2006-1174: THRIVING OR SURVIVING K-12 ENGINEERING OUTREACH AT A RESEARCH EXTENSIVE UNIVERSITY

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Thriving or Surviving K-12 Engineering Outreach at a Research Extensive University

Abstract

Successful K-12 engineering outreach at any university requires substantial support from the administration at the department, school/college and university levels. It also requires dedication of faculty, staff and university students to the outreach activities. Historically the traditional faculty performance metrics at research extensive universities have not included K-12 outreach initiatives. Therefore faculty members at these universities may not have the incentive to create and sustain K-12 outreach programs. Many engineering faculty and students at research extensive universities are beginning to play a critical role in the education of K-12 students. A national trend is occurring at such universities, where K-12 engineering outreach excellence is deemed consistent with the mission of the research university. This trend represents *institutional change*, a required program attribute by the National Science Foundation. This paper examines the *institutional changes* taking place at research extensive universities across the nation that support K-12 engineering outreach and compares them to those taking place in the Pratt School of Engineering at Duke University. We describe the critical events that have changed the Duke University *institution* and have led to faculty incentives for K-12 engineering outreach participation.

Introduction

Flat or declining math and science competency in K-12 students in the U.S.[1], flat or declining enrollments of U.S. citizens in undergraduate engineering programs[2], and the rising dependence of society on technology have led to several initiatives in the last decade. These include the creation of the American Society for Engineering Education EngineeringK-12 Center[3], the National Science Foundation's GK-12 Teaching Fellows[4] and Math Science Partnership[5] programs, Project Lead the Way[6], and a substantial list of institutions that have developed K-12 engineering outreach programs nationally[7].

Doctoral/Research university engineering programs have a unique and essential role in K-12 engineering outreach. These programs have the resources to translate both the process and content from cutting edge research into lessons and activities that provide immediate relevance and add inspiration and excitement to the math and science concepts children learn in the K-12 classroom[8]. The primary commitment of a research university is the generation and transmission of new knowledge. The traditional metrics used in the appointment, promotion and tenure process for faculty at research universities include scholarly publication of cutting edge research results, successful graduation of Ph.D. students, funding of research activities leading to indirect cost recovery by the university, and to some extent effective teaching.

There are three necessary conditions for the development and sustainment of successful K-12 engineering outreach at a research university. First, the requirement of committed faculty members who are dedicated to the mission K-12 engineering outreach programs. Second, the faculty members' careers must benefit from the outreach activities. Third, the institution must

genuinely support these activities. These conditions suggest an important question addressed in this paper is: Are the necessary conditions for successful K-12 engineering outreach orthogonal to the mission of research extensive universities?

There is significant institutional change taking place at several research extensive universities with respect to K-12 engineering outreach and engineering education in general. A pioneer in the emerging discipline of engineering education is Purdue University[9], which offers both M.S. and Ph.D. degrees in engineering education. The first class in this program began in the fall of 2005. Graduates are expected to pursue careers in innovative undergraduate pedagogy in "two-year and four-year engineering programs both with and without graduate programs and in community colleges. Graduates may be employed as engineers, educational training specialists, technical communication specialists, and directors of teaching/learning centers, diversity programs, or outreach programs[9]." Other research extensive universities pioneering graduate programs in engineering education include Carnegie Mellon, Virginia Polytechnic Institute and Utah State University.

In 2002, The National Academy of Engineering (NAE) established the Center for the Advancement of Scholarship on Engineering Education (CASEE) to "promote the technological welfare of the nation[10]." The CASEE recently held a workshop entitled, "Social Dynamics of Campus Change: Creating an Interdisciplinary Research Agenda." The purpose of this workshop was "to examine how to promote the diffusion of innovation in engineering education." Innovations in undergraduate engineering education and successful K-12 engineering outreach are intimately coupled because a) many of the future leaders of K-12 engineering outreach programs will be graduates from engineering education programs, b) innovations in undergraduate engineering education target the learning process, which also apply at the K-12 level and c) recognition of the validity of engineering education innovations by the research university administration will drive the institutional change necessary for successful K-12 outreach.

This paper is organized as follows. The Carnegie classification system of Doctoral/Research Universities is reviewed. The mission of research extensive universities is examined and its compatibility with the conditions necessary for successful K-12 engineering outreach is explored. Innovations in undergraduate and graduate education at research extensive universities are examined. Elements of sustainability models for K-12 engineering outreach programs are examined in the context of the mission of research extensive universities. Finally, conclusions are drawn regarding the future of K-12 engineering outreach at research extensive universities.

Doctoral/Research University Classification

The Carnegie Commission on Higher Education[11] created a classification of institutions of higher education (IHE) in 1970. An IHE is classified based on institutional attributes, such as the types and number of degrees that are awarded, enrollment and an index of research activity. The research activity index is based on correlates including: Research and development expenditures, postdoctoral appointees, non-faculty research staff, and doctoral conferrals[12]. The Carnegie Classification provides a convenient framework for studying the differences among universities.

Although classification is based on a time-specific "snapshot" of institutional attributes, the classification of many institutions endures. A Research Extensive University "offers a wide range of baccalaureate programs and they are committed to graduate education through the doctorate. They award 50 or more doctoral degrees per year across at least 15 disciplines[13]." Research Intensive Universities "offer a wide range of baccalaureate programs and are committed to graduate education through the doctorate. They award at least 10 doctoral degrees per year across three or more disciplines, or at least 20 doctoral degrees per year overall[13,14]. There are approximately 50 private and 110 public institutions - for a total of 160 - Research Extensive Universities in the U.S. Within the category of research extensive are four subcategories: R1, R2, D1, and D2. R1 universities receive at least $40M in federal support. R2 universities receive between $15.5M and $40M in support from federal agencies. There are no federal funding criteria for the D1 and D2 subcategories, only specifications on the number of doctoral graduates per year and the number of disciplines in which they received their degrees. Duke University is an R1 Research Extensive University. There are approximately 60 public and 30 private – for a total of 90 - R1 universities.

Mission of Research Extensive Universities and Compatibility with K-12 Outreach

"The mission of Duke University is to provide a superior liberal education to undergraduate students, attending not only to their intellectual growth but also to their development as adults committed to high ethical standards and full participation as leaders in their communities; to prepare future members of the learned professions for lives of skilled and ethical service by providing excellent graduate and professional education; to advance the frontiers of knowledge and contribute boldly to the international community of scholarship; to promote an intellectual environment built on a commitment to free and open inquiry; to help those who suffer, cure disease, and promote health, through sophisticated medical research and thoughtful patient care; to provide wide ranging educational opportunities, on and beyond our campuses, for traditional students, active professionals and life-long learners using the power of information technologies; and to promote a deep appreciation for the range of human difference and potential, a sense of the obligations and rewards of citizenship, and a commitment to learning, freedom and truth[15]."

While the mission of Duke University is unique, it shares several elements with other R1 universities. These elements are stated succinctly by Purdue's mission statement that reads in part, "discovery that expands the realm of knowledge, learning through dissemination and preservation of knowledge, and engagement through exchange of knowledge[16]." K-12 outreach activities are well-aligned with these mission elements. Additionally, *service-learning*, a form of experiential education widely recognized as a highly valuable component of undergraduate and graduate programs[17], is frequently coupled with K-12 outreach activities at R1 universities. Hence, it appears that K-12 outreach fits well within the mission and educational programs at R1 universities.

Enter engineering at an R1 University, where faculty appointment, promotion and tenure are based on external funding, graduation of Ph.D. students, and scholarly publication all centered around cutting edge research, and one will typically find that if K-12 outreach is active, the effort is led by a non-tenure track faculty member. These non-tenure track faculty members have titles such as Research Associate, Professor of the Practice, Research Professor, Research Scientist,

and Visiting Professor. However, the climate is changing and some research extensive institutions are piloting tenure cases based heavily on scholarly publication related to innovation in engineering education including K-12 engineering outreach. There are also many faculty members who have chosen to lead K-12 engineering outreach programs after successfully achieving tenure in the traditional manner.

K-12 engineering outreach in the Pratt School of Engineering at Duke University began in 1999 with the creation of the Duke-NCSU Engineering Teaching Fellows Program[18]. The Principal Investigator, Ybarra, was hired as an Assistant Research Professor in 1993, primarily to resurrect the introductory circuits course in the Department of Electrical and Computer Engineering. After creating the Duke-NCSU Engineering Teaching Fellows program, Ybarra created several other K-12 engineering outreach programs with the help of colleagues Klenk and Kelly including Techtronics: Hands-on Exploration of Technology in Everyday Life[19], MUSCLE: Math Understanding through the Science of Life[20], MUSIC: Math Understanding through Science Integrated with Curriculum[21], and TASC: Teachers and Scientists Collaborating. In 1999 Ybarra was promoted to Associate Professor of the Practice, a new position title in the Pratt School of Engineering, primarily due to his innovative contributions to engineering education at the undergraduate level at Duke University and his K-12 outreach programs. In 2005 he was promoted to full Professor of the Practice primarily based on his work in K-12 engineering. Since the Professor of the Practice track was established in Pratt in 1999, there have been five others who have been hired into this faculty track. Ybarra is the first and only person to go through the promotion process to full Professor of the Practice. It remains to be seen how the basis for promotion and tenure will evolve in the Pratt School.

Innovations in Engineering Education Programs at Research Extensive Universities

Institutional changes in a global sense[22] are exemplified by changes in expectations and norms, not just the changes in the behavior of specific faculty in specific situations. "The changes alter the distribution of recognition in a significant way. The new expectations, like the old ones they supersede or replace, become self-reproducing over time, and create their own inertia. Typically, this means that the changes must be broadly accepted as legitimate[22]". Institutional change in the context of engineering education and K-12 outreach at R1 institutions results from partnering of individuals with a shared vision, desire and resources to drive the change. One of the most remarkable examples of institutional change has occurred at Purdue University (R1 Research Extensive) where a new Department of Engineering Education was created in 2004 and "marked the first time any university in the country had created a dedicated academic department to engineering education[23]." According to Dr. Kamyar Haghighi, Professor and Head of the new department, the program was created to address the declining student interest in math and science in K-12 as well as pedagogy problems in undergraduate engineering education. Expected career paths for graduates from the department include faculty appointments in engineering and engineering technology programs at two-year and four-year institutions spanning all Carnegie categories, "educational training specialists in industry, technical communication specialists, and directors of teaching/learning centers, diversity programs, or outreach programs[23]". For those graduates who become faculty members at R1 universities and choose to direct K-12 engineering outreach programs as their primary focus, it is unclear at this time whether such a career path will be deemed tenure worthy across institutions in general or whether it will be limited to a few

isolated institutions like Purdue where tenured and tenure-track faculty positions are currently being solicited in the Department of Engineering Education. Another interesting development of tenure process recognition of K-12 engineering outreach activities is taking place at the University of Maryland, Baltimore County (D2 research extensive). The Department of Mechanical Engineering has established a tenure track assistant professorship held by Dr. Anne Spence who directs several nationally recognized engineering outreach programs.

Virginia Polytechnic Institute (R1 Research Extensive) has established a Department of Engineering Education that offers both Master of Science and Ph.D. degrees in Engineering Education[24]. The M.S. program targets students interested in engineering policy, teaching at community colleges, engineering education research, corporate staff training staff and university assessment staff. The Ph.D. degree targets students interested in engineering policy, teaching at non-research colleges and universities, educational research, corporate training management and university assessment staff or administrative faculty. The engineering education faculty at VPI have a diverse set of research interests including, "Assessment, cultural change in engineering education, perceptions of rigor in engineering education research, development of engineering education as legitimate field, design of effective engineering courses and curricula, impact of active learning and project based activities on student learning and retention, and the creation of learning environments and design projects to support a diverse student population[25]."

Utah State University (R1 Research Extensive) has established a Department of Engineering and Technology Education and offers a B.S. in Engineering and Technology Education that prepares "individuals to teach technology education in grades 6-12[26]," a B.S. in Trade and Technical Education that "prepares and licenses graduates to teach trade and technical subjects in high schools and colleges," and both an M.S. and Ph.D. in Engineering and Technology Education. The Engineering and Technology Education programs are intended to prepare their graduates to teach in public schools, applied technology colleges, and community colleges[26].

Sustainability Models of K-12 Engineering Outreach Programs at Research Extensive Universities

There are numerous outstanding K-12 engineering outreach programs at Research Extensive Universities. Many of these are listed in the new American Society for Engineering Education EngineeringK12 Center database[7]. One attribute common to all of these programs is the need for sustainability. Sustainability requires internal and external support. Examples of internal support includes matching funds, indirect cost waivers, space for training students and teachers, storage space for materials, credit in lieu of a stipend for teaching fellows, office space for investigators and teaching fellows, administrative assistants and assertive advocacy at every level of the administration including the Dean, Provost and President.

Conclusion

Research Extensive Universities thrive on external funding including grants from federal agencies and industry as well as private sector donations. These universities thrive on scholarly research leading to publication of journal papers and books, large numbers of Ph.D.s awarded per year and substantial external funding. The traditional metrics for appointment, promotion and

tenure at research universities do not include K-12 engineering outreach. However, hundreds of university engineering faculty across the nation have become involved in K-12 outreach in the past 10 years, and the number is growing. In the past two years, three R1 Research Extensive Universities have established Ph.D. programs in Engineering Education. These programs are preparing the next generation of K-12 outreach program directors. It remains to be seen whether these graduates will be appointed to the faculties of Research Extensive Universities and whether institutional change will occur such that the tenure process rewards successful K-12 engineering outreach.

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