It thereby gives the college the insight required to “tweak” the undergraduate curriculum according to the skills necessary for success in the current industrial setting.

IV. Supporting Case Studies

One of the largest and most well-documented industrial partnerships in existence is the Manufacturing Engineering Education Partnership (MEEP), which is a collaborative effort between Penn State, the University of Washington, the University of Puerto Rico-Mayaguez, Sandia National Labs, and nearly 100 industrial affiliates. Some of the more prominent engineering partners of MEEP are listed in Table 1. The overall outcome of this partnership is the development of “The Learning Factory” at each of the institutions involved.

Table 1: Some of the prominent industrial partners of MEEP

AT&T	Hewlett Packard
Boeing	IBM
DuPont	Kodak
General Electric	Motorola
General Motors	Proctor and Gamble

In 2006, the achievements of this partnership were recognized by the National Academy of Engineering with the Bernard M. Gordon Prize for Innovation in Engineering and Technology Education. [3] One of the key factors of the Learning Factory was the industrial partnering, which included but were not limited to guest lectures by practicing engineers, and the provision of project sponsors by practicing engineers. The Learning Factory system was continually reviewed and revised by an industry advisory board. This advisory board was able to provide program guidance and curriculum feedback. Members of the industry partners made the following comments on the program: [6]

- “…provides access to pool of engineers for potential hiring.”
- “…helps students bridge academic and professional careers…more mature and better prepared students.”
- “…real day to day engineering, teaching the student how to apply what they have learned in the compressed time frame of real industry.”

Another interesting case study is the Boeing A.D. Welliver Faculty Summer Fellowship – an industrial partnership for faculty fellows. Every year since 1995, the Boeing Company competitively selects ten faculty fellows across the nation’s universities to visit Boeing operations in Seattle, Phildelphia, Huntsville, and Wichita. This is an eight-week program which focuses on “shadowing assignments” in which each faculty fellow “looks over the shoulders” of practicing engineering professionals. [7] This program concludes with a reflection on the essential attributes of engineering graduates. According to this reflection, the ten most important desired attributes are: (1) communication skills, (2) technical knowledge, (3) ability to define problems clearly and come up with solutions, (4) understanding the impact of engineering decisions on the environment, (5) team work, (6) critical and creative thinking, (7) practical knowledge, (8) concept of continuing education while working, (9) ability to work with shop floor employees, and (10) understand the concept of cross functional training/learning.

Dr. Owusu states that as a direct result of the Boeing fellowship, two new courses have been developed in the Department of Industrial Engineering at his university: Concurrent Engineering, and Environmentally Conscious Design and Manufacturing. This experience also allowed Dr. Owusu to develop a model for engineering education that takes into account how educators, industry, and government participate in the education system. [8]

The Boeing partnership is unique in that it involves industrial contact with the faculty of an institution, rather than the students. It allows faculty fellows to form a network of contacts with engineers and scientists within Boeing Company for the purpose of research and development. These research projects can be used for industrial sponsored projects carried out by students, fostering an industrial relationship with the students.

V. The Role of Educators in Fostering Relationships

The faculty of a college plays one of the most pivotal roles in creating and fostering an industrial partnership. According to Dr. Lamancusa from the Learning Factory, there are three important impediments to including industry-sponsored partnerships in the engineering curriculum: (1) lack of enthusiasm/support from faculty, (2) uncertain sources of present and future industry sponsors, and (3) a scarcity of space and facilities on campus to house the possible projects.

Invariably, every institution will experience each of these impediments to some extent. However, of all three factors presented, the most influential and determinant is the enthusiasm and support (or lack thereof) of the faculty. Dr. Lamancusa asserts that it is absolutely necessary that the administration and senior faculty uniformly endorse the industrial partnership activities as part of the undergraduate curriculum. [5]

In order to make the partnership as effective as possible, the faculty must be present and involved in all steps of its associated activities. The faculty provides the continual contact with industrial partners, and cultivates and maintains the relationship between the industry and the university. They also must periodically review and assess the practicality and development of the activities to be implemented. Most authorities agree that to sustain a successful industrial partnership, two or three faculty members (minimum) must be permanently involved in its progression.

VI Concluding Remarks

The focus of engineering education in America has shifted from scientific knowledge to practical experience according to the changes in societal demands over the last 200 years. In order for American engineering to move forward into the 21st century, both of these methods of training must be utilized by universities, since they are both critical to engineering practice. Industrial partnerships can prepare engineering students for real-world projects and problems while creating powerful contacts which could lead to job opportunities. This statement is supported by the two case studies presented here: the Learning Factory and the Boeing Partnership.

These industrial partnerships also enhance the “soft skills” of budding engineers. The industrial partnership experience allows students to learn and perfect skills not formally taught in the classroom such as oral and written communication, inter-disciplinary group work, and personal interactions.

Partnerships between industry and college also help foster students’ technical knowledge of practical engineering applications. Students are given the opportunity, through an industrial partnership, to gain industrial experience before leaving college. This type of technical experience is invaluable to employers.

Educators play an important role in the success of industrial partnerships, and must remain active in order for the projects to be successful. Students are motivated by a project’s relevance when attempting to solve a real-world problem, and are therefore more apt to perform better during the course of the partnership than they would in a typical classroom setting. An educator’s level of enthusiasm and participation in an industrial partnership affects the student’s enthusiasm and participation. It is therefore the responsibility of engineering professors to remain active and involved in the industrial partnerships of their college in order to ensure their success.

References

1. Reynolds, Terry S. *The Engineer in America: a Historical Anthology from Technology and Culture*. Chicago U.a.: Univ. of Chicago, 1991. Print.
2. Grayson, Lawrence. *The Making of an Engineer - An Illustrated History of Engineering Education in the United States and Canada*. John Wiley and Sons, 1993. Print.
3. Lamancusa, John S., Jose L. Zayas, Allen L. Soyster, Lueny Morell, and Jens Jorgensen. "THE LEARNING FACTORY: Industry-Partnered Active Learning." *Journal of Engineering Education* (2008). Print.
4. Lamancusa, John S., Jens E. Jorgensen, Jose L. Zayas-Castro, and Julie Ratner. "THE LEARNING FACTORY - A New Approach to Integrating Design and Manufacturing into Engineering Curricula." *1995 ASEE Conference Proceedings* (1995). Print.
5. Lamancusa, John, Allen Soyster, and Robert George. "Industry-Based Projects in Academia - What Works and What Doesn't." *1997 ASEE Annual Conference Proceedings* (1997). Print.
6. Morell, Lueny, John S. Lamancusa, Jose L. Zayas, and Jens E. Jorgensen. "Making a Partnership Work: Outcomes Assessment of the Manufacturing Engineering Education Partnership." *Journal of Engineering Education* 87.5 (1998). Print.
7. Owusu, Yaw A. "Impact of Industrial Partnership Experience on Engineering Education: Case Study with Boeing Company." *ASEE Southeast Section Conference* (2000). Print.
8. Owusu, Yaw A. "Systems Model for Improving Standards and Retention in Engineering Education." *Proceedings of the 2001 ASEE Annual Conference and Exposition* (2001). Print.
9. Smith, Robert P., Russell R. Barton, Craig A. Nowack, and Jose L. Zayas. "Concurrent Engineering: A Partnership Approach." *ASEE Annual Conference Proceedings* (1996). Print.
10. Gavert, Roy V. "Business and Academe: An Emerging Partnership." *Change* 15.3 (1983): 23-28. Print.