AC 2011-459: PREPARING ENGINEERING STUDENTS FOR WORK IN THE 21ST CENTURY

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Dean C. Millar is an Assistant Dean of Engineering at the University at Buffalo, State University of New York. In 1994, he began the Engineering Career Institute, a program that complements engineering coursework and gives engineering students key career-professional skills, including pre-employment classes and credit-worthy industrial employment experience.

Preparing Engineering Students for Work in the 21st Century

A Proven Professional Development Program to Supplement Required Engineering Technical Coursework. Goal: Enhanced Success of Students' Careers and Engineering Schools' Accreditation

Abstract

Statement of Need:
For students- Engineering undergraduate students are well prepared with engineering theory and fundamentals when they graduate but generally lack broader professional success skills. This imbalance diminishes the likelihood that undergraduate students will have sufficient career development tools for the right job or graduate school decision by commencement.

For engineering schools- ABET now requires proven technical as well as broader educational outcomes in their *Criteria for Accrediting Engineering Programs* specifically, Criterion 3, Program Outcomes, (a) though (k). A sample of these required outcomes are (d) "an ability to function in a multidisciplinary teams", (f) "an understanding of professional and ethical responsibility" (h) "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" and (k) "an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice".

A Proven Engineering Professional Development Program (17 continuous years) that supplements technical coursework to meet both student and engineering school needs:

Pre-employment success- includes step by step actions for engineering undergraduates to accomplish personal assessment and job-search skills to obtain career related co-op/internship employment and secure the best for them job offer when they graduate at the Bachelor's, Masters or Doctoral level.

Professional success- experts from industry and academia- includes essential engineering professional success subjects offering wisdom from appropriate industrial and academic experts. Presentation of professional success subjects enable engineering students to "hit the ground running" when they enter employment or graduate school.

Co-op or internship experience- is strongly recommended for undergraduate engineers in order to gain career related, on-the-job experience enabling application of theoretical knowledge to achieve tangible project results.

Paper

What does it take for a student to become an ideal engineering employment candidate now and during the next decade? That is a question that all forward-thinking students and educators should be asking themselves. An engineering education has to be outcome-oriented; that is, both students and institutions should have strategies to optimize the probability of students having a good job and career launch at commencement whether the bachelors, masters, or doctoral level.

Professional Development needed to supplement engineering coursework

Engineering undergraduate students are well prepared technically, but lack broader success skills when they graduate. Evidence of this imbalance follows. These "Major Research Findings" are evidence of the importance of business success skills as a supplement to standard engineering coursework.

Major research and findings are taken from a National Society of Professional Engineers publication entitled *Engineering Education Issues: Report on Surveys of Opinions by Engineering Deans and Employers of Engineering Graduates on the First Professional Degree.*[1]

"Preparedness for Practice: Engineering deans and employer respondents were asked to rate new engineers' preparedness for practice in eight areas and then indicate the value their organization places on preparation in that area. Figure 1 shows the results for each area."

"With the exception of 'Math and Science' there appears to be a wide discrepancy between the value expectations of the employer and the extent to which their employees are seen to be well prepared. This would further appear to reflect on the mismatch between curricular emphasis and employer expectation. It must be recognized, of course, that math and science are without argument the key ingredients—at least in the lower division—of an undergraduate engineering education."

These research findings are, more than ever, valid today. For proof of this one can Google search "engineering soft skills" and find hundreds of articles, speeches, and courses-- all designed to emphasize the reality that it takes a person with broad professional skills as well as technical competence to reach a full career potential and value to an organization. Accordingly, this paper contains important information for engineering students who expect to reach their full professional and life potential.

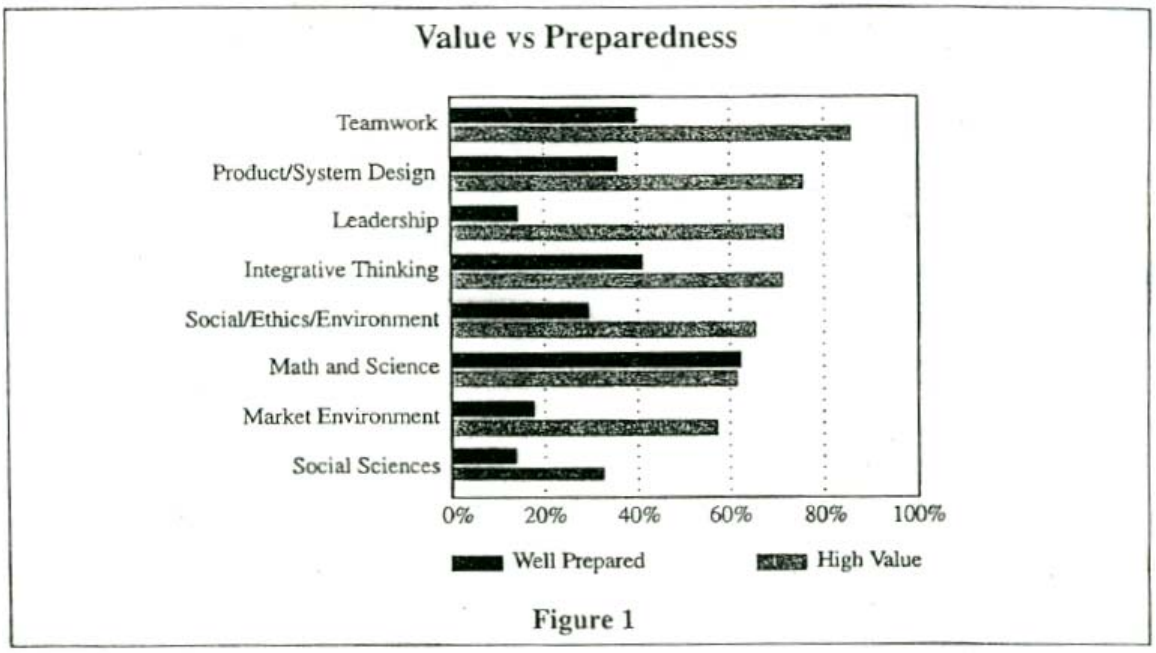

Figure 1

Employers Place a Premium on 'Soft' Skills

Ted W. Hissey, Director Emeritus of the Institute of Electrical and Electronics Engineers (IEEE), has said, "Today's companies place a premium on individuals who develop, practice, and continue to improve certain extra, or 'soft' skills… In the past many engineers preferred taking individual responsibility for developing a product…Today, corporations want individuals who exhibit strong teamwork, global perspective, and multiplexing capability." Mr. Hissey based these observations on "interviews with industry executives and managers, industry savvy government leaders, and academic leaders from around the world… The consensus results indicate that engineers and scientists should understand the career enhancing value of soft skills to progress in today's global, open market economy." Mr. Hissey concludes "highly successful professional engineers are not only technically astute, but also possess some of the extra, or 'soft' skills that many experts believe are becoming more critical for engineers and scientists today."[2]

Engineering schools need to comply with ABET Inc.

Our accreditation agency now requires proven technical as well as broader educational outcomes in their *Criteria for Accrediting Engineering Programs.*

Following are relevant ABET's Criterion 3, Program Outcomes which must be met for accreditation.

(a) An ability to apply knowledge of mathematics, science, and engineering
(d) An ability to function on multidisciplinary teams
(f) An understanding of professional and ethical responsibility
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic and environmental and societal context

(i) Recognition of the need for, and an ability to engage in, life-long learning
(j) Knowledge of contemporary issues
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice[3]

Our Response

This paper proposes that engineering education will, because of logical and competitive factors, be drawn to a strategic plan for ideal engineering professional preparation. That preparation will include the goal of a student having a right job when they graduate. Moreover, it will include exposure to the professional requirements of an on-the-job engineer. Going forward, this paper emphasizes the need for high-quality technical coursework, and then expands to a proposed strategy for students to not only land the right job but also receive early-start professional career information. Results competition is increasingly keen for both students and their institutions; this paper encourages students and schools to meet that challenge.

The following "Keys to Success" are, and will become, important for any student to become an ideal engineering employment candidate.

Key 1. A solid technical engineering education- Specifically, students need a sound grasp of engineering theory and fundamentals from an accredited college engineering curriculum. This includes the theoretical, applied lab, and computer knowledge to meet the technical requirements to be an entry level engineer. The remainder of this paper should in no way be interpreted as diminishing the requirement for engineering students and professionals to be technically competent. A solid foundation of technical coursework is essential for a practicing engineer.

Key 2. A professional development course- This paper proposes a professional skills course or program designed for engineering students who want to complement their technical curriculum with employment/ professional preparation. This includes engineering career planning, effective job search, and professional success subjects for transition from school to ready-to-start co-op employment. More details for this proposal will follow in this paper.

Key 3. Co-op/internship experience- Career related, on-the-job experience allows students to apply theoretical knowledge to achieve evidence-based project results. Co-op and internship programs provide great value, allowing students to gain exposure to real engineering employment situations and demonstrate their applied technical and teamwork skills. An additional benefit for students is auditioning for a permanent job offer with their co-op or internship employer when they graduate.

A solid technical engineering education (Key 1 above)

Engineering curricula are intently focused on providing a sound grasp of engineering theory and fundamentals, as stated above. This observation is reinforced by the ASEE observation earlier in this paper that "it must be recognized that math and science are without argument the key ingredients—at least in the lower division—of and undergraduate engineering education." Again, this paper absolutely supports the requirement for graduating engineers to

have a solid technical engineering education. The proposed ideal academic preparation for a right job at commencement and a successful engineering career, however, takes engineering education two steps further as suggested by ASEE and ABET previously in this paper:

A professional development course (Key 2 above)

The School of Engineering and Applied Sciences, University at Buffalo, the State University of New York has offered an Engineering Career Institute for the past 17 years. It is presented here as a course model to supplement engineering coursework, meet the needs of students' career success and support engineering schools' accreditation. **The Engineering Career Institute (ECI)** is a preparation for co-op employment course. ECI provides one academic credit for pre-employment classes with instruction on how to get the right job, culminated by presentations from experts from industry and academia who enlighten students on essential career success subjects. Dean C. Millar has taught the course for 17 years and has just written a textbook for ECI, *Ready for Takeoff!* -- A Winning Process for Launching Your Engineering Career, published by Prentice Hall/Pearson in August, 2010. This textbook is currently used in ECI classes. The following syllabus is offered in this paper as a model for supplementing technical coursework with logical steps for getting a right job/career launch.[4]

Pre-employment Subjects-- can be taught in spring or fall semester. Some subjects can be combined into one class, for example, the first three and last two subjects. These subjects constitute a series of steps that students can take to ensure maximum probability of obtaining a co-op/intern job or position when they graduate. Emphasis is placed on providing students with comprehensive information so they can take self-initiated, competent action at each stage in the process. Following is a summary of the pre-employment subjects.

- Introduction to your plan of career development. You are in charge of your future.
- Self-analysis- to know yourself, and subsequently, sell yourself to an employer.
- Market research of engineering opportunities- engineering functions/employment options
- Your resume and cover letter-geared to obtain interviews with targeted employers.
- Your university's career center- for career planning, job-search, campus interviews etc.
- Organizing and executing your job search, including networking, Internet search, etc.
- The successful interview-presenting your competence to a researched employer.
- Follow-up action-after sending resumes and after interviews. ABC = always be closing.
- Starting employment- your boss and you, learning the culture and professional etiquette.

Professional Success Subjects-from Industrial and Academic Experts—the University at Buffalo's Engineering Career Institute (ECI) features classes at the end of the semester in these professional success subjects, taught by experts in each area. For those schools where it is impractical to bring in this range of presenters, the *Ready for Takeoff!* textbook offers the expert advice on each subject that is taught in the classroom. The professional categories and subjects follow.

Professional functions and opportunities- this part of ECI begins, as indicated, with an overview of industry- featuring three chief executive officers and two engineering directors who explain to students their perspectives of what it takes to be successful as an engineer. The section continues with subjects of project management, value engineering, quality engineering,

lean enterprise, engineering professionalism, and entrepreneurship, academic careers and graduate school, and becoming a global citizen. Each subject is very important to employers and engineers' careers. Each topic gives wisdom of industrial or academic experts and how to apply the concepts.

- Overview of industry: executive panel- from 3 CEOs and 2 engineering directors
- Project management-how to manage a project, by two project managers
- Value engineering-including value analysis and its use for engineering optimization
- Quality engineering-including Total Quality Management, Six Sigma and ISO
- Lean enterprise-including the seven forms of waste and five lean principles
- Engineering professionalism, ethics, and responsibility-essential knowledge
- Entrepreneurship-for those who want to start their own business
- Academic careers and graduate school-advice from the Dean of Engineering
- Becoming a global citizen-including an international academic experience

Personal and professional success skills- This part of ECI completes the total engineering career launch information package by focusing on personal and professional success skills, the importance of which is introduced as a corollary throughout the Professional Functions and Opportunities section, above. This final section of ECI also responds to the conclusion of the major research findings, earlier, "with the exception of 'Math and Science', and there appears to be a wide discrepancy between the value expectations of the employer and the extent to which their employees are seen to be well prepared."

- Self-reliance, planning, and time management- you are in charge
- Empowerment and motivation- for peak performance of yourself and others
- Interpersonal skills- dealing with people on the job
- Teamwork in industry- being successful on engineering teams
- Leadership- how to become an effective leader
- Effective writing and presentation skills- including reports and public speaking
- Transition to industry- success advice from recent engineering graduates

Co-op/Internship Experience (Key 3 above)

"Evidence sells" is a mantra we encourage engineering job hunting students to embrace. Resumes and interview responses should include every relevant evidence-fact that will convince an employer that a job candidate is competent, motivated and successfully results-oriented. Therefore, students are encouraged to quantify their contributions as co-op students.

It has proven very beneficial to students and the co-op program for co-ops to, when possible, establish a dollar or percentage value to co-op/internship results. This becomes "track record" evidence of quantifiable success. It verifies the value of the student and the co-op program to future employers.

With "evidence sells" in mind, following is actual feedback from employers about the value that co-op students contributed to their organizations:

Co-op Success Stories; Valuable Results from UB Student Employees[4]

Northrop Grumman - Eric used Visual C++ to automate laboratory test procedures on new component devices in order to speed up the production of these devices. As a result of the improved test procedures time spent on testing has decreased by 68%.

BOC Edwards/Precision & Vacuum Parts - Hilbert came up with a very good substitute vane material for vacuum pumps. This reduced the cost of these vanes by over 90%.

BMP America - Tomasz's analysis of our oil roller productions process allowed him to incorporate several design changes which increased productivity. He reorganized the material database into an improved and user-friendly format. Both projects were immediately implemented and each has displayed successful results. “Estimated value of work results: $40,000 per year.

United Rentals - Shaun, with an employee teammate, designed an automatic device which reduced production cycle time by 80%.

Goodyear Dunlop Tires - Jennifer developed part of an improved steam line program which is being implemented. The result will be a projected 20% cost saving, i.e. $ 500,000/yr.

HBE Company - Maureen was responsible for changes in sub-contracting and purchase orders that totaled $134,350. She also saved the company about $8,000 by negotiating quotes with contractors**.**

Reichert -Bob designed a new test protocol for a laboratory instrument that was about to be released by the company. The protocol was instituted as a standard procedure for all new instruments.

Motorola - Chris saved a minimum of $50,000 by building a more economical way of manufacturing heated seat modules. He accomplished this by narrowing process flow options and obtaining budgetary cost estimates from equipment suppliers.

Praxair - Kathryn recovered $100,000 in capital investment by troubleshooting and developing methodologies on a laboratory analytical instrument.

Prestolite Electric - Without the competent assistance of our UB Engineering interns, we may not have accomplished our goal of QS 9000 certification. They worked on elements of product flow, operator's instructions and other advanced product quality planning requirements for QS 9000.

Steuben Foods - Using Value Engineering principles, Rick convinced us to purchase a $110,000 machine which increased production efficiency such that the equipment paid for itself in six months.

Xerox Corporation: Ink Jet Focus Factory – Sawson demonstrated good problem solving skills and saved $20,000 for the company.

Conclusion

This paper has been founded on evidence that engineering undergraduate students are generally well prepared with engineering theory and fundamentals when they graduate but generally lack the broader professional success skills to optimize their chance of obtaining the right job or graduate school admission by commencement. In addition, engineering schools need to comply with ABET's broader professional educational outcomes in order to be accredited.

Implementing the proposed "Keys to Success" will help students to become attractive engineering employment candidates, while ensuring that engineering schools meet ABET accreditation requirements. Essential, solid engineering coursework, a professional development course and co-op/internship experience will offer a full package of educational preparation for successful engineering careers. Both students and engineering schools who adopt this process should emerge as winners.

References

[1] *Engineering Education Issues: Report on Surveys of Opinions by Engineering Deans and Employers of Engineering Graduates on the First Professional Degree.*[1] NSPE Publication No. 3059, November 1992- *First Professional Degree Survey Report, page 5*.

[2] Ted W. Hissey, "Enhanced Skills for Engineers," *Proceedings of the IEEE* 88:8, (August, 2000).

[3] *Criteria for Accrediting Engineering Programs*, "Effective for Evaluations During the 2009 – 2010 Accreditation Cycle," Incorporates all changes approved by ABET Board of Directors as of November 1, 2008.

[4] Dean C.Millar, *Ready for Takeoff! -- A Winning Process for Launching Your Engineering Career*, Prentice Hall/Pearson, 2011.