Training Engineering Faculty to be Educators: History, Motivations and a Comparison of US and International Systems

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Introduction/Motivation

If you look at almost any engineering faculty position advertisement in the US, in addition to a cover letter and a curriculum vitae, applicants are asked to provide a statement on their research interests and their teaching interests/philosophy. For the former, the prospective faculty member (if he/she wants to be competitive for the position) will normally provide a document (with ample citations and figures) that focuses on the direction they want their research to go if hired. There will also be comments on potential funding sources (government agencies, foundations, industries, etc.) and, perhaps, identification of some colleagues at that university (inside and outside of the engineering college) with whom they may overlap – perhaps with an eye towards establishing a center down the road. This research interest document can often be dozens of pages as the applicant tries to impress the search committee not only with their accomplishments to date, but their "rain-making" plans for the future.

The teaching interest/philosophy statement, on the other hand, does not often receive the same level of detail by the applicant for a variety of reasons (they don't know educational literature exists, they don't know how to properly prepare a meaningful teaching statement, they haven't been trained in that area, they perceive it as having low value in the application process so they do not spend much time on the statement, they don't have much to write, etc.). If this statement is two pages, that is often a lot.

Is this a problem? It depends on your perspective. If you are a college or university administrator, you need to hire faculty members who can justify their (normally) large start-up packages. In other words, they need to have an acceptable return on investment for this start-up (including externally-funded research projects and the fruits of that work – journal publications, presentations, Ph. D. dissertations, etc.). If they are good in the classroom as well, all the better, (though it can sometimes be looked at as a negative by a tenure committee and others, since good teaching requires a time investment – time the tenure-track faculty member might better have spent on writing another research proposal, for example).

If you have the perspective of an undergraduate student, on the other hand, a faculty member's shortcomings in their ability and training to effectively run a course might encourage you to emphatically state that "yes", there is a problem. Students (and their parents) will voice their displeasure through formalized teaching evaluations, through external instructor rating sites, through emails/phone calls to administrators, through letters in the newspaper, etc. However, many/most undergraduate students will "play the game"[1] – which means navigate a course to get a good grade and look towards finding a position after graduation or move to graduate school. They have opted into the system that exists to graduate with an engineering degree.

If put into a broader context, there are a number of additional reasons to reflect on the current widespread lack of professional pedagogical preparation of engineering faculty in the US and its potential long-term ramifications if no corrective action is taken.

It stands to reason that the prosperity and well-being of a nation can be linked to the education and qualification of its population[2,3]. Therefore, parents as key stakeholders of the higher education system aspire to send their children to the best universities so they can get an

education that, hopefully, will turn out to be a pathway to a successful and financially secure life. And this is where the dilemma begins. Most of the nation's top universities who compete for undergraduate students tend to build their reputation (and prestige) reflected through rankings and tables predominantly on national and international research performance, which means, in essence, external funding level, research quality of the faculty, scholarly journal publications, and Ph.D. graduation rate[4]. The rankings on undergraduate programs, on the other hand, are normally not based on any quantitative information. For example, US News' "Best Undergraduate Engineering Programs" are based solely on peer assessment surveys[5]. This subjective approach is, no doubt, highly-influenced by the prestige of the institution – if it is selective, prestigious, note-worthy (often almost exclusively on the back of its research performance), then its undergraduate engineering program is assumed to be top-quality as well. Accordingly, a parent and/or student exploring the quality of undergraduate engineering programs will unknowingly be looking at undergraduate program rankings that are strongly influenced by the research performance of the institution. While it is crucially important for the US to continue to push the envelope in terms of world class research, it is also important to ensure that the professional pedagogical preparation of those responsible with passing on the required knowledge and expertise for the next generation of US engineers does this in an effective manner – the prosperity and competitiveness of the nation is at stake.

Engineering Teacher Training: Why Now?

Several years ago, Richard Felder wrote an article for Chemical Engineering Education where he aptly compares a 12th century classroom in Bologna to a 21st century classroom[6]. Other than some obvious differences associated with the time period, he argues that one would recognize what is going on in both locations: a "sage on the stage" is lecturing to a classroom of students and many are not engaged with what is being said.

The situation is different now for a variety of reasons. For example, outcomes-based assessment is required for accreditation. Also, retention at the university is important since state appropriation is now often linked to retention/completion rates. This can require the incorporation of high-impact practices on retention[7], which change strategies inside and outside of the classroom. The demographics of students are different, with classrooms filed with students of various races, both domestic and international. In addition, more and more students participate in online/distance learning programs for a variety of reasons. With the push for greater diversity is the fact that students often are not as well-prepared leaving high school for an engineering curriculum as they were generations ago. Also, the emphasis on team work is stressed in industry, so incorporation of such training during the undergraduate curriculum is required. Finally, the explosion of technology allows faculty to be creative in the utilization of the technology for improved impact, which results in classroom models that would look much different than 12th century Bologna, or even 20st century US, such as the flipped classroom[8] or the use of desktop modules[9]. Addressing all of these changes requires engineering faculty to be better trained to take advantage of such industry needs and technological/pedagogical innovations[10,11].

Calls for Reform

Higher education and its value in the US has received a spotlight recently, especially delivered through a movie called "Ivory Tower", which explored the rising cost of higher education in the US[12]. Additionally, the Obama Administration has made headlines with its "College Scorecard" program[13] and a plan towards making community colleges free for students. However, seemingly not discussed (or not at the forefront) is whether faculty (especially in engineering) have the requisite educational preparation and delivery skills to adapt to the changing landscape. Karl Fisch reports that former US Secretary of Education Richard Riley said: "*We are currently preparing students for jobs that don't yet exist using technologies that haven't been invented in order to solve problems we don't even know are problems.*"[14] – This statement conveys very effectively that being an engineering educator tasked with shaping the engineer of today and near tomorrow is anything but "some job" that can be done without proper training.

This current question of engineering educator training is not new. Indeed, the call for reform in engineering educator training has been echoed in various forms for more than a century. The President of the Society for the Promotion of Engineering Education (SPEE – the precursor to ASEE), J.B. Johnson, famously wrote that "*the time is ripe for [teachers] to prepare themselves expressly to teach in the engineering colleges.*"[15] Johnson made his comments in 1901.

Other examples include the Mann Report (SPEE) in 1918 that commented "*Schools of engineering might also do well to consider seriously cooperation with departments of education in the professional training of teachers…*"[16] In 1955, the Grinter Report stated that "*It is essential that those selected to teach be properly trained for this function.*"[17] More recently, the CCSSIEE from ASEE in 2009 recommended that "*It is reasonable to expect students aspiring to faculty positions to know something about pedagogy and how people learn when they begin their academic careers.*"[18]

Over the past decade, the future of engineering and engineering technology faculty preparation in the US has received an increasing amount of attention, specifically from within the American Society for Engineering Education. Related activities included an analysis of the current state, overviews of domestic and international faculty development activities, a discussion of principal opportunities and challenges with implementing professional faculty preparation on a national level, as well as a proposal for a related national initiative.[19-24] These are signs indicating a developing state of change with respect to this important topic, though without a tipping-point, little long-term gains in this area are likely to be realized.

Barriers to Addressing the Call for Reform

A new tenure-track faculty member has to fit within an established culture in his/her department. There is truth in the fact that time spent refining educational approaches by a new faculty member could be used for additional technical pursuits. Instead of attending that ASEE conference, for example, a faculty member could attend that Gordon conference in their research

area. If a faculty member wants to make tenure, they must be sensitive to the expectations (stated or otherwise) of the departmental tenure committee, college tenure committee, etc.

There are also times where faculty are rewarded for poor teaching. In a quick solution to the problem of a tenured-faculty member being a poor classroom teacher, those faculty are sometimes removed from that load, which is then picked up by someone who is more effective in the classroom. This may be crucial for a program whose appropriation (from the State or from an institution's responsibility centered management approach) is tied to retention. New faculty can identify this as a long-term strategy (once tenured) to limit teaching load.

Reflecting on these initial thoughts it becomes clear that the main barriers to change relate to our traditional academic reward system. Over recent decades, engineering faculty have been promoted and tenured predominantly based on their accomplishments in research as return-on-investment becomes a key factor. Adding to this is that an economic-centered approach to education identifies that a non-tenure track/adjunct faculty member is much more cost-effective than a typical tenure-track faculty member. The former can often be paid less, will not take up much/if any research lab space and can teach a full-load each semester (or, if part-time, may not be offered benefits). This person can teach the important/impactful first-year engineering course, leaving the newly-hired tenure-track faculty member to develop their research program (and work on that Ph.D.-level course in their niche area). This specialization only creates more of a divide as the cutting-edge engineering professor does not develop the skills and experience in working with undergraduate students in the classroom. However, the non-tenure-track hires are often made to satisfy last-minute enrollment surges and staffing needs, as opposed to part of a properly implemented strategy. This can impact the intended effectiveness of the non-tenure track hires (on student retention, for example).[25]

So, with a well-established reward system in place that deemphasizes a faculty member's in-class performance, what can be done to answer the call for engineering educator reform?

Carrots and Sticks

Regardless of the level of training of US engineering faculty (and prospective faculty) in pedagogy, there are incentives that exist or can be developed to provide the "carrot" for a faculty member to improve their teaching skills. For example, faculty with strong teaching skills are more competitive for teaching awards, locally and nationally. Research dollars exist in educational pursuits and, for some schools (but not every school), "all money is green and of equal value" during the evaluation process for tenure and promotion.

Incentives can be developed such as increasing the importance of teaching in tenure criteria and providing additional (internal) research dollars for those with high-marks in their teaching evaluations. Indeed, internal seed money for educational research may be the right catalyst to encourage a faculty member to explore an educational research topic (as opposed to submitting a proposal to DUE of NSF as their initial foray into the educational research arena).

Another interesting option might be the introduction of more flexible career paths that allow faculty members at certain career stages to choose between a research-focused track, a teaching-focused track, and the traditional hybrid model (with equal pay and career development options) as their interests or personal situations may change. Such an approach would emphasize a perceived equality of research and teaching careers and might encourage more faculty to voluntarily strengthen their competencies as professional educators.

Sometimes, however, despite the incentives available, other constraints mitigate the impact of these incentives. Thus, when carrots don't provide the necessary appeal for a desired action to occur for the greater good, sticks will appear. For example, energy companies are challenged to make their processes cleaner/greener through regulations on emissions. Within the engineering education realm, Wankat suggests that the Broader Impacts criteria of NSF grants in the CAREER program require a teacher-training plan[26]. Wankat goes further and links engineering faculty training with whether the faculty have the qualifications necessary to perform their job functions in teaching[26]. He cites the AIChE Code of Ethics, which states that "Members shall: Perform professional services only in areas of competence." The question here is obvious: Is it ethical for a chemical engineering faculty member who belongs to AIChE to <u>teach</u> if they are not competent in that area? Of course, the next question is: what defines competency in the area of teaching? Is it competency in the material or competency in the material <u>and</u> the delivery of the material? The former has been the interpretation and this is especially true for ABET, Inc., whose Criterion 6 states "*The program faculty must have appropriate qualifications…*".[27] Here, the 'appropriate qualifications' focuses almost exclusively on the requisite technical understanding in the material to be taught. Wankat argues that the Engineering Accreditation Commission of ABET "*could require programs to prove that every professor who teaches undergraduates is a competent teacher or is pursuing an educational program.*"[26] Considering that, basically, every US engineering faculty member is impacted by ABET, Inc. (e.g. creating outcomes for courses that map onto student outcomes), enforcement of Criterion 6 in the manner suggested by Wankat could prove the mechanism that answers the century-long call for training engineering educators on how to teach.

Engineering Faculty Training in the US

To become a faculty member (especially tenure-track) in an engineering program in the US normally has just a single requirement: a Ph.D. in the discipline (or a related area). The teacher training, if it is done at all, is regularly completed after a faculty member is hired. It can be something local (e.g. at the campus' center for teaching and learning) or external (e.g. through a workshop), or a combination of both (or nothing at all).

ASEE, through the National Effective Teaching Institute (NETI), provides external workshops for new faculty in engineering[28]. There are others that run external as well, and include Rose-Hulman Institute of Technology (Making Academic Change Happen)[29] and Bucknell University (How to Engineer Engineering Education) [30]. Every five years, the ChE Division of ASEE provides a week-long summer school for new Chemical Engineering faculty[31]. ASCE offers

annual, week-long ExCEEd Teaching Workshops during the summer for all engineering educators. This includes the first workshop and a 1 ½-day refresher (ExCEEd II) for those who have already attended an ExCEEd workshop[32].

Colleges of Engineering (or institutions) can bring in outside experts for day-long workshops and this model serves often as a "one-off" approach where an institution can boast of providing access to such expert training. However, depending on the workshop facilitator, this training is often out of context (i.e. not perceived as being directly-relatable to engineering) and, without follow-up, tends to have limited measureable outcomes or impact.

Locally, engineering faculty often have access to centers for teaching and learning on campus. While this is a convenient resource for many faculty (as opposed to the commitment of travelling somewhere else for training), it often does not have the desired impact. Notably, there is often a mismatch between the instructors providing this training and the engineering faculty attendees, since the transfer of theory and approaches of general teacher training to a relatable engineering setting becomes a barrier that is a challenge to cross. The pedagogical experts struggle to provide the most relatable scenarios to an engineering setting and, likewise, engineering faculty can quickly (and, often, incorrectly) conclude that an engineering classroom is outside of the benefits of the approaches presented. Thus, one single (and initial) interaction can poison that particular engineering faculty member towards the entire field of educational research.

Ideally, a center for teaching and learning would exist within a College of Engineering, staffed with experts who are knowledgeable about the unique challenges of an engineering classroom/curriculum and, who, in the best-case scenario, are engineers as well. A handful of those centers exist around the US, such as the Leonhard Center for the Advancement of Engineering Education [33] at Penn State University and the NCEER at Northwestern University[34].

There are also approaches to provide prospective engineering faculty with the pedagogical training they need prior to starting their first tenure-track position. For example, the "Preparing Future Faculty Program", which started in 1993 by the American Association of Colleges & Universities and the Council of Graduate Schools, involves over 300 institutions in their training programs, though only a very small number have engineering components.[35] Also, the University of Cincinnati has a future faculty program that combines a 3-credit hour course on effective teaching and a 2-credit hour job-search course, with 40-hours of mentored teaching. This past year, however, the 14 graduates of this special program included zero engineering students[36]. Additionally, the University of Maryland has a future faculty training program in engineering that includes three, 1-credit hour seminars, a teaching practicum (where a prospective faculty member teaches a course under faculty advisement) and a research practicum (where a prospective faculty member provides mentoring for graduate students). The program had 24 graduates last year[37].

The Education Division of AIChE provides a Future Faculty Program for its members who are interested in earning a faculty position. The program starts in the final year of a student's Ph.D. or post-doctoral study and matches mentees with experienced chemical engineering faculty. The

year-long program has required conference calls and a mentoring project. Since its inception a few years ago, more than 27 prospective faculty members have participated[38].

Larger, multi-institutional networks exist that leverage member capabilities across the network. The Center for Integration of Research, Teaching and Learning (CIRTL) is one such network[39]. This group of 22 institutions is "*committed to advancing the teaching of STEM disciplines in higher education*". They offer weekly seminars and on-line course (while encouraging graduate credit at the local institutions). They also offer learning communities, presentation/publication resources and Facebook groups. CIRTL emphasizes "teaching as research" or, in other words, the deliberate use of what is known in the research literature by STEM instructors to positively impact the outcomes for instructors and students.

At the Georgia Institute of Technology, there are three Teaching Certificate levels in the "Tech to Teaching" Higher Education Pathway program: Foundation, Intermediate, and Advanced[40]. Currently, the Foundation Level does not have an associated certificate and consists only of the practical experience of being a Teaching Assistant (TA) with instructional responsibilities (such as leading a recitation or discussion section or lab). Students who complete the requirements for the Intermediate or Advanced Level Teaching Certificate receive recognition via a Certificate that is awarded upon completion of either level.

The intent of the Tech to Teaching program is to provide flexible pathways for students to take the various graduate courses that make up the Intermediate and Advanced Tech to Teaching certificates. Individuals may progress through the courses in different orders based on previous teaching experience, career goals, home department programs and policies, and other factors. While there is a recommended route and various alternative routes, students can proceed at the pace and to the step or level certificate that they desire. Both the Intermediate and Advanced Certificate levels represent the recommended pathway for "future faculty" development based on the stages of TA/Future Faculty Development as described by Nyquist and Wuff[41].

Engineering Faculty Training Overseas

Some countries have pedagogical training programs for faculty, regardless of discipline, such as Denmark, Norway, Sweden and the UK, which require completion during the tenure period. Other countries offer certifications, where achievement is treated as a professional credential, like the PE license. There are also programs (similar to US) where workshops are offered and faculty will self-select to attend and participate.

In the United Kingdom, all junior faculty are required to successfully complete the "UK Professional Standards Framework" during the tenure period. This program, which is managed by the Higher Education Academy, allows faculty to gain competency in activity areas, core knowledge and professional values. Faculty (or Ph.D. students) can achieve various levels, including Associate Fellow (normally Ph.D. students as instructors), Fellow (early career faculty), Senior Fellow (experienced, post-tenure faculty) and Principal Fellow (leading the

training of others). In 2014, the UK Higher Education Academy surpassed the 50,000 mark of formally trained, qualified and certified educators[42].

In Denmark, all institutions require their Assistant Professors to complete training in educational pedagogy called the "*adjunktpædagogikum Programme*". Within the framework provided centrally, institutions develop their own programs to meet these requirements. The focus is on learning theory, instructional techniques and practical applications in the classroom (where faculty implement what they are learning). The programs are normally modular, with some aspects available on-line, and include portfolios, poster presentations and mentoring/supervision of activities, with feedback and evaluations at the end of the program. The time commitment is extensive, with some programs requiring 175 hours to complete.

Engineering educators not just overseas, but around the world, can become a certified IGIP International Engineering Educator. This program, which comes from the International Society of Engineering Education (the acronym "IGIP" is derived from the society's original German/Austrian name, "Internationale Gesellschaft für Ingenieurpedagogik"), accredits training centers to offer this certification. Centers exist in Germany, Russia, Austria, Brazil, Switzerland, Czech Republic, Estonia, Kazakhstan, Estonia, The Netherlands, Poland, Portugal, Slovakia, Slovenia and Ukraine. The curriculum requirements are modular and extensive, requiring 600 hours total, across eight areas, including: Theoretical and Practical Engineering Pedagogy (180 hours), Laboratory Methodology (60 hours), Psychology and Sociology (90 hours), Ethics/Intercultural (30 hours), Communication Skills (90 hours), Project Work (30 hours), Electronic Technologies (60 hours) and Electives (60 hours).[43] It is anticipated that the IGIP program, in addition to its traditional format, will be offered in an online format as well in the future.

While both the British and the IGIP programs are accredited, other countries have just embarked on the avenue of professional educational training[24,44]. In Australia, for example, a number of efforts have been initiated at the federal level to ostensibly track and improve teaching quality. However, some question whether this criteria has the strength to make the requisite changes in the quality of teaching within engineering. Nonetheless, there are individual institutions whose engineering programs have made first moves towards more formal requirements regarding teaching quality. As of yet, little is known about corresponding developments in Asia, though some in Japan mention that faculty salary can be linked to educational experience. For a more detailed discussion of existing faculty development and recognition programs around the world, please refer to Schaefer and Utschig[24,44].

SPEED and COMPLEETE

If the US were to adopt a formal engineering faculty training program (through governmental intervention, through ABET, Inc. *de facto* requirement or other means), what might this look like? The authors of this manuscript were involved in an approach to design such a program, though implementation/piloting has stalled without such a national mandate.   The program, first called SPEED and then reformulated as ***COMP**etencies in **L**earning for **E**ngineering and*

Engineering Technology Educators (COMPLEETE)[45-47], was to be a national-level ASEE program with four main goals: (1) defining frameworks and metrics for core teaching competencies, (2) designing a modular curricular framework for implementation, (3) establish the appropriate administrative processes/provider certifications for implementation and (4) involve multiple constituencies in the processes to attain the first three goals. Learning outcomes for COMPLEETE were drafted and attainment levels proposed.

The proposed COMPLEETE curriculum revolved around seven areas of core competency that were articulated as a synthesis of faculty development needs by experienced faculty development experts in engineering. These seven areas of core competence are: (1) learning theory, (2) student development, (3) instructional design, (4) instructional facilitation methods, (5) assessing and providing feedback, (6) instructional technology, and (7) reflective practice. The proposed curriculum is also consistent with previously proposed critical elements for successful faculty development programs at a national level in the US and, in essence, serves as one response to numerous calls for a national reform. It also integrates with values and programming already present within ASEE[48], serves as a foundation for further development at higher levels, and is flexible to suit the needs of a diverse instructional community[49].

The Impact of Engineering Education Research

Several funding agencies, most notably the US National Science Foundation, provide support for research in engineering education. However, is the data and information being generated from this research being used to inform decisions on the selection of instructional techniques by faculty? Borrego and co-workers looked to explore the above question by asking engineering faculty members on their self-reported knowledge and use of research-based instructional strategies (RBIS) in teaching their core engineering science courses[50]. What they found from the 208 respondents to their survey was that more than half still used active learning and collaborative learning, but less than a 1/3rd still used the other RBIS identified on the survey (including think-pair-share, problem-based learning, concept tests, etc.). There was also a significant (between $10-20\%$) amount of users who had previously implemented a particular RBIS technique, but do not currently use it. The research indicated that this was mainly because the technique took too much class time or too much preparation time. Finally, the research also indicated that the most popular mode for a faculty member to learn about a RBIS was from a colleague who used the approach or from an on-campus presentation[50].

Final Thoughts

Is it really necessary for there to be another "call to action" for engineering educator training? The calls exist and have existed for more than a century. Programs exist in the US at the local, regional and national level that define competencies and levels for faculty to attain in their pedagogical training. Various models exist overseas for implementation of national certification programs. The next step for the US is the use of the catalyst/stick to enforce mandatory

pedagogical training for engineering faculty. Whether that will come through government enforcement, accrediting boards or professional societies remains to be seen. Of course, whether this same unanswered call exists five, ten, twenty or fifty years from today also remains to be seen.

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