Bridging the Gap

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I'd like to address the gap between the academic and practice control community – why it exists, the issues it creates, things that can be done to bridge the gap, and the need for industry mobilization to cause change. My focus is on the US situation. There are two issues. One is the general lack of practice experience in the faculty, which aligns student perspectives to the science/research 'way'. And the other is the absence of a control engineering BS curriculum.

Engineering is a method, an approach, a way. It is in contrast to the way of the scientific method. Engineering must lead to action, not knowledge.

We need industrial experience to participate in the definition of the curriculum content, but not to the exclusion of best practices in education. We need industrial experience to help faculty understand that human resource development is much more than just the intellectual aspects of engineering science, but we need to retain their research drivers for scientific advance. I am hoping that this article awakens the power that can cause change, while preserving the good that we have.

Although the fundamental reasons for the gap are both many and large, and although I do not think the gap can or should be eliminated; I think that there is much that can be done within rational funding models to bridge the gap.

The first part of this essay will describe the problem. The second part will discuss solutions. I am addressing both the industrial and academic individuals. I think that each side has misperceptions about the gap, and that sustainable solutions must be grounded in understanding the phenomenon.

The Gap

There seems to be general agreement, in both industry and academe, that engineering faculty should have engineering practice experience. If professors are going to teach students how to be engineers, the instructors need to understand engineering. However, there is little practice experience among faculty. As a result students are guided by the research, science, perfection, individual performance, and intellectual values that characterize their teachers; not the contrasting values related to sufficiency, urgency, compliance, partnership, safety, personal effectiveness, and fruition that are essential for business success. Further, students are taught engineering science principles (which is good), but in an idealized and out-of-context manner (which is not).

While I think we do an excellent job in preparing engineering students with the technical skills needed for them to become engineers, we do it within an academic context. As a result, they do not graduate with the perspectives and expectations to be successful in the disparate context of industrial practice.

I am one of them. It took me two years of work as a process engineer to understand the new environment, to begin my becoming 'industrialized' to be able to be an independent and relevant contributor within the business environment. Two years is a typical induction period. In all, I worked in industry 13 years. My last role, supervising a group of engineers, led me to understand the importance of human resource development, and the need to accelerate the transition of entry-levels from academe to industry.

The two-year transition period is substantially the result of the misdirection of the student persona for engineering function, and is often called 'the gap'. It is not just the result of which topics are taught, or not included in the curriculum. More so, it is the result of being raised as a student, not as a business partner. The gap undermines careers, delays productivity, and costs industry. I see it as a national productivity issue. And, industry, academe, and government are all involved as stakeholders. We need to bridge the gap. Unfortunately, the ways, the *modus operandi*, of those three stakeholders are very different. If we are going to bridge the gap, we need to understand the environment that creates the gap and its impact on industry. What seems to be obvious solutions from a business perspective will not work in academe.

I believe that engineering education is substantially fulfilling its multiple missions, that my university is as good a place to work as any, and am particularly very proud of the accomplishment and quality of the students in my program. Having switched to an academic position after working in industry, I see that what is taught is useful and relevant, even if the instructor is not fully aware of the application context. And, I find that instructors without industrial experience can be excellent teachers.

Although, happy about my situation and educational outcomes, I believe much needs to be done to improve education. I would like this criticism to be accepted as an initiative to add value, so that Engineering Education can achieve what is possible.

The gap is not about the topics in the curriculum

Some think the gap is about the topics in the curriculum. We don't teach what a particular entry-level engineer needs to know – like programming in a particular DCS or PLC, using a particular technique, or writing reports in a particular manner. That is not the issue. The curriculum topics are directed by Industrial Advisory Committees, the accreditation agency (ABET), the Fundamentals of Engineering Exam, and collective exchange of best practices and curriculum content sponsored by several professional societies. They are, substantially, the right topics. But, we cannot teach in only 4 years what one 40-year career needs for one industry sector, let alone the needs of every separate career in all sectors.

Figure 1 uses a Venn diagram to illustrate the concept of career relevant knowledge. 95% of what we teach in school is useful for any particular career and life, but it comprises only 5% of what the individual needs to be functional, happy, and successful.

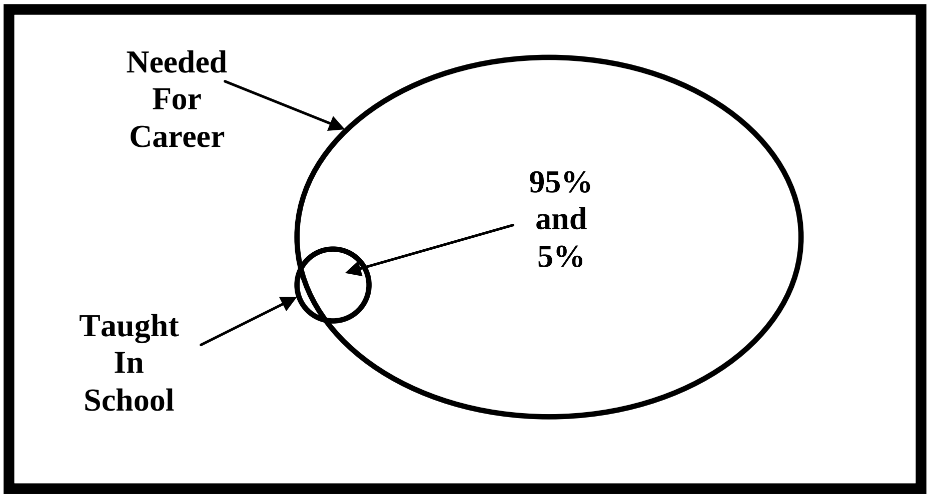

Figure 1 - A Venn diagram of career-useful knowledge

Education is to provide graduates with adequacy in the fundamental skills of a discipline and certify their fitness to self-learn. Often, students and employers think that college education is about teaching the necessary skills. That is partly right, but the subset that can be taught in 4 years represents the tip of the iceberg, perhaps 5% of what will be needed. We can only teach the essential minimal set. Employees must learn the other 95%.

Exactly what topics comprise that 5%, to me, is not the question. Many subsets of knowledge are fully equivalent for developing functional engineers. Sometimes educators think it is about teaching the fundamental skills and misdirect curriculum development energy in seeking the perfect subset. But, what is often missing in the faculty understanding of their role is that we need to prepare students to self-learn the other 95%. While we are teaching any particular 5% subset, we need to be preparing students to self-learn, integrate, think critically, and evaluate. The essential career grounding that education needs to provide is the student's ability to learn the other 95%.

Why is there a gap?

The 'business' of academe contributes to the gap. We need funding and stature, and how we get both shapes who we hire as faculty members and how they understand our discipline. We teach initial concepts to a mass of novices, which is in contrast to one-on-one coaching of apprentices for professional development. There is a 'way' of education that is different from the 'way' of business, and this 'way' is what causes the gap. There are several aspects of the unique way of academe:

Stature: Academic stature comes from public visibility of intellectual contributions. If creativity led to a great invention, we would quietly patent it, manufacture it, generate income, and not need stature. But, academe does not invent, manufacture, or run business. The private sector does that. Academics investigate pre-commercial, years ahead, possibilities; or provide the technical and science underpinning of techniques that have arisen in either academe or industry. We publish our findings in the open literature (textbooks and handbooks) providing access to knowledge and tools facilitating those in the practice. We give away our product. Our job description requires each of us to establish a public reputation as an individual expert who advanced the understanding of science or technology. Necessarily for journal acceptance, engineering understanding must be stated in our mathematical language. So, we hire creative, self-driven people who can investigate, mathematically analyze, openly publish, and establish individual stature. We seek individual performers who are competitive in a public, intellectual, mathematical, one-upmanship game. This is probably not the persona that industry is seeking in a business partner, but it is the persona that is shaping students.

Funding: A substantial portion of university funding comes from research grants, and the magnitude of research funding has become our primary metric of success and university ranking. Research funding supports the University infrastructure, the research activities that lead to stature, and the professor's salary.

Most funding comes from the government, and it is not directed for product or process development. Value creation is the role of the private sector. Academic research funding is aimed at developing the pre-commercial knowledge base (to position graduates to be able to use technology when it becomes practicable in the future), or solving social problems (such as medical, health, biofuels). Most academic research funding steers the faculty away from solving extant problems for industry. Although disbursed by government agencies, the proposals are judged by the visible national experts – primarily senior academics. So, we hire people who can appeal to the established academic values to be successful in getting grants. Again, that skill probably does not represent the persona that makes a good engineering partner in the private sector; but, again, it is the one that is shaping student perspectives.

Experience: To transition from a student to a partner, it takes about 2 years immersed in the industrial environment, full time, subject to industrial performance appraisals, within the energy and competitive aspirations of other new employees, within the diverse risks, and perceiving industry as your exclusive career path. It takes about 5 years of experience to be able to identify and articulate the misperceptions of others, to coach entry-levels for the transition. Although academe does not hire for industrial experience, we recognize that it is a positive attribute, albeit inconsequential to university goals. And, two issues 1) a 5-year delay in starting a research career, and 2) the industrial values that contaminate purity in proposals, are often viewed as a significant negative attributes when seeking a person who can be a successful faculty hire.

Research: The technical work of professors is related to the exploration of possibilities. It is not even applied research within an entrepreneurial context. It is not development, and certainly not design or operations within a manufacturing context. It is done external to the context of economics, manufacturing EHS&LP considerations, or the legal issues associated with contracts, patents, and trademarks. When we find success in analyzing one aspect of a problem, we celebrate glorious achievement with a publication. But, the success is about one end of the stick, it is related to the tip of the iceberg, and is far from a complete comprehensive solution. It is far from describing a sustainable implementation. The academic environment attracts those who are interested in mathematical analysis or concept creation. It does not attract those who are interested in bringing it to fruition. It rewards those who are good at the academic way, and participation and success direct them further away from engineering utility.

Pedagogy: The business of academe also includes instruction, and best practices in teaching contribute to the gap. Pedagogy is the art and science of best practices in getting students to learn. We are aware of this, and are good at teaching. But, consider the context: Students do not yet have industrial practice experience. Accordingly, they cannot relate to either the complexity of equipment or confounding impact of the business context. Further, they are learning the fundamental concepts for their first time. So, purposely we teach idealized, simplistic concepts that are isolated from confounding distractions. We must create attainable challenges to keep students incentivized. Further, we have to teach to the masses, but test for individual ability. Accordingly, we assign exercises and tests that can be done by novices, which can be efficiently graded, which have absolutely right or wrong solutions that cannot entangle us in pseudo-legal grading challenges. We have neither the time nor the funding to provide extensive labs, or to coach for performance on open-ended projects.

Time: Four years of college cannot prepare a person for a lifetime of skills. When I teach the chemical process control course, I include many practice relevant aspects, but cannot include all. There is not time in the one control course within the chemical engineering curriculum to fully prepare engineers for process control jobs. Further, presently, some educators are questioning the need for a process control course within the academically-perceived priority of all of the other topics and legislative pressure to reduce the credit hours in the degree requirements.

Survival of the fittest: Table 1 summarizes the differences in the environment between school and practice; contrasting similar aspects. We prepare students within the environment of the left hand column, and promote them for fitness in that environment. We develop their *modus operandi* for success in school, which misdirects their understanding of what life in the practice is all about. To be able to lead themselves across the gap, they need to understand the 'way' that they acquired and the new 'way' needed for success in industry.

Table 1 - Comparing the student and engineering environment

STUDENT	ENTERPRISE PARTNER
Learning, Internal	Bringing change to fruition, Value creation, External
Follow Professor's guidance	Leads own studies
General studies, Probable importance	Task-specific studies, Necessary
Professor evaluates and assigns grade	Self-evaluation of sufficiency
Quantify progress by skill inventory	Quantify progress by trail of contributions
Simple, idealized, isolated concepts	Complex, interactive, nonideal reality
Individual	Team
Old and known, Certainty	New and uncertain
No risk, Little accountability to others	Significant risk, Accountability to many others
Describe it mathematically	Make it work

Abstract (concepts, equations, schematics)	Concrete (equipment, measurements, people)
Answer = equation, number, report	Answer = cash flow
Write to show technical prowess	Write to get action
Understand thoroughly and quantitatively	Understand qualitatively
Passive	Active
Science & skill focus	Business impact & market focus
Perfection	Sufficiency
Research	Development
Unconstrained, unbounded, freedom	Constrained by laws, regulations, EHS&LP, contracts, economics
Self-paced, for personal convenience	Urgency
Celebrate youth	Develop adults
Solve problems	Realize opportunities

One can also contrast the performance measures between academe and industry. We select students for graduation based on their ability to get high grades through knowledge accumulation and success in playing the testing game (speed, elementary, etc.) – as defined by the teacher. We recognize them for honors courses, isolated creativity, and intellectual achievement; and reward them with letters (after their name). By contrast, industry honors employees for project fruition, for comprehensive sustainable solutions to business relevant opportunities, by facilitation of others; and rewards them with expanded responsibility and independence.

Don't Send Money

This is an opinion related to the gap between the preparation of graduates for engineering, specifically control engineering, and the needs of the practice. There are solutions. The reader might be aware that I am a professor, that universities need money, and anticipate that my solutions will be grounded in industry and alumni providing university financing. By contrast, my message is, "Don't send money." If you do, we will use it to attain our aspirations, which you may likely find to be a misguided use of your hard-earned resources.

Engineering education is important. The role of professors is to develop 1) human resources, 2) professional knowledge, and 3) the infrastructure – all through which engineering can contribute to human welfare. Item 1: Developing human resources is more than just teaching the engineering sciences; it implies full-person preparation for career and life. To properly direct human development, teachers need to understand the practice context. Item 2: Developing professional knowledge is the creation of a body of knowledge, tools, and procedures that are useful. Developing something useful requires application understanding, validation within context, and creative exploration to unveil new and practicable. Item 3: Developing the infrastructure means creating instructional materials, agencies, societies, etc. To be sustainable, systems must be grounded in the reality of all constituencies.

Embodying engineering values, it all should be aimed to improve the human situation. Utility within context is essential. Scientific perfection and intellectual knowledge are important, but those are academic values. Those are enabling tools, not the goal. The problem is that a professor's focus, understanding, experience is about the enabling tools, not the context of their application.

A Summary of the Situation

Research is the primary criteria for hiring faculty members and for defining salary and career promotion. Research success is dominated by government funding which is directed to define enabling knowledge for future possible technologies, support defense, enhance health, and address social problems. Research in academe focuses on one small part of a comprehensive problem, a bite that can be successfully worked by a small research team in a short time. The gatekeepers of publication and awards are primarily top-ranking academics. There is essentially miniscule funding related to solving extant industry problems. This all means the incentive is to hire those who can be successful with isolated issues within the idealized math-science arena of today's research funding.   Accordingly, although we can be creative and skilled in the fundamentals of engineering science, we fall short of the knowledge development that is relevant for the practice.

What we teach has utility and embodies the essential skills. However, teachers have little application or business understanding, teach novices, teach external to engineering practice, and only have time to include the basic and idealized concepts. Accordingly, although we can be excellent in getting graduates to understand the fundamentals of engineering science, we fall short of the human resource development for career preparation and life. An engineering professor attempting to help a student understand engineering practice is like a high school math teacher trying to differentiate a chemistry degree and from one in chemical engineering.   The absence of substantial and definitive experience relays fuzzy notions, folklore, or wholly misses aspects.

There is a gap in skills earned in school and those needed for practice. But a 4-year program cannot prepare every graduate with every skill that every diverse career will need. Education can prepare them to be able to learn those skills. I think we do, and do not believe that the gap is related to skills. I believe the gap is related to perspectives contrasted by 'way' of industry and that of academe.

That was about engineering education in general; and in the United States it is one step worse for automation, instrumentation, or control engineering because there are no such BS engineering programs. This contrasts to the availability of such programs in many other countries. Having attempted to start control programs at two universities, and serving on ISA taskforces seeking to initiate others, it seems obvious to me that universities have no incentive to create control or automation programs. Reason 1: The number of high school graduates seeking engineering degrees is limited. Adding a new program will not increase engineering enrollment, it will only shift students from one program to another. There is no enrollment incentive to create an automation engineering program. Reason 2: A new program, of modest size, requires the resources to support about 7 to 12 faculty members, staff (department and services), labs, facilities, materials, and research. I estimate the annual cost to run a minimal program to be $6M per year. The only incentive for a university to initiate a new program is if the anticipated research or endowment income would more than finance the program cost. There has not been such a source of funding for control engineering in the US.

What are the consequences of the gap?

Although graduates enter industry with fundamental skills, their perspectives are academic. They are aligned with learning, not doing; with perfection, not sufficiency; with knowledge, not fruition. Their perspectives about their role are not aligned with the 'way' of business. Accordingly, industry must invest in the coaching, training, and activities to redirect new hires. The gap costs employers time and money, and delays new hires from attaining functionality.

A second aspect of the gap deals with full utilization of faculty creativity and insight. Faculty members are skilled in understanding details, and seeing possibilities. They are creative, energetic, intellectually select, and grounded in critical thinking and logical mechanistic analysis. One would think that they are capable of helping industry solve problems, but they have little inclination or skill to solve a problem within a confounding context. They are good at analyzing one idealized portion of the issue. My greatest criticism of the content of academic publication in control journals is grounded in the incompleteness to an application context (such as bumpless transfer, constraint handling, robustness to process changes, accommodation of noise or spurious signals, computational time, or skill level to implement), which is replaced by a demonstration of advanced mathematical analysis (Lyapunov theory, extended Kalman filtering, and such greatness). The gap means that the potential for faculty to contribute to the practice is not fully utilized for the greater good.

Industry cannot expect to hire a faculty member to provide a practicable solution. Although, with close supervision, they can be kept on track. Also, faculty members can provide advanced training to facilitate your engineers.

The gap is especially significant in the field of automation and control. Not only does it include the academic to industrial perspective contrast, but it also has a skill component. Undergraduates in the US, primarily in chemical, electrical, and mechanical programs, have one course in control. Usually, it is taught by a professor with no control practice experience, and taught from a textbook chosen by the instructor for its content-compatibility with the professor's inclinations. Mostly, the control course is comprised of lessons in the mathematical analysis of dynamic systems, and the glorious magic of solving ODEs with Laplace techniques. Since there is no automation or control undergraduate program in the US, just one course in the underlying mathematical analysis, industry must invest significant post-graduation training to prepare new hires for instrument and control systems.

We use the term "ivory tower". Wikipedia indicates, "From the 19th century, it has been used to designate a world or atmosphere where intellectuals engage in pursuits that are disconnected from the practical concerns of everyday life. It usually carries pejorative connotations of a willful disconnect from the everyday world: esoteric, over-specialized, or even useless research, and academic elitism."

I liken the gap to a split of a landmass that isolated members of a common species, and created diverse environments. Then independent evolution created new species. Now the two species can no longer share genes. Because of the gap, I think academe and the practice are in danger of not being able to synergize (share genes).

Here is an example of the barrier to synergism: Early in my academic career industry feedback was, “New hires don’t know how to communicate.” Faculty agreed, and initiated a fix. They had English graduate students grade for grammar and punctuation perfection, and directed the undergraduate students toward literary quality and intellectual stature in sentence structure. But, they still had students write academic papers: Start with an abstract that talks all about the issue but provide no substance, and bury the conclusion in the end, after lengthy distractions about experimental and methodology. Make conclusions which are based on rational logic and absolute knowledge, not issues or context. Make claims with certainty about the past, not directing what to do in the future. And, write in a passive, third person voice (to imply human disengagement; and, as a result, untainted rational scientific analysis), neither active nor present. How the academics interpreted “improved communication” was not consistent with the practice feedback, and the academically prescribed solution sent students farther from the industrially desired target.

What initiatives are underway to bridge the gap?

Recognition of the gap is not new. In the early 70s the American Chemical Society programmed national sessions related to addressing the problem and its solutions. In the late 70s ISA (presently the International Society of Automation, formerly the Instrument Society of America) members proposed a control engineering curriculum to prepare graduates; but developed by those in the practice, the wish-list of courses was incompatible with Higher Education goals and engineering accreditation requirements. The ISA effort was resurrected in the early 90s, which redeveloped Automation Engineering curricula compatible with accreditation, and led to the creation of an ISA Education Division and the Automation Federation. These groups are active in national conference programming, engineering accreditation, and championing Automation Workforce Development initiatives at federal and state levels. In the mid 2000’s the Council for Chemical Research surveyed industry managers about graduate degrees and found that the perceived value was related to developing an ability to independently analyze, solve, and apply critical thinking. The value was in the experience of doing, not in the acquired knowledge. Recently the International Federation of Automatic Control formed an Industrial Initiatives Committee and hosted a session at the IFAC World Congress in Cape Town last August. A few years back the AIChE initiated a study, and working jointly with the National Science Foundation hosted a workshop this March that integrated industry and academic leaders to provide an analysis and devise recommendations.

It is not a new problem. And, it is worldwide.

What can be done to bridge the gap?

The gap is systemic – it is caused by disparate aspects of the mission and *modus operandi* of academe and industry. Having worked in academe for 29 years, with 13 as a School Head, it seems to me that academe cannot act alone to bridge the gap. Education needs to teach the bare essentials of engineering to the masses, and test for individual performance within institutions that are marginally funded. We like teaching, but it is a secondary aspect of the reality. And we teach what we know, which is normally the isolated science and math of our research.

Some have said, “We should mend the gap”; but to make the gap disappear, universities would need to change into for-profit development (not research) labs, or be fully industrially funded and hire faculty to meet industrial criteria. I don't think there is a big enough incentive to generate an economic force to make such a change. If it did, we would lose the attraction and benefits of the undirected creative investigation of the current University system. It took a long time for Education to find a sustainable way. I suspect if there were better paradigms, they would have evolved. I believe that we are doing it right related to creation, validation, and dissemination of knowledge. I believe that we are doing it right in best practices for teaching novices with the right fundamental skills.

Some say, "Add a year to the curriculum to get students to acquire the relevant courses. Make engineering a 5-year professional degree." But, if we add a year to the curriculum, the courses will still be taught by research-oriented faculty, who lack the context understanding of the 'way' on the other side of the gap. And, it will cost society more: It means we need 25% more faculty to teach the additional courses. And, extending the curriculum adds financial burden to parents and States, and delays income earning for the individual (and, perhaps most importantly, income tax revenue for the government). I don't think a 5-year first professional degree is the answer.

I believe that our hope is in bridging the gap, not mending it, not eliminating it, not curing it. Preserve an academic environment that can be productive in education, research, and dissemination. But, simultaneously direct the faculty experience toward application needs to make better application use of the research creativity. Acknowledge the gap, its "+" and "-" attributes, to prepare students for the transition.

Key things will remain unchanged. We still teach youth and graduate young adults, with their persona and little business experience. Faculty interest and guided investigation will still be related to isolated aspects of non-commercial projects. Faculty reward will be based on publication within the academic community of stature.

But there is hope for improvement.

The need for industry mobilization

I think industry will have to continue its complementary training of new hires for the practical side of engineering education. Significant industrial experience is needed to qualify mentors to be professional competence coaches for new graduates. They graduate with 5% of what is important to know, and need to learn much more. Their 20 years of preparation has trained them to be learners, not doers.

Who has the incentive to fix the gap? Consider academe. We seek quality in education and faculty members are dedicated to excellence, but we follow the money. We don't shape our environment, the funding model shapes us. The promise of developing a well-funded graduate program is the primary criterion for selecting faculty hires.

Consider industry. What are the costs associated with new hires that need considerable coaching to become partners? If it is possible to accelerate the transition and gain a year in productivity from each new hire, and a company hires 10 per year (a medium small business) at a cost of $200k/year (salary, benefits, support), that is a $2M per year increase in human productivity. How would your company evaluate the potential?

Consider government. What is the opportunity cost to a Nation related to delayed new-hire productivity and the inability of faculty to directly aid business in bringing complex and comprehensive solutions to fruition?

I believe that Industry and government must take the initiative to solve the problem. They have the incentive, and shape the funding model for academe.

There are dozens of solutions, but to be sustainable they need to be grounded in the reality of academe and industry. In spite of what message you might get from academe, don't send money! Academe critically needs funding, but don't let the academic way control the use of your gifts. Be sure that you steer the use of your resources.

Solutions must have a 'win' for all participants. For students this means job opportunities and career and life success. For professors this means access to funding and publication stature, and quality teaching. For industry this means faster-starting entry-level employees, workforce development, and problem-solving help from academe. For government this means greater national productivity and development.

Industry can:

Industry can participate in:

- Consortia for workforce development: Fund and guide projects directed to prepare students for hiring needs. This is not faculty-driven research. The topics are shaped by the industrial representatives to explore concepts of interest to them and to prepare students with needed skills. This is not funding to develop intellectual property. I have been a part of two consortia, and find that they lead to publications, degrees, academic stature, relevant hires, and industrially useful knowledge.
- Student organizations: Host evening seminars and field trips. This relays the industrial 'way' to both students and faculty advisors.
- Summer internships and Co-Op programs for graduate students and faculty as well as undergraduates. Tie-in to the higher level skills and provide experiences for faculty to understand context. Apprenticeship within the context provides an essential bridging experience.
- Training seminars/workshops for faculty about industry needs: Host events to help faculty understand your need for human resources, technology, and context.
- Courses: Provide challenge problems and feedback on design projects and laboratory experiments.
- Voice your concerns: Relay the issues with the gap at the legislative level, and on departmental and college industrial advisory committees. Relay the message that control courses and automation in experiments are important.
- Graduate seminars: Present seminars for graduate students and faculty to understand your technical challenges and way of solving them.
- Understand the gap: Know what it is that misdirects the perspective of new hires. Then you can initiate appropriate training conversations to redirect the 'way' of the new hires.
- Support efforts of ISA and the Automation Federation: Enhance control in the curriculum, and make its importance known.

- Initiate taskforces within industrial associations: Explore the issues, calculate the opportunity cost, and collectively initiate solutions.
- Understand what professors can and cannot deliver when engaged in problem solving: It is not what you can expect from a contractor. Make contract research or consulting expectations grounded in the reality of possible outcomes.

"Support education? What's in it for us?" an employer might ask. Access to top new hires is one benefit: Students are serious about preparation for their career success, and they appreciate companies that provide insight, resources, and opportunities to help them, and provide affirmation of their personal mission. Through participation in education, industry develops visibility and student allegiance, which aids recruiting of those best suited for your company. Better prepared graduates is another benefit. Faculty members are dedicated to teaching and to preparing student for their future success. Through industrial classroom, laboratory, and project guidance, instructors begin to understand the issues that are important on the other side of the gap and can shift student perspectives.

Be a good customer.

Don't let evolution on separate sides of the gap, lead to our inability to synergize.

Professional societies can:

Professional societies can:

- Program workshops and sessions during conferences that are largely attended by academics to help faculty understand the contrast between the industrial 'way' and academic 'way' so that they can shape the instructional environment to prepare students for the transition.
- Solicit articles for periodicals, for which there is a large academic readership, relating stories from those who experienced the transition, for a national conversation about the needs.
- Initiate task forces, action groups, or such that integrate industry and academe folks to address what topics constitute the best 5%, how to prepare students for the transition, topical guides for courses and textbooks, etc.

What is Engineering?

Billy Vaughn Koen [Definition of the Engineering Method, ASEE, 1985] defines 'the engineering method' as "the use of heuristics to cause best change in a poorly understood situation within available resources." Malcolm R. Cooper, HR Lead for ConocoPhillips [in a discussion at OSU about what they are seeking in new hires] said, "The ability to be an engineer is more important than the discipline knowledge." There is a 'way' of engineering that is not the same as the knowledge base that we consider to be our 'Body of Knowledge'. Unfortunately, many career academics only know the discipline knowledge; they neither understand nor value the other end of the stick. They know the discipline material and the associated science investigation aspects. But, they have never experienced 'doing', the application in practice, the purpose of making a customer-satisfying product within trillions of constraints – engineering.

I think that we teach the right discipline specific material, and that most of the professors are excellent teachers. But often, the lessons are grounded in idealizations, and the student learns out of context. Further learning and doing are different. How to 'be' an engineer should be included in the curriculum, even if just in seminars and other professionalism-related messages to the students.

Here is my translation of being the engineer:

- The ability to be an engineer is more important than the discipline knowledge. Doing engineering is not just following calculational procedures that you have learned. The valid procedures are important, but choosing which to use and what basis to use within the context is more important. While we are teaching the fundamentals we also need to convey the 'way' of engineering, the way of making right choices.
- Engineering must clearly understand the cause-and-effect mechanisms of the product, process, or procedure. The mechanisms are often unknown, and will remain unknowable. In spite of that, the engineer must devise knowledge and know that it is right, both valid (logical and consistent with data) and comprehensive.
- Engineers must analyze the new situation within its human, business, political, and legal context; in addition to its discipline fundamentals. The context is much larger than the engineering science fundamentals that constitute textbooks and in-class exercises.
- Engineering must test and validate to develop surety and establish credibility. Data is required to support (and often correct) the intellectual concept (often naive and superficial in spite of grand knowledge and mathematical self-delusions about reality).
- Engineering must devise comprehensive assessments that will be used to as the objective functions that evaluate solutions.
- Engineering must organize and prioritize data, information, knowledge, and separate surety from possibility form folklore and misunderstanding.
- Engineers must devise solutions (designs, procedures, activities) that satisfy all constituents (customers, participants, stakeholders representing multiple extra-technical perspectives, operators, officers in responsible charge, community).
- Engineers must convince the human environment that the solutions are legitimate, credible, best, practicable, sustainable to acquire resources and permissions to cause change. Here, engineers must promote, market, sell. Oral and written communication and establishing credibility with the audience is essential. It is not an audience of research professors. How to establish credibility with research professors is not how among normal humans.
- Engineers must bring the change to fruition. It is not just the idea, but the results of its implementation – the benefit to humankind from the solution. Continual promotion is often needed.
- Engineers must balance perfection with sufficiency. When it is good enough, do it. Know when it is good enough.
- Engineers must make concrete action recommendations, acknowledging and accommodating uncertainty. It is not an analysis of uncertainty. It is the, "So, … Now what should we do?" decision after.

Engineering is not just about technical competence - State-of-the-Art commercial software beats novice humans in speed and completeness with technical calculations. Engineering is a decision-making process about technology within human enterprises, human value systems, and human aspirations.

In an exercise with our faculty and Industrial Advisory Committee members to understand our constituent's desires, it became apparent that engineering is a process of balancing opposing ideals; and we developed this list in an effort to capture the timeless balance of values that guide the activity of engineering. Originally developed in about 2002, we periodically review this with our IAC members, and fine tune wording.

I believe this list addresses a fundamental aspect of the essence of engineering, and that students should graduate knowing these fundamentals about the activity as a complement to fundamental knowledge and skill of the core science and technical topics.

Instructors need to understand the opposing ideals of the following desired engineering attributes so that they can integrate the issues into the student's experience; so that student exercises have students practice right perspectives as they train for technical competency.

Engineering is an activity that delivers solutions that work for all stakeholders. Desirably, engineering:

- Seeks simplicity in analysis and solutions, while being comprehensive in scope.
- Is careful, correct, self-critical, and defensible; yet is performed with a sense of urgency.
- Analyzes individual mechanisms, then integrates the stages to understand the whole.
- Uses state-of-the-art science and heuristics.
- Balances sufficiency and practicality with perfection.
- Develops sustainable solutions – profitable and accepted today, without burdening future stakeholders.
- Tempers personal gain with benefit to others.
- Is creative; yet follows codes, regulations, and standard practices.
- Balances probable loss with probable gain but not at the expense of EHS&LP – Managed Risk.
- Is a collaborative, partnership activity, which is energized by individuals.
- Is an intellectual analysis that leads to implementation and fruition.
- Is scientifically valid, yet effectively communicated for all stakeholders.
- Generates concrete recommendations that honestly reveal uncertainty.
- Is grounded in technical fundamentals and the human context (societal, economic, and political).
- Is grounded in allegiance to the bottom line of the company and to ethical, legal, and social standards of technical and personal conduct.
- Supports enterprise harmony while seeking to cause beneficent change.