CONTRIBUTIONS OF INDUSTRY EXPERTS TO FACULTY DEVELOPMENT: EXPERIENCES FROM THREE UNIVERSITIES IN NORTH AMERICA

Edward F. Crawley
Massachusetts Institute of Technology
Cambridge, Massachusetts, USA

Robert J. Niewoehner
United States Naval Academy
Annapolis, Maryland, USA

Ron Britton
University of Manitoba
Winnipeg, Manitoba, Canada

Huan Lei
Tsinghua University
Beijing, P. R. China

Abstract
Fifty years ago, university faculty were distinguished practitioners of engineering with rich experiences in the practice of engineering in industrial settings. Today, most engineering faculty are experts in research and development in very specific disciplines. There is a gap between need and reality. Involving industry experts in the faculty development process may be a way to narrow the gap. This paper provides a rationale for faculty development in engineering skills, and links it with CDIO Standard 9. Three universities that have adopted the CDIO approach to engineering education – Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba – provide examples of bringing industrial professionals to engineering faculty teams, and of inviting industry experts to be involved in engineering education programs.

Keywords: faculty development, industry involvement, CDIO Standard 9

Introduction

The history of faculty development in engineering education has deep roots in engineering practice. Fifty years ago, university faculty were distinguished practitioners of engineering with rich experiences in the practice of engineering in industrial settings. Today, most engineering faculty are experts in research and development in very specific disciplines. They are evaluated on the basis of their disciplinary knowledge and achievements in terms of the impact and quantity of their engineering scholarship, and the levels of research income they generate. [1] New Ph.D. graduates join university faculties with limited experience in the practice of engineering.

There is a gap between need and reality. Involving industry experts in the faculty development process may be a way to narrow the gap. For example, sending engineering faculty to industry or introducing industrial experts to faculty teams could benefit engineering education programs, overall. This paper provides a rationale for faculty development in engineering skills, and links it with CDIO Standard 9. Three universities who have adopted the CDIO approach to engineering education - Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba – provide examples of bringing industrial professionals to faculty teams, and of inviting industry experts to be involved in engineering education programs.

Background

Engineering programs that adopt a CDIO approach to engineering education set high standards for faculty. They are expected to demonstrate competence in the personal, interpersonal, and product, process, and system building skills, delineated in the *CDIO Syllabus*, and be able to educate students in these same engineering skills. [2] As part of the *CDIO Initiative*, (www.cdio.org), universities have been exploring ways to enhance faculty competence in engineering skills. They examining best practices in building bridges between engineering education in the university and engineering practice in industry.

Past experiences of CDIO collaborating universities have shown that industry's involvement in engineering education has contributed to the improvement of the quality of that education, by providing learning contexts and environments, as well as much-needed resources. Specifically, industry contributes to engineering education programs by

- Building the context of engineering education (CDIO Standard 1)
- Identifying specific learning outcomes of graduates who are ready to engineer (CDIO Standard 2)
- Providing projects to stimulate 1st-year students' interest in engineering (CDIO Standard 4)
- Providing design-implement projects so that students experience the C-D-I-O cycle of product, process and system (CDIO Standard 5)
- Providing opportunities to faculty members to gain industry working experiences and professional skills, or by directly sending engineers to the program as lecturers or advisors (CDIO Standard 9)

It is this last reference to CDIO Standard 9 that is the focus of this paper.

Enhancement of Faculty Competence in Engineering Skills

Engineering faculty are expected to be innovators in research and development, and in teaching and learning methods. They are asked to adapt their teaching styles to one that is more student-centered, and to teach the personal and interpersonal skills, and product, process, and system building skills specified in the *CDIO Syllabus*. There must be a process for supporting faculty as they enhance their competence in project-based learning approaches, and in the practice of engineering skills that are highlighted in project-based learning experiences.

Enhancement of faculty competence must be accomplished while protecting the academic careers of faculty. Professional development activities should enhance their opportunities for promotion and tenure without putting future academic promotions at risk. The recognition and incentives for faculty need to support faculty professional development.

Effective CDIO programs provide support for faculty to improve their individual competence in personal and interpersonal skills, and product, process, and system building skills as described in the *CDIO Syllabus*. The nature and scope of faculty development varies with the resources and intentions of each program and institution. Actions that enhance faculty competence in engineering skills may include:

- Professional leave to work in industry
- Partnerships with industry colleagues in research and education projects
- Inclusion of engineering practice as a criterion for hiring and promotion
- Appropriate professional development experiences at the university

Enhancement of faculty competence in engineering skills related to the *CDIO Syllabus* is the focus of CDIO Standard 9.

STANDARD 9 -- ENHANCEMENT OF FACULTY SKILLS COMPETENCE
Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills

If faculty are expected to teach a curriculum of personal and interpersonal skills, and product, process, and system building skills integrated with disciplinary knowledge, they need to be competent in those skills themselves. Most engineering professors tend to be experts in the research and knowledge base of their respective disciplines, with only limited experience in the practice of engineering in business and industrial settings. Faculty need to enhance their engineering knowledge and skills so that they can provide relevant examples to students and also serve as role models of contemporary engineers. Faculty development and support may take forms similar to these three basic approaches.

- Hire new faculty who have industrial experience or give newly hired faculty a year in industry to gain the experience before they begin teaching.
- Provide educational programs, such as seminars, workshops, and short courses, for current faculty, or allow current faculty leave or sabbaticals to work in industry.
- Recruit senior faculty with significant industry experience to teach and mentor other faculty, or attract practicing engineers from industry to spend time teaching at the university. [2]

Each of these three approaches is described below.

Faculty Experience in Industry

In hiring new faculty, one would consider whether they have had any actual engineering experience. If so, this should be valued as a positive aspect of their background. If not, the department or program could offer released time to fill in this professional experience. As an example, some programs send newly hired faculty to work with industry for one year prior to the start of their formal teaching responsibilities. This program is aimed at professionals beginning their faculty careers immediately after their advanced degrees. The goal of the year with industry is to develop product, process, and system building skills, as well as to broaden their perspectives on engineering research. This time does not count toward the time required to gain promotion. As an added benefit, they return with a deeper understanding of the research needs of industry. Programs must have institutional support to resource this effort.

Education in Engineering Skills

Programs also face the challenge of encouraging existing faculty to teach personal and interpersonal skills, and product, process, and system building skills in their courses. A variety of approaches can lead to enhanced skills of existing faculty. One approach is to sponsor short courses or training programs within the university on personal and interpersonal skills, and product, process, and system building skills. Commercially available short courses can be used as well. Larger industrial enterprises often have extensive internal training programs and will allow local faculty to participate. Encouraging such programs also sends the message to faculty that program leaders consider these skills important and are willing to expend resources to help faculty acquire them.

Faculty leaves and sabbaticals that are often taken at other universities or in government agencies can be taken in industry. Again, program leaders must ensure this time is used to expand the faculty member's competence in teaching the engineering skills specified in the *CDIO Syllabus*. Otherwise, faculty might be inclined to pursue only their research interests.

Contributions of Practicing Engineers

Finally, programs can attract distinguished engineers with significant experience in product development and system building. Programs will need institutional support for this effort, as career engineers often do not satisfy traditional hiring criteria. An excellent example of a nationally sponsored effort of this type is the *Visiting Professors' Scheme*, sponsored by the Royal Academy of Engineering in the United Kingdom. [3] This program brings experienced engineering professionals back to the university to share their experiences with both students and faculty.

Faculty Development Practices at Three Universities

Three universities that have adopted the CDIO approach to engineering education describe ways in which their engineering programs involve industry experts in faculty development.

Massachusetts Institute of Technology

Since the Massachusetts Institute of Technology (MIT) was founded in 1861, its motto, *Mens et Manus*, has been at the core of its culture. What Founder William Barton Rogers called "the most earnest cooperation of intelligent culture with industrial pursuits" [4] shaped MIT in its dedication and respect for practical learning, and defined its purpose of "instituting and maintaining a society of arts, a museum of arts, and a school of industrial science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures, and commerce". [5] In such a cultural environment, MIT faculty have diverse academic and industrial backgrounds. They are dedicated to teaching and research, with relevance to the practical world as a guiding principle. The extensive collaboration between MIT and industry has an important effect on faculty development and the support of a practical learning culture.

Professors-of-the-Practice. The MIT School of Engineering has always had full-time and part-time appointments of practicing engineers. In the 1990s, the position of *Professor-of-the-Practice* was created to recruit and hire high-level expertise from the world of practice into the academy. Their main responsibilities were to teach and to conduct and supervise research. There are currently more than 20 *Professors-of-the-Practice* in the MIT School of Engineering. For example, the Department of Aeronautics and Astronautics has three *Professors-of-the-Practice*: Jeffrey Hoffman, Robert Liebeck, and Deborah J. Nightingale.

Dr. Jeffrey Hoffman, former NASA astronaut with extensive spaceflight experience, continues to participate in international space cooperation activities. He now combines his research projects related to the International Space Station with his teaching of space operations, design, and space policy. Robert Liebeck, member of the National Academy of Engineering, is a world-renowned authority in the fields of aerodynamics, hydrodynamics, and aircraft design. He now heads Boeing's blended-wing aircraft project, and works with students in experimental and capstone courses. Deborah J. Nightingale, member of the National Academy of Engineering, has a distinguished career in higher education, the private sector, and U.S. government agencies. With her experience in executive leadership positions in operations, engineering, and program management, she contributes relevant and practical insights to students' studies in these areas.

Visiting Lecturers From Industry. MIT also has *Visiting Lecturer* and *Senior Lecturer* positions that attract senior practitioners from industry and government to teach and advise students. Senior Lecturers complement the faculty; their professional experience and distinguished teaching accomplishments are equivalent to those of the faculty. Visiting Lecturers come to MIT to present series of lectures. The flexibility in appointments to these positions enables MIT to have faculty teams who stand on the frontier of knowledge and practice. For example, Fredric F. Ehrich of General Electric, Colonel John Keesee of the U. S. Air Force, and the late Robert Seamans of the National Aeronautics and Space Administration, served as Senior Lecturers in MIT's Department of Aeronautics and Astronautics.

CDIO programs aim to provide a Conceiving — Designing — Implementing — Operating context for engineering education. One of the main responsibilities of industry professionals is to help students understand real engineering environments, and to develop personal, interpersonal, and product, process, and system building skills. At MIT, these practitioners not only bring their experiences into the classroom, but also provide guidance in student engineering projects.

United States Naval Academy

When considering the engineering faculty composition at the United States Naval Academy (USNA), it is important to recognize the career activities of its graduating seniors. First, the Navy hires all USNA graduates. Secondly, all graduates go into operational fields, for example, driving ships, submarines or airplanes, or commanding marines in the field. No USNA graduates go directly into engineering jobs. After an initial operational sea tour (4 to 6 years after graduation), some will elect to move to career opportunities in engineering, acquisition, program management, or test and evaluation. There they will work in concert with the Navy's civil service engineering manpower, with the engineering officers, progressing to roles in systems engineering and program leadership. In contrast to other U. S. services, all officers in engineering and acquisition start their careers as fleet operators. For those who ultimately land in engineering capacities, they will necessarily be thrust into systems engineering or management roles. As long as they're in uniform, they do not work as discipline-specific engineers.

Military Faculty. From its founding, the Naval Academy has had a unique civilian/military faculty structure, distinct from both traditional university faculties and the faculties of the other U. S. service academies. USNA attempts to keep the Engineering Division staffing at 50% active duty military, and 50% civilian, believing that each contributes distinctive strengths to the overall program. The civilians are largely tenure-track with Ph.D.'s in their respective fields. The uniformed officers have at least a Master's degree, with half having a Ph.D. as well. The uniformed faculty members provide the connection with fleet applications, helping to motivate students to the relevance of engineering studies to their operational careers. The younger officers serve three-year tours, returning afterward to their sea-duty careers. In most engineering departments, they teach either service courses, such as *Statics* and *Dynamics*, or core courses such as *Electrical Engineering*, which are required of all midshipmen regardless of major. These junior officers provide a youthful enthusiasm, and model the role of young officers of high technical competence, drawing the connection between operations and engineering for students.

The more senior officers come to the Naval Academy after significant career accomplishments either at sea or in engineering roles, and then complete a Ph.D. en route to joining the faculty for the last decade of their uniformed service (nominally, in their forties). For the aviators, most are graduates of the Test Pilot School and will have served in acquisition, test and evaluation, or engineering assignments. Officers from other warfare areas will have served as engineers at sea, shipyards, or acquisition. Regardless of their academic discipline, they unavoidably bring a systems and operations perspective to engineering, viewing disciplines such as thermodynamics or materials science from the perspective of the 'whole airplane' or 'whole ship.' While they do not have the disciplinary or publishing credentials of the civilian faculty members, they have better insight into both what engineering officers do in the field, and commonly will have spent years working with civilian engineers in both government and industry. Hence, many are very conversant with the skills required of a practicing engineer in the modern workplace.

Civilian Faculty. Civilian faculty members fall into four categories. *Adjuncts*, as elsewhere, are term appointments with a Master's degree, teaching exclusively lower-level service courses, such as *Statics*, or core courses in electrical engineering. All have industry credentials. *Tenure-track* civilian professors have career histories, credentials, and expectations similar to those at research institutions, with the research and teaching balance shifted more toward teaching. Due to the promotion and tenure requirements, their development has the same strengths and weaknesses as at other research institutions. They are nationally published scholars with deep disciplinary expertise, and are expected to be master teachers. Few have held jobs outside of higher education, and lean toward a reductionist or engineering science perspective on the skills of engineers.

The last two groups are similar, both which are designed to be analogs of MIT's *Professors-of-the-Practice*, though that term is not applied locally. These two groups are distinguished only by the source of their funding. Internally funded members must hold a Ph.D. by law, whereas externally funded members need only hold a Master's degree. The latter is important, allowing USNA to include individuals with stunning credentials as senior executives in government and industry. Their appointments are rolling multi-year terms, paid on a full-professor's scale, yet without tenure. Of five Aerospace Department members in this category, four are retirees from industry or government, and three hold Ph.D.'s.

Boeing's John McMasters wrote insightful articles on the subject of aerospace industry workforce skills. He whimsically describes the industry demand for both the deep disciplinary expert and the systems thinker as "splitters" and "lumpers." The former are reductionists and analysts, while the latter are synthesists and integrators. One wants to split problems to their constituent parts; the other is interested principally sweeping the whole together. The aerospace industry, he insists, needs both, while noting that the latter are more difficult to develop and tend to be both more rare and more valuable to modern industry. [6]

Educators, developed and rewarded in traditional engineering science domains, will not likely transform themselves into systems thinkers. The process of their growth has demanded that they become disciplinary experts in order to gain promotion and tenure. If students are to grow to be systems thinkers, to respond to customer needs, they must see both "splitters" and "lumpers" in the classroom. Hence, while USNA military faculty are expected to bring a systems perspective. USNA is very deliberate about targeting hires within each of these categories among the civilians. The tenure-track system tends toward disciplinary expertise—the splitters, while senior military and *Professors-of-the-Practice* tend toward system-building perspectives—the lumpers.

University Of Manitoba

Manitoba is a province of approximately 1.1 million persons, about 800,000 of whom live in or near the capital city of Winnipeg. The economy is based on a mix of manufacturing, mineral exploitation, transportation, hydroelectric generation, medical research, financial services, agriculture and food processing. The University of Manitoba, located in Winnipeg, is home to the only Faculty of Engineering in the province. At any point in time, the student population averages about 1,200 undergraduate students and 400 graduate students. The university offers five different accredited engineering programs at the undergraduate level. Approximately 80% of the Professional Engineers in Manitoba hold at least one degree from the University of Manitoba, creating a close working relationship with industry.

Chair in Design Engineering. In July 2000, with the appointment of an Associate Dean for Design Education, responsibility for the further development of this relationship was established. This was further strengthened in January 2001 when the faculty was awarded a Natural Sciences and Engineering Research Council (NSERC) Chair in Design Engineering with the mandate to improve the quantity and quality of design within the curriculum, and improve the image of design, in general, throughout the province. As is the case in most engineering schools located in research-based universities, the majority of faculty members at Manitoba have based their careers on their research interests. Fewer than 10% of tenured staff have industry experience. Design classes, where they existed, tended to focus on the application of technical tools to constrained problems. In fact, there was, and continues to be, a great deal of debate over the definition of the term *design*.

The NSERC Chair provided resources to develop a home for design. It has provided a non-departmental base to appoint persons who support engineering skills, such as, communications and team building. It has become the Design Center to which students, staff and industry look for a broader perspective on design in particular, and engineering in general. Looking at the mandates of the NSERC Chair and the Associate Dean for Design Education positions, it was necessary to change the mix of professional resources available to students. The basic solution was to create positions defined as *Engineers-in-Residence* (E-i-R).

Engineers-in-Residence. Initially these were part-time (60%) positions filled by either retired engineers from industry, or principals in small consulting firms. They were provided with offices, communication connections and a mandate to establish relationships on campus, based on their industrial backgrounds. *Engineers-in-Residence* have exceeded initial expectations. It was anticipated that they would be a convenient source of industry-based input for both academic staff and students. They have become much more. There are now seven *Engineers-in-Residence* involved in a variety of ways. They are teaching, both singly and on teams, at both undergraduate and graduate levels. Within the capstone design courses, they serve as advisors, or, in civil engineering, as course coordinators. In these roles, they encourage their colleagues from industry to participate as advisors in the capstone courses. Design reviews have become a feature of capstone courses, with the review panels composed of engineers from industry. This broadens input well beyond the formal meetings, and improves communication between students and potential employers.

Supervision of student clubs, such as SAE, IEEE, and the Great Northern Concrete Toboggan Competition, is a time commitment that many academic staff find difficult to meet. Because these groups are focused on design, construction and competition, the backgrounds of the *Engineers-in-Residence* are very appropriate to teams' needs, and they have become very involved. One notable involvement is with the SAE student branch that has grown to be the 6th-largest student branch in the world. Competitive success has improved significantly and industry now provides financial, technical and in-kind support, thanks largely to connections developed by E-i-R faculty advisors.

Industry Collaboration. Because researchers are always looking for support from industry, the *Engineers-in-Residence* have become a source of information input. For the most part, their roles have been that of facilitators who appreciate the constraints experienced both on and off campus. This has led to a number of new research projects that have industry involvement beyond that of a funding source. Because of the pre-existing relationship that one of the *E-i-Rs* brought to the discussion, it has been possible to develop a formal working relationship with the Manitoba aerospace industry. Four industry partners -- three major companies and an aerospace human resources group -- have entered into a Memorandum of Understanding with the University that provides the resources needed to fund one of the *E-i-R* positions. Functionally, the Manitoba Aerospace Engineering Liaison Group meets quarterly for a working dinner at which the education needs of the companies and the functional academic constraints of the university are discussed in detail and at length. This has raised the level of understanding and involvement to a higher plain. Three other industry groups have approached the University with the intent of establishing similar arrangements.

An idea that sought to bring a limited number of individuals on campus to share their specific experiences with students and staff has grown well beyond the initial expectations. The University has benefited from the communication links that *Engineers-in-Residence* bring with them to access both human and physical resources from local and regional industries. Traditionally, the academic staff established connections by approaching industry. Today, industry is approaching the University to determine how to work together to improve the quality of engineering graduates and research results.

Summary

The involvement of industry in faculty development is growing with great benefit to engineering students and programs. The practices at the Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba are examples of introducing industrial professionals into the education program, and helping to increase the proficiency level of the entire faculty team.

MIT has created positions that attract practitioners from industry, including *Professor-of-the-Practic*e, *Senior Lecturer*, and *Visiting Lecturer*. These industry experts help faculty to incorporate personal and interpersonal skills, and product, process, and system building skills into the classroom and student projects.

The U. S. Naval Academy has a unique civilian/military faculty structure, with each group accounting for 50% of the faculty. The civilian faculties are largely tenure-track with Ph.D.'s in their respective fields, while the military group has rich working experiences and achievements at sea or in engineering roles. The combination of the two provides both disciplinary expertise and systems perspectives to engineering education.

The University of Manitoba appointed an Associate Dean for Design Education, and an NSERC Chair in Design, and created a Design Center. The University created several positions for *Engineers-in-Residence* who serve as teachers, team directors, advisors, project reviewers, and research facilitators, and help to bring more human and physical resources into engineering education.

At all three universities, they have created positions for practicing engineers in the faculty structure, and established flexible management systems to attract industry experts. These professionals join in every aspect of the education process, including program design, teaching, project instruction, student assessment, thus, providing real contexts for product and system lifecycle development.

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Biographical Information

Edward F. Crawley is Ford Professor of Engineering, and Professor of Aeronautics and Astronautics and of Engineering Systems at MIT. He is Co-Director of the CDIO Initiative, and co-authored *Rethinking Engineering Education: The CDIO Approach*. He currently directs the Bernard M. Gordon - MIT Engineering Leadership Program, and can be reached at crawley@mit.edu.

Robert J. Niewoehner is a Captain in the United States Navy and Professor of Aeronautics at the United States Naval Academy. Prior to joining the U. S. Naval Academy faculty, he served as a fleet F-14 pilot, and then as an experimental test pilot, including Chief Test Pilot for the F/A-18 E/F Super Hornet, throughout its development. He can be reached at niewoehn@usna.edu

Myron G. (Ron) Britton is Associate Dean for Design Education and Professor of Biosystems Engineering and Civil Engineering at the University of Manitoba. He has received numerous teaching awards, including the Canadian Council of Professional Engineers Medal for Distinction in Engineering Education. He can be reached at ron_britton@umanitoba.ca

Huan Lei is a Visiting Student and Research Associate to the CDIO Initiative at MIT. She is an Education Specialist and Ph.D. Candidate in Educational Management at Tsinghua University in Beijing, P. R. China. Her research interests are in engineering education, educational accreditation, and faculty development. She can be reached at leih.thu@gmail.com

Corresponding Author
Edward F. Crawley
Massachusetts Institute of Technology
77 Massachusetts Avenue – 33-402
Cambridge, MA 02139
1-617-253-3251
crawley@mit.edu