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The Engineering Professor of 2020: the Forgotten Variable

Abstract

Much has been said about the profile of the engineering graduate of the future and about effective and innovative teaching and learning strategies, yet only a few have spoken about the skills and competencies of the ideal engineering professor – key individual of the heart of the process education process. How can engineering faculty instill the novel skills and competencies of the profession if they themselves do not possess these, have never experienced real-life engineering, and do not consciously study their own teaching methods? Engineering education gathers experts that blend two professions – engineering and education. Thus, engineering professors need to be both <u>engineers AND educators</u> and be trained and/or have experience in both disciplines. Engineering educators need to both understand what it takes to practice the engineering profession and how to effectively catalyze student learning. If we are requiring students to engage in real-life, practice-based learning experiences (co-op, internships, etc.), shouldn't this be also a required activity for those teaching students?

This paper shares the results of an informal survey on the skills and competencies of the ideal engineering professor done in the Fall of 2009 among students, faculty/deans and industry members. The paper aims to initiate a dialogue among engineering education leaders around the "forgotten variable" in the education process: the set of desired skills and competencies of an ideal engineering professor. It hopes to kick off discussions around the following questions: What does the nascent engineer of 2020 need from his or her professor? What should the profile, skills and competencies of the engineering educator of 2020 be?   Why has the current system allowed us to forget this critical variable, and how can we grow these skills in engineering faculty? Furthermore, how can we nurture effective partnerships, develop capacity building programs and find the resources to bring a significant change in this most critical protagonist of engineering education?

If these questions are answered jointly by all stakeholders and an action agenda is developed during the next few years - similar to the NAE Engineering of 2020 Report - one of the biggest challenges in creating a culture for innovation in engineering education will be addressed.

I. Introduction and motivation for this work

A. <u>Growing and changing demands on the student</u>

While the crucial engineering professor variable has certainly been overlooked, much attention has been directed towards related areas that depend on concurrent change in the professoriate. There have been numerous attempts to innovate the American engineering curriculum during the last 10 to 15 years. With the aim to better prepare engineering graduates in response to workforce needs, a number of reports and papers have focused on the skill set and competencies of the upcoming engineering graduate. The literature on the American situation mirrors that of universities and colleges with engineering programs around the world. Several come to mind:

the new ABET criteria adopted in the year 2000[1], the US National Academy of Engineering 2020 Report[2], the ASEE Corporate Members Council engineering attributes[3], the 2004 National Association of Colleges and Employers skills survey[4], as well as profiles put together by individual enterprises like Siemens and Boeing[5,6]. One of the authors of this paper has brought industry panels together during dozens of curriculum innovation workshops around the world asking industry representatives the same question, and irrespective of the kind and size of industry or geography, the profile of engineering graduate attributes appear to follow the same pattern, i.e., engineering graduates should be knowledgeable in science and technology fundamentals and be problem solvers, but should also possess a number of professional skills (i.e., "soft skills") important for the profession such as effective communication and understanding the world where engineering is practiced (business constraints, flexibility/adaptability, societal and ethical issues, global sensitivity, etc). Numerous student-focused events on a variety of curriculum, policy, and pedagogical issues conducted by one of the authors have yielded similar conclusions.

Some authors and reports have comprehensively outlined the elusive set of "soft skills" that are widely-agreed upon as vital. Dr. Bob Johansen has served as both President and CEO of the Institute for the Future and is currently a Distinguished Fellow of that organization. He is author of seven books, the most recent of which is "Get There Early: Sensing the Future to Compete in the Present", ranked as one of the top 30 business books of 2007. In this work, Dr. Johansen proposes the following list of new attributes for technology leaders of the future[7], an interesting catalogue of words that still need to find their way into the dictionary:

- **Mobability** — the ability to work in large groups; a talent for organizing and collaborating with many people simultaneously
- **Influency** — the ability to be persuasive in multiple social contexts and media spaces; an understanding that each context and space requires a different persuasive strategy and technique
- **Ping Quotient** — measures your responsiveness to other people's requests for engagement; your propensity and ability to reach out to others in a network
- **Multi-Capitalism** — fluency in working with different kinds of capital: natural, intellectual, social, financial, etc.
- **Protovation** — fearless innovation in rapid, iterative cycles
- **Open Authorship** — creating content for public consumption and modification
- **Emergensight** — ability to prepare for and handle surprising results and complexity
- **Longbroading** — thinking in terms of higher-level systems and cycles
- **Signal/Noise** — filtering meaningful information, patterns and commonalities from massively multiple streams of data
- **Cooperation Radar** — the ability to sense, almost intuitively, who would make the best collaborators on a particular task.

If these and similar skills and competencies will be required from the engineers of the future, then they will also be required from those who will be educating those engineers of the future. Change has to occur first in the teacher to become a mentor and role model to the student; the professor must continue to be a student.

B. Resources devoted to curriculum development

During the past 10 to 15 years there have also been significant amounts of resources spent in the US in innovating engineering curricula (the most prominent initiatives being the mid 90's NSF-funded Engineering Coalitions; for example: www.gatewaycoalition.com; www.synthesis.org ; www.succeed.ufl.edu) . These have focused primarily on innovating the engineering curricula, integrating assessment, using complementary technology and implementing new learning strategies. One of the authors of this paper - together with colleagues from Penn State University, the University of Washington and Sandia National Labs - also participated in a somewhat smaller but successful partnership called the Learning Factory, which received the US NAE Gordon Prize in 2006 for innovation in engineering education.[8]

C. Limited success

All of these efforts have been successful, but they have not permeated the engineering education (EE) ecosystem the way the sponsors and participants thought they would. The EE culture – the model for training the next generation of engineers– is still the same. Notwithstanding the current global economic crises, the fact remains that the economic progress and achievements of US and many other nations is rooted in their science and engineering talent. Why then has the engineering education model not evolved at the pace science and technology has? How has top-tier science continued if students are not appropriately prepared? The workplace demands new engineers to be technically qualified, flexible, and dynamic thinkers, but their classrooms are not necessarily and systemically supplying them with these tools. Perhaps the lack of attention to the educators themselves is the key oversight in this system. Evidence of this perceived lag can be seen in Figure 1. About 50% of industry and academia respondents in an Engineering 2020 survey dissent from the assertion that the current undergraduate engineering education is sufficiently flexible to adequately meet the needs of 21st century engineers.

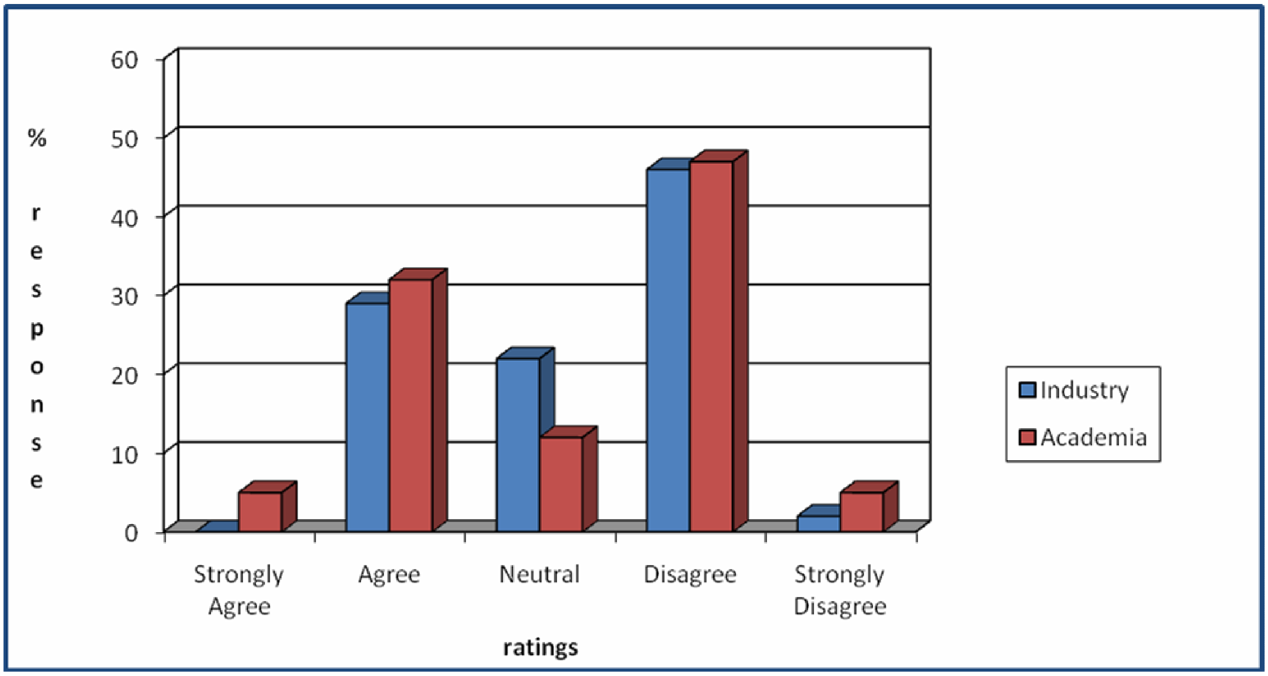

Figure 1.

Responses to Question: "Current undergraduate engineering education is sufficiently flexible to adequately meet the needs of the 21st century engineers" (Source: Engineering 2020 Report, 2004)

In June 2006, the American Society for Engineering Education launched an initiative to promote broad-based discussions within the society on the role and importance of educational scholarship to ensure the long-term excellence of U.S. engineering education. Those discussions led to a project which began in October 2007 with support from ASEE and the National Science Foundation. The project represents an important step by ASEE to enable even broader conversations across the American engineering education enterprise on creating a vibrant engineering academic culture for systematic and scholarly engineering educational innovation; these efforts hope to ensure that the U.S. engineering profession has the right people with the right talent for a global society[9]. Most reports on engineering education tend to emphasize "what" needs to be changed. "How" the change should be driven and "who" should drive the change have generally not been as fully addressed, both of which largely determine how quickly and how well change occurs and how it is sustained. The report resulting from ASEE's project emphasizes "how" and "who" more than "what". While the report contains valuable general information, it focuses mainly on the need to engage in engineering education research (as a discipline). This concentration will certainly augment the practice of teaching engineering. Nevertheless, and most fundamentally, it fails to reach the base: absent are guidelines for the engineering professor looking for best practices and roadmaps to become a better educator and professional. For example, the report mentions the desirability of faculty having industry/real life engineering experience only once, and the comment is somehow lost toward the end of the report.

In spite of all these efforts, still the same questions remain unanswered: What is the problem with engineering education, and why has the profile of the faculty been ignored in this discussion? Why the continuing problems of recruitment and retention of engineering students with all of the resources devoted to curriculum development? Why the lag, as previously described, between the advancement of science and technology vis-à-vis the evolution of the engineering education model? Why are so many worried that the profession will not be able to serve society and support and sustain economic development as it has in the past?

Many may argue that the ideal engineering graduate of today and tomorrow has already been described *ad nauseam* and that - as a result - millions of dollars have been invested to innovate and reform engineering education. But the fact remains that the engineering education ecosystem has not developed in the way expected and required.

II. Research question

Given that other variables of the education process have been adequately addressed (e.g., curriculum, student retention), the authors bring to the forefront of the discussion the one variable that has been forgotten, relegated to a lower priority than warranted: **the engineering professor,** the individual who catalyzes learning. The objective is to promote a dialogue among the engineering education community around the question of the profile of the ideal engineering professor.

III. The nature and challenges of the engineering profession

Engineering is one of mankind's most important and essential professions. Few professions have such a direct and positive effect on people's everyday lives. And few professions unleash the spirit of innovation like engineering does. Yet, the practice of engineering can be unappeasable and difficult, the reason why so many students shy away from choosing it as a career.

> *"Engineering…is an unforgiving and demanding environment…for students to succeed as engineers, they must acquire skills that go far beyond theories, simulations and exam-taking ….there is absolutely no substitute for the hard edged technical and business skills that are required to bring products and projects to market."*
>
> ~ Bernard M. Gordon, founder of NeuroLogica Corp., founder & former chair of Analogic Corp., and co-founder of Epsco Inc.

> *"[Chuck House] was a Hewlett-Packard engineer in the 1960s, eager to build a large-screen display monitor, when company founder David Packard told him it was a stupid idea. House built it anyway. The device became a big hit with customers. Packard -- swallowing his pride -- eventually awarded House the Medal of Defiance, "in recognition of extraordinary contempt and defiance beyond the normal call of engineering duty."*
>
> ~ Forbes.com's Behind The Screen At Hewlett-Packard

Engineers who enter the domain of academia face additional specific challenges. The demands of the tenure process constrain decisions about priorities, dictate research agenda, and sometimes create perverse incentives.
But, the fact is that the world needs top- notch engineers in ever-increasing quantities to address not only local problems but grand engineering challenges, to support economic as well as social development. This stern reality should be a clarion call for society and for the EE field.

Engineering educators, unfortunately, do not have the massive and diverse capacity to solve this problem alone. So, all stakeholders must come together to address the challenge.

> *"We are continually trying to find better, cheaper, safer, less harmful, more energy-efficient ways to do things. Yet we don't use an engineering approach to engineering education!"*
>
> ~ Karl Smith, Purdue University

IV. The engineering professor of today

Higher education seems to be locked in the 18th century model, where students gather around a professor to hear him share lectures. While this model may have had previous successes, the innovation needs of today's society make this model a problem today. What are the attributes of the engineering professor of today in theory and in reality? In many universities, engineering faculty members are hired primarily to bring in external funds to sponsor research. The typical professor ideally has a PhD and is very technically competent. As part of his/her academic load, he/she has been asked to teach, maybe an undergraduate course and a couple of graduate courses, but in reality has never (or seldom) received any instruction about how to teach, and most likely is not interested in receiving any capacity building coaching in these topics. He/she is very organized, and relies mostly on lecture as the method for teaching - just as his/her former professors did (in fact, according to a 2001 US Department of Education statistic, 87% of U.S. engineering faculty use lecture as their primary method of instruction). Aloof, with a "god-like" attitude, he/she is unreachable to students, "way up there", delegating this most fundamental interaction with students to teaching assistants. His/her exams are very difficult; oftentimes nothing seems to be as presented in class. Furthermore, he/she has little or no engineering practice/experience, with no real clue about what it takes to be an engineer in real-life conditions. The role model he/she presents to the engineering student is that of a researcher, focused on the next discovery, publishing a paper, and perhaps submitting a patent. However, only 5% to 10% of those sitting in the classroom will assume this lifestyle! The rest will become 'regular' engineers in the field.

A recent Purdue study on how engineering faculty members define "engineering"[10] found that faculty members' descriptions are at odds with the recommendations of the US NAE "Changing the Conversation" Report[11]. In other words, the engineering faculty's understanding of what engineering is differs from what the profession itself is. But this should not come as a surprise! The great majority of engineering faculty has never practiced the profession, has never been exposed to business constraints when designing a solution, has never had to work in multi-disciplinary, multi-national, multi-discipline teams; when asked about estimates of how many engineering faculty have industry experience, one high level NSF official in the Engineering Directorate said unofficially he believes the figure is less than 10% (citation). Engineering faculty are hired and evaluated mostly around their research outcomes, but practical, real life experience is seldom required, valued, or promoted. Merit criteria in many engineering schools focus on research dollars, patents and publications with little or no consideration to teaching effectiveness. Yet schools expect faculty to teach well. Quoting Felder[12]:

> *"The classical academic fantasy is that every professor should resemble this combination of Leonardo, Socrates, and Mother Teresa, but the reality is that very few can pull it off -*

certainly not enough to populate every engineering department. Nevertheless, requiring every new engineering professor to be first and foremost a researcher has become standard academic policy in the past several decades, with dramatic effects on every aspect of academia from the makeup of the faculty to the structure and content of courses and curricula."

The incentive system for engineering faculty may be the central reason that the problem of inadequate faculty preparation exists. Teaching and research have different goals and require different skills. They are equally important to society. Service to society is indeed one of the three missions of higher education. So, who is the ideal engineering professor?

V. The ideal engineering professor

A Google search on the topic "ideal engineering professor" yielded 6.25 million responses in 0.23 seconds! Unfortunately, the response was not what was expected. The first item on the list was a link to a 2004 paper by Dr. Jack Lohmann on the ideal engineering education[13], and most of the remaining top 10 items were advertisements of engineering faculty positions looking for ideal candidates (of course, focused on research). Lohmann's paper reflects on an article by Professor W.H. Burr, Professor of Civil Engineering at the Columbia College School of Mines in New York. (Burr's article, published in 1894, appeared in the first proceedings of the then-newly formed Society for the Promotion of Engineering Education, ASEE's predecessor.) Lohmann argues that although engineering curricula has not changed much in a hundred years, assuring a solid education requires a vibrant community of scholars dedicated to the continual exploration of <u>principles and practices</u> (authors' underline) that prove effective in the education of engineers. He quotes Burr:

"The method of instruction to be pursued in the school which affords the ideal education in engineering must be of such a character as to yield the best results with the least amount of unproductive labor to the student, and at the same time train him in the ways of vigorous and independent thought. Dry and lifeless text book recitation work yields by itself little enough that is desirable, while the pure lecture method is equally unsatisfactory. The one is uninteresting routine and utterly ill adapted to the development of mental fertility and strength, while the other involves a mass of misdirected labor on the part of the lecturer, which, without supplementary exercises, leaves the student to shift for himself, without producing much of any result. The main purpose is to convey instruction, and it should be done in such a way as to induce the student to do his own thinking. No instructor can justify himself in merely puzzling the student with grotesque problems, or in harassing him with abnormal difficulties, but on the other hand the student should be made constantly to feel himself a working part of the system, and that he cannot, without serious loss to himself, take a mere passive part."

In 1894, Burr was already describing the ideal engineering education and the ideal engineering education process, therein tangentially describing the ideal engineering professor.
A search for the 'perfect professor' yielded some interesting results as well. For example, a blog called Economics for Teachers [http://economicsforteachers.blogspot.com/2008/12/perfect-professor.html] describes a perfect professor (interestingly referring to a woman professor) as one that

"…inspires all her students, leading them to think critically and become lifelong learners. Her lectures are always so clear and interesting that students never fall asleep, read newspapers, surf the web or text their friends in class (except to comment on something class-related, of course). The perfect professor's students are never grade-grubbers because she has inspired them to want to learn for learning's sake. She manages to convey how much she cares about her students without giving them the impression that she is a pushover. The perfect professor never gets emails from students complaining that her grading is unfair because her students never get confused about deadlines and/or they understand the exact repercussions of missed assignments. Her classes are challenging, but not impossible, in that way that even the B and C students feel like they are learning a lot. She makes her field of study seem so fascinating that her students all want to change their majors."

Felder[14] describes a recent chemical engineering graduate in her first job. One can see in the struggle this new engineer goes through that what she was taught by her professors in four years is not what engineering is all about. Why is this? Felder[15] argues it is because most engineering faculty members learn the craft (education) by trial and error.

Reflecting on the history of chemical engineering and pedagogy, Wankat[16] states that in spite of all the attempts to add flexibility, the Chemical Engineering curriculum remains monolithic (all students take almost identical sequences of courses) and hierarchical after 60 years. He states:

"…a long-term change not readily evident from looking at curricula is who teaches chemical engineering. Initially, there were no chemical engineers and the courses were taught by chemists and mechanical engineers. Once chemical engineers had graduated and were available to become professors, most of the chemical engineering professors had significant industrial experience and rarely had a PhD. Over the years an earned PhD became a requirement and the expectation that engineering professors would have practical experience was lost."

Haddock[17], who states he wrote the paper while studying to become a father, describes the profile of a nurturing college professor, one who believes that being a good role model involves more than being professionally competent. He suggests that professors can improve the quality of teaching by becoming more sensitive to the students' needs and by understanding and appreciating their individuality, by developing a 'nurturing environment' very much like parents with children. In that way, the teacher's needs are also met.

VI. Methods

The idea of the "ideal engineering professor" is a novel construct. The dearth of literature on this specific concept demands an initial inductive perspective on the question of what characteristics the engineering community thinks the ideal professor would have. This paper uses a qualitative framework to begin to generate a hypothetical picture of this concept. Grounded theory provides the basis for this work, as a large amount of information was gathered (survey described below) and broad characteristics emerged.

Rather than possibly influence participants' responses by having prescribed categories to check, an open-ended question was distributed to all of the survey respondents. As with performance reviews in industry, the same simple question was asked to all of the groups. Answers were collected by the authors in the form of text-based lists of five "characteristics". In many cases, these characteristics were not just single-word adjectives, but phrases or even multiple-sentence descriptions of the traits an ideal engineering professor would display.

Data coding and summarization was completed by the authors. The numerous lists of characteristics were first scanned for words or groups of words that could be pooled. The authors' judgment as experienced members of the engineering education community was used to continue grouping these responses together into broader categories. These categories were named to describe the broader trait they refer to and the number of references by the respondents was noted. This method provided the categories and prioritization discussed in the results.

VII. The survey

In an effort to gather thoughts and ideas on the ideal engineering professor, an email was sent during the Fall of 2009 to distribution lists of the two authors, composed of mostly faculty, engineering education associations, members of the International Federation of Engineering Education Societies (IFEES: www.ifees.net), industry members and engineering students members of the Board of European Students of Technology (BEST: http://www.best.eu.org) and the Student Platform for Engineering Education Development (SPEED: http://worldspeed.org/). BEST is a non-profit student network organization located in 30 countries that strives to help European students of technology to become more internationally minded, by reaching a better understanding of European cultures and developing capacities to work on an international basis. SPEED is a recently created global non-profit engineering student organization that aims at supporting tomorrow's leaders in improving their own training to answer the demands placed on graduating engineers. By connecting students from diverse backgrounds to discuss their schooling, bridging the gap between students and other stakeholders, and empowering students to take steps to effect change, SPEED hopes to systematically advance the field of international engineering education. Jennifer DeBoer (co-author of this paper), a PhD student international education policy, is current president of SPEED.

The memo required the recipient to "list the top five (5) attributes of an ideal engineering professor". Respondents were assured that their reply would be kept confidential (unless permission to quote was required). There were 88 responses: 28 from academia (US, Brazil, Portugal, India and Canada), 4 from industry and 56 from students from US, South Africa, India, Turkey, Russia, Mexico, Spain, Portugal, Netherlands, Serbia, Macedonia, Ukraine, France and Belgium. Some of the respondents listed more than five attributes, and there was variety in how much detail was given.

Survey results are described in Table 1 in three categories: 1) Engineering Faculty/Deans, 2) Engineering Students, and 3) Industry.

Table 1. Top Five Attributes of Respondents by Category

1. Knowledge of engineering fundamentals, engineering practice and technically competent **2.** Effective teacher **3.** Strong sense of professional responsibility /ethics **4.** Influential Communicator **5.** Mentor	**1.** (Tied) **a.** Engineering experience **b.** Current (up-to-date) in research, publish **c.** Multi-culture sensitive, inclusive of people and environments **2.** (Tied) **a.** Superior technical depth and savvy **b.** Highly networked and open minded; fosters collaboration & teamwork **c.** Superior communication skills (incl, articulate in context of non-engineering disciplines, especially business) **d.** Able and willing to nurture curiosity, fostering bold, innovative thinking; receive and formulate big and tough questions	**1.** Inspiring, motivating **2.** Prepared and knowledgeable (including real-world knowledge) **3.** Committed to teaching and helping **4.** (Tied) **a.** effective communicator **b.** person of integrity

In closing this section on the survey data complied, we want to include some comments whose publication was authorized by their authors.

> *"A good teacher is worth more than a thousand priests."*
> ~ Pritvi Raj Bhupal, Deputy Director, Ballari Institute of Technology and Management, India.

> *"The ideal professor will depend on the context – what type of school and what level. At research universities, ideal professors are world-class researchers who bring in sufficient research money. Without research money, the professor will not survive."*
> ~ Phil Wankat, Purdue University.

> *"(an ideal professor should be a) mentor, with the ability to coach, share, discuss and work with students – not just be an authority".*
> ~ Marc Hoit, North Carolina State University

> *"(an ideal professor should have) deep connections with enterprises and in-depth knowledge of challenges of enterprises and societies."*
> ~ Seeram Ramakrishna, Former Dean of Engineering and Vice President for Research Strategy, National University of Singapore

> *"This may seem a little backwards but I honestly feel that a professor with all the knowledge in the world will not be able to transfer it to the students without the first 4 on the list."*
> *~Student from West Virginia University, US*

VIII. Key findings—the respondents' ideal professor

All three *groups* selected "*technical expertise and communication skills"* as their top five attributes. Thus, "*practiced, well prepared & competent in the field"* seemed important for both students and faculty - this was the number one attribute. The second highest attribute in the industry list was "c*urrent in research and publishing",* which may be construed as another way of expressing the necessity of maintaining technical competency.

Variants of *communication skills* were submitted as distinct attributes by each group; e.g., "*influential communicator*; *amusing communicator, possessing a sense of humor ("funny/makes jokes"); able to formulate 'big' questions, etc"*. In addition, the "*ability to nurture networks and collaboration"*, an attribute high on the industry list, is related to superior communication skills. In may also be argued that "*passion and motivation"*, high on the students list, can best be expressed and evidenced through riveting communication.

Faculty and deans chose "*effective teacher"* as one of the top five. Expanding on the comments provided by responders, we can assume that the adjective "effective" was used in the context of being capable of producing an intended result and/or having a remarkable effect. It may be argued that "*mentor",* another attribute in top five of the faculty and deans' list, is a variant of effective teacher. In fact, *mentor* is commonly used as a synonym of *teacher*. Similarly, the attribute "*helpful"*, listed in the top five of the students list, may be construed as related to the effective teacher/mentor factor. Finally, it can be pointed out that the "*ability/willingness to nurture curiosity",* a fundamental coaching tool mentioned in the industry list, is also related to effective teaching.

The top attribute for industry was "e*ngineering experience"*. This attribute was not explicitly included in the top five of neither the faculty/deans nor the students' lists. Nevertheless, the first attribute in the faculty/deans' list – "*knowledge of engineering fundamentals"* – is further qualified as entailing "practice" in his/her discipline; i.e., engineering experience. Furthermore, one can speculate if when the students identify "*well prepared in the field"* as the most important attribute they are implicitly suggesting their professors should have professional experience as part of that preparation. That is, there is no way to tell if they are contemplating only academic preparation.

"Global citizenship" ranked high on the faculty/deans' list, together with a "s*trong sense of professional responsibility and ethics"*. Similarly, we found high on the industry list the quality of "*multi-culture sensitive and inclusive of people and environments"*. Both these attributes can be grouped together under *global citizenship,* a concept that embraces a commitment to align one's priorities and actions with the needs of the society and the planet. It aspires to focus one's energies and expertise in areas such as: ethics, environmental sustainability, human rights.

Interestingly, only one respondent in the faculty/dean group explicitly said the ideal professor should possess a PhD. Among remarkable *omissions* from these lists include "*diversity*" (from all of the lists), though multiple groups of *stakeholders* pointed to multi-cultural sensitivity as important. Students did not describe the ideal professor as a "mentor". Although the adjective "helpful" came up repeatedly, the idea of the mentor as a role model was not prevalent.

The essence of these findings highlights can be represented in the following figure:

Figure 3. The Ideal Engineering Professor?

IX. The authors' ideal engineering professor

"The only source of knowledge is experience"

~ Einstein

The engineering professor of today and tomorrow needs to be a blend of the two professions, engineer and educator. He/she must be an individual who:

1. *Is competent in his/her own discipline, engineering fundamentals and problem solving*
2. *Is current in his/her research, publishes, networks, communicates effectively and keeps up with trends in his/her discipline; and does all of the above with an entrepreneurial spirit.*
3. *Is an effective teacher, knows about learning and outcomes assessment, facilitates learning using learner-centered strategies, keeps up with developments in engineering education, studies and uses the effectively, cares about the students and their learning, enjoys being as a mentor.*

4. *Understands the role that the profession has in society both locally and globally, practices it as part of his/her career development as well as leads, serves and participate in forums to promote policy making and excellence in engineering education and research/innovation.*
5. *Aims at developing the skills and competencies engineers should possess through practice and experience in order to better serve society and be a role model for students.*

An individual cannot possess the perfect amount of every important quality. The most important characteristics are some knowledge of the subject in theory and practice, an ability to convey this knowledge, and the perspective to see why it is important and uphold this value. These attributes reflect the three-pronged mission of higher education institutions: educate, develop knowledge and serve society. However, they do not all fit into the current structure that is realistically in place. The conclusions and recommendations that follow allude to possible steps to modify the practice of the engineering education profession to address the problems stated at the beginning of this work.

X. Conclusions

In these days and times of economic, environmental and social tempestuousness, the need for engineering educators to be aware of what should the future skills and attributes of technology leaders (including engineering faculty) will be is more critical than ever. If anything, this need will - in all probability - become more pressing in the future. The world has changed to the point of literally being a newfangled arena, technology – virtually by definition – is constantly changing, and the students of today have changed as their world and the technology they have to manage has changed. The engineering professor of today and tomorrow needs therefore to adapt to these unrelenting changes if he/she wants to carry on being germane as an effective catalytic agent of students' learning.

Engineering professors need to be both <u>engineers AND educators</u> and be trained and have experience in both disciplines. They need to both understand what it takes to practice the engineering profession and how to effectively facilitate student learning. Beyond the authors' own views about what constitutes the ideal engineering professor (as discussed in the previous section), and referring back to Figure 3 (which depicts the aggregate view of the sample of the survey participants), we can summarize the profile of the Ideal Engineering Professor of 2020 as follows:

- A technical expert,
- … with a savvy and adaptability rooted on actual engineering practice
- … with superior communication skills
- … recognized as an effective teacher and mentor

- … and committed to ethical and inclusiveness abidance.

This list – deceivingly short in appearance – is in fact highly ambitious, calling for radical changes in the paradigm of the engineering educator we have been relying on for too long. Changing the system of creating engineering educators as well as all the associated parties that perpetuate this system will not be an easy feat. It represents only a first step towards a more robust and purposeful characterization of what needs to be done to launch and support the next generation of engineers, those that will be addressing the emerging wave of society's grand challenges.

"Everyone thinks of changing the world, but no one thinks of changing himself."

~ Lev Nikolayevich Tolstoy

"*… the single most effective action that can be taken to improve engineering education is to require all new engineering professors and encourage current engineering professors to take a course on how to teach.*"

~ Phillip Wankat

"*Here in the 21st century, with all the issues of global competitiveness and pressing technological challenges, it is high time for American engineering academics to recognize these issues and truly embrace change. Perhaps professors should take a sabbatical and spend it in the cutthroat world of Silicon Valley or Detroit. Or better yet, colleges should hire some star engineers fresh from a competitive, save-the-company, 24/7 product development effort. Students need to understand viscerally that all professions—but particularly those proudly called "practical"—demand real results from their practitioners. Only when we can convey that message successfully will our graduates be equipped with the drive, energy and purpose to successfully apply knowledge in today's real world. And when academia learns to enlarge its own conception of mission to include that values message, it will have earned itself a new position of power and respect in our society.*"

~ Bernard M. Gordon

XI. Recommendations and final words

A larger, worldwide and more extensive survey/study is recommended to fully characterize the attributes our profession requires from the engineering educator of 2020. This survey could also help to illuminate the variation in the "ideal" between populations, locales, fields, etc. In addition to including faculty and academia leaders, students, and industry partners, a new survey/study should incorporate government stakeholders. Such a study should be followed by a profound dialogue among stakeholders to draw an action agenda to address engineering professors' capacity development both as practicing engineers and educators. Of course, this would involve gathering information on best practices on these kinds of initiatives and capacity development programs to reach them to eventually develop a database accessible to all. One possible result of the dialogue and discussion of this large study would be the development of a set of strategies to help engineering education leaders draft a roadmap, a set of academic/administrative strategies similar to the NAE Engineering 2020 report, to develop the Engineering Professor 2020. These could include, promoting the practice of engineering before and during the academic career, establishing career roadmaps akin to faculty interests and balancing research with teaching loads, promoting and requiring faculty capacity building in teaching/pedagogy, establishing teaching/learning institutes to provide for faculty training, strengthen industry alliances to have faculty spend sabbaticals, summer internships in industry and other activities to ensure that an engineering professor is a well balance professional in both the engineering and pedagogy professions.

Finally, further discussion of this issue should foster steps be taken to agree on a societal commitment to make engineering faculty capacity building a national/global priority to sustain and grow economic development. Identifying the skills and competencies that engineering professors should possess in order to develop the engineer of 2020 is no marginal issue. Quite to the contrary, this goes to the core of building the capacity our society needs to address its global grand challenges – present and emerging. The forgotten variable of the engineering educator cannot continue to go unnoticed.

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