A system for generating and sustaining interest in engineering

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ABSTRACT: The role of engineering in innovation and creation of new paradigms is critical. Engineers and scientists have played an indispensable role in most innovations over the past century. While all this is true, it is also troubling to note the interest in these professions is diminishing gradually. Young people in many countries do not see a career in engineering as a pursuable profession. The reasons range from being too difficult to being irrelevant to their own goals. The College of Engineering and Engineering Technology at Northern Illinois University has had excellent success in building interesting pathway bridges through several initiatives. A number of effective practices and innovations for creating and sustaining interest in engineering for both continuing and future engineering students are presented and discussed in this paper.

INTRODUCTION

The enrolment numbers in engineering programmes at most of the engineering schools in the USA are in decline, or at best, stable. Institutions such as the National Science Foundation, the National Academy of Engineering and the US Department of Education believe this to be a serious trend and are doing everything possible to change it. They have combined the interrelated fields of science, technology, engineering and mathematics and termed it STEM. The NSF recently held a conference on *Science Education and Workforce Development: Key Challenges for Innovation in the States*, in Washington, DC [1]. The conference focused on programmes and challenges in STEM. For the first time, the NSF is anxious to evaluate the impact of programmes on STEM recruitment and retention. Most of the universities are also gearing up to strengthen their STEM programmes and to assess the effectiveness of their programmes. It is well-known that unless the US improves its shrivelling numbers in engineering and science, these disciplines will constitute a very small percentage in the global workforce. The situation is far more critical in engineering. At present, it can be roughly estimated that the United States has approximately 5-10 per cent of the worldwide engineering workforce. In contrast, India and China produce more than 800,000 science and engineering graduates every year. It is ironic that the USA being the major economic force considering the G-8, the European Union, BRIC (Brazil, Russia, India, China), and other economic conglomerates, cannot fill the necessary academic pipeline at the undergraduate level to maintain the *minimum* engineering professional workforce required. Replenishments are needed to replace retiring engineers and the significant number of engineers choosing non-technical or non-research careers in service and business sectors such as safety, transportation, health systems, banking, non-technical management.

Therefore, it is imperative to address this situation in order to assure a sustained engineering workforce in the USA. It its evident that many countries in the world are struggling with pipeline issues and it is the sincere hope of the authors that the initiatives described in this paper will be useful in diverse scenarios and contexts. Furthermore, if the model proposed in this paper has any credence to it, its applicability in the world market is non-debatable. The world needs well-qualified and well-rounded engineers.

The need for a sustainable pipeline for the technical workforce is necessary because of the critical need for the world to be innovative. Innovations are the creation of new ideas and their transformation into a product or a process that would bring positive changes to the world. Additionally, these innovations can then be converted into new wealth through entrepreneurship. As engineering professionals, the authors are biased towards the importance of innovation over entrepreneurship. It is logical to assume that unless innovation takes place, there will be very few opportunities for entrepreneurship to address the needs of the market place. In the context of *good business needs good engineering and good engineering needs good business*, it is very important for the global world to understand the need for engineers in the product life cycle. The first step of any product life cycle is its development and design and then comes the business aspect of managing the impact created by that product. This impact may include financing, marketing, accounting and management aspect of product life cycle. Nevertheless, innovation is the first and the most critical part of the cycle. Therefore, the engineering profession will continue to play a critical role in the workforce needs of the future.

While it is safe to assume that most people understand this aspect of engineering, it is also clear that the world is not prepared enough to encourage young minds to pursue engineering and embrace innovation and entrepreneurship to take this world through the next cycle of wealth creation and prosperity. In countries such as India and China, even though the number of engineers graduating from universities is incredible, the need for quality assurance and reciprocity of education with other countries is a major challenge. Many countries in Europe are just beginning to develop quality assurance standards (the Bologna Process, for example). Obviously, international agreements on broad-based recognition of accreditation processes such as the Washington Accord [2] and the UGC [3], etc, must be developed.

In countries such as the USA, the pipeline of students to pursue engineering degrees is critically low and the trend does not look favourable. One possibility in the USA is to attract well-prepared minorities (including women) and first-generation immigrants into engineering programmes. Said groups are not yet fully represented in the US engineering workforce, as well as in the engineering academic programmes. Several national, regional and local initiatives are being developed to attract minorities into the academic programmes in engineering and technology.

The College of Engineering and Engineering Technology (CEET) at Northern Illinois University (NIU) has launched a concerted multi-faceted approach for increasing awareness of the engineering profession in general. The elements of this approach range from summer camps to special masters programmes to high school teachers to programmes such as adopt a high school. By attracting competitive grants from foundations such as Carter Rodriguez, Motorola and Exxon Mobile Harris Foundation, the CEET is able to offer summer camps to introduce middle school and high school students to exciting engineering and technology concepts. The information about engineering provided to high schools, must be complete and with specific details to empower the students with the decision-making capability. CEET provides information to more than 300 high schools every semester under their Adopt a High School Program. The programme also enables high school students to visit the CEET engineering facilities. It is also evident from surveys conducted by NIU that in most cases high school teachers and counsellors have limited knowledge about engineering programmes and, therefore, are unable to motivate young students to pursue programmes and careers in engineering. On the other hand, engineering schools must be properly equipped to offer practice-based programmes that could enable students to feel real engineering and be excited to pursue it in the future. Again, there must be a continuous dialogue between the engineering schools and high schools.

The College of Engineering and Engineering Technology at NIU has created a unique blend of programmes to sustain engineering pipeline into its programmes. The college is 22 years old and has about 1,500 students in the four departments of the college. The trend over the past few years has been positive, resulting in a record yield of students and also an improvement in their retention. To ensure their success, CEET provides a multitude of activities such as student academic success support, student internships and co-op placements, student involvement in professional organisations, overall student intellectual growth, seamless transition for transfer students, and undergraduate research. These support systems, which were established during the earlier years of the college, were expanded and strengthened during the last 6 years. Since the college was established, there has been a change in demographics and curriculum. Therefore, the programmes and services for student success had to be revisited. The changes made since 2003 have resulted in continuous improvement. It is interesting to note that graduation rates have gone up by 7 per cent in the first four years.

According to info-brief provided by the National Science Foundation [1], 49 per cent of science and engineering (S&E) graduates earn a higher degree within the decade of earning their baccalaureate degree. Only 13 per cent had earned an advanced degree in their broad field of undergraduate study. The disturbing fact is that 29 per cent of those went on to earn a degree in a non S&E field and only 20 per cent earned a degree in S&E. Therefore, the field lost a significant number of students to non S&E fields. This trend is not favourable to the engineering pipeline issue faced by the US. The above distribution of S&E advanced degrees is yet another challenge to the US engineering schools. In view of these trends, CEET at NIU integrated several initiatives including undergraduate research into the existing programmes to continue students' interest in S&E fields. Though similar data were not available for other countries, it is safe to assume that the percentages may differ but the same patterns may exist in other countries as well.

RECENT INITIATIVES

Master of Science in Teaching (MST)

This is a unique programme. It awards a masters degree in teaching (MST) to high school mathematics and science teachers who hold teaching qualifications. This is a special programme created by funding from the state, which also needed special approval from the state. State funding of the programme and its support is yet more evidence that the state recognises the need for additional students to pursue careers in science and engineering. This is a two-year programme and 26 teachers have enrolled during the first cohort programme. The degree assumes that the students will possess classroom pedagogy and other attributes to be effective teachers. The concentration of courses is on general engineering content and engineering projects. The immediate expectation of the programme is that the teachers will be able to teach mathematics and science better because of engineering applications. It is well known that project-based learning not only improves learning and teaching, but also motivates students to go beyond succeeding in the classroom and pursuing further studies in related fields.

A sample curriculum of the programme is listed below:

- *IEET 590 - Topics in Engineering and Engineering Technology* Credits: 1-3
- *TECH 532 - Disaster Preparedness* Credits: 3
- *TLCI 537 - Improvement of Instruction* Credits: 3
- *UEET 601 - Introduction to Emerging Technologies* Credits: 3
- *UEET 602 - Nanotechnology and Applications* Credits: 3
- *UEET 603 - Introduction to Energy Engineering* Credits: 3
- *UEET 604 - Introduction to Fuel Cell and Fuel Cell Power Generation* Credits: 3
- *UEET 605 – Nano-electronics and Applications* Credits: 3
- *UEET 606 - Applied Modern Manufacturing and Quality Control* Credits: 3
- *UEET 607 - Internship* Credits: 3
- *UEET 608 - Master's Project* Credits: 3

Curriculum for Master of Science in Teaching (MST) programme with specialisation in Engineering Education

The teachers participating in the programme were given a unique clinical opportunity as team teachers and counsellors to work during several summer camps held by the College in 2009. The College held four summer camps, which were supported by Motorola Foundation, Exxon Mobile/Harris Foundation and Carter Rodriguez Foundation. There were more than 200 students from middle and high schools from 82 cities, 33 high schools and 49 middle schools and from 88 school districts. The teachers enrolled in the MST programme were hired as active counsellors for the summer camps to provide them with a unique opportunity to gain insight into engineering projects and engineering pedagogy.

Utilising an interdisciplinary team of faculty members from engineering, sciences, and business, the proposed curriculum (MST) demonstrates a problem-based pedagogical approach to increase content retention for undergraduate students in STEM areas.

In another project involving an NSF grant, curriculum is being developed to place a special emphasis on nanotechnology with focus on biological nano-self assembly, nano-sensors, marketing, health and ethics aspects of nano-scale engineering. This programme is in line with the needs expressed by the high school community [4]. The capstone modules in this programme will provide students with interdisciplinary experiences on projects using nanotechnology in applied, hands-on projects. It is envisioned that as students progress through the courses, they will feel part of a community of learning with their fellow students and professors. In addition, for the students in the CEET engineering pipeline, further interest is maintained through undergraduate research, and BS/MS programme [5].

Summer Camps

The college has been exceptionally successful in attracting outside support (explained later) for holding summer camps (described below) for middle and high school students. Other disciplines such as medical fields have also tried different programmes to sustain and improve their recruitment and retention statistics [6]. The programmes launched by various schools and disciplines are exemplary but their overall impact on a national level is still far from optimal.

Exxon Mobil Harris Foundation

Exxon Mobil Harris Foundation - this summer camp had the theme *Life in Motion: Seen and Unseen*, Northern Illinois University's College of Engineering and Engineering Technology in partnership with the Challenger Centre. It engaged middle school children with applications of science, technology, engineering and mathematics (STEM) through hands-on collaborative learning projects in two-week residential summer camp sponsored by the Exxon Mobil Bernard Harris Foundation Science Summer Camp. The instructional modules were designed using an inquiry-based learning known as 5E model. The Challenger Centre in Woodstock, Illinois, is one of the several centres established by NASA throughout the country to enhance communities' understanding of space programmes. The students get to know about space and get to experience a space flight through a simulator.

A diverse team of instruction personnel consisting of engineering faculty members, teachers from partnering school districts, engineering undergraduate and graduate students, and high school students participated in content delivery of instructional modules. They facilitated the conduct of experiments dealing with: 1. Rocket design and launching; 2. Robot design and programming; 3. Mission Control; 4. Experiments involving measurement of energy, velocity and acceleration; 5. Electromagnetic spectrum with special emphasis on UV radiation and solar cells; 6. Plant photosynthesis; 7. Design of a Calorimeter; 8. Nutrition and computation of Body Mass Index and Basal Metabolic Rate (BMR).

Motorola Foundation for Women in Engineering

Supported by the Motorola Foundation, this project has established an alliance between the CEET at NIU, the Collegiate section of the Society of Women Engineers (SWE), the Prairie Winds Girl Scouts Council and the Sybaquay Girl Scouts Council to develop a Saturday Academy programme to introduce engineering to the Cadettes and the Senior Girl Scout members. These two groups comprise middle and high school age children. In addition, the Saturday Academy activities culminate in a summer camp, which is focused on engineering design through hands-on activities, teamwork to enable the participants to earn an Interest Project Patch from the Girl Scouts Council and an Event Patch from the Society of Women Engineers and a mentoring programme for the senior scout members.

Prior to attending the summer camp, the students are introduced to key leaders in engineering and are given an opportunity to ask questions from them. Mentorship opportunities are offered through connections with the leaders. In many cases, students continue the dialog with their mentors and are ready for a meaningful experience when they come for the summer camps.

Carter Rodriguez Foundation for Women in Engineering (2 camps)

This project also known as Get WISE (Women In Step with Engineering), co-sponsored by the Carter Rodriguez Foundation and CEET at NIU is a new programme dedicated to helping young women in middle school and high school explore the exciting and rewarding field of engineering. Through partnerships with local businesses, in-school and on-campus group activities, and one-on-one mentoring opportunities, Get WISE provides students with valuable hands-on experiences and a support system that includes current NIU engineering students and faculty. The programme has been running for two years and has had tremendous success in stimulating students' interest in science and engineering.

The above two camps (one for middle school students and one for high school students) have attracted more than 600 applications from high school and middle school students for 200 slots. The camps are of 1-2 weeks duration and provide hands on experience to students empowering them with education, awareness and motivation for careers in engineering and science. Furthermore, it is expected that the students attending the camps will have a higher appreciation of foundation courses in mathematics and science.

These camps have their roots in some of the projects undertaken by the College in the past. One of these projects was SIMPLE: Success in Mathematics and Physics through Linkages in Engineering. The project engaged several students to learn math and physics through engineering applications. It was found that the experience enhanced the students' ability to understand mathematics and science better by understanding their application to real life problems. The application aspect not only enhanced their understanding of mathematics and science but also enabled them to think about science and engineering majors seriously. The same principles were emphasised in the summer camps listed above. The students were also given a chance to experience university life which addressed some of the fears and uncertainties about living on large campus away from home. Students enjoyed the practice-based activities during the day and enjoyed the evenings doing extracurricular activities. All participants expressed an increased learning in science and mathematics due to the real life based engineering application. Students appreciated the application aspect of engineering to understand the reasoning behind learning mathematics and science.

Partnership with Boy Scouts

The College has established a relationship with the regional boy scouts organisation and has sponsored their pine derby contest. The pine derby contest engages young students to design a model car and enter it in a regional competition. The car utilises several engineering and science principles and enables students to be exposed informally to utilising science and technology concepts to design a functional project. This was done with the intention of increasing awareness of engineering in the youths' minds. The College has also planned regular visits with the boy scouts over the year to apprise them of careers in science and engineering. The youth participating as boy scouts are usually creative and have an interest in hands-on projects. It is expected that these students will see a potential career in the engineering profession.

Innovation in Curriculum

The College is diligent in its approach to bringing the latest concepts to the undergraduate curriculum. In the past three years, the College has developed curriculum tracks in mechatronics, systems engineering, health systems engineering, biomedical engineering, fuel cells and homeland security. The purpose of this activity was to sustain students' interest in the programmes and also to address the needs of industry. One of the recent grants from NSF addresses undergraduate curriculum development in nanotechnology. Very few programmes address nanotechnology at the undergraduate level. The grant from NSF will enable the College to educate undergraduate engineering students in concepts related to nanotechnology. In a recent study conducted on 1,600 high school teachers, nanotechnology was listed as one of the top areas of interest [4].

To prepare undergraduate students for this nano-driven global competition, universities must offer their students a curriculum that builds an interdisciplinary understanding of engineering and science, including a first-hand view of the collaboration among engineers and scientists in disciplines such as biology, chemistry, and physics. In recent years, the significance of team-based, problem-based projects has been increasingly recognised. This is best evidenced from the Engineering Criteria 2000 (EC2000) of the Accreditation Board for Engineering and Engineering Technology (ABET), which places special significance on insightful team design projects and experiences in learning and practising project proposing, planning, and control. With CEET offering practice-based programmes, these transitions were easily accomplished.

In addition, the role of business cannot be ignored. Emerging technology is effective only if it can find a willing market. Businesses that can bridge the gap between the creation of a new product and the sale of that product will be competitive. The university graduates entering the workplace need to understand patenting and the business/societal aspects of their work, which at CEET is covered in the capstone design project courses and associated seminars.

In addition, a large percentage of science and engineering graduates in the USA are not involved in engineering jobs. They have either evolved into other areas of employment or have been promoted to management, where they are not utilising their engineering skills to create innovation. Programmes such as Executive MBA programmes are not helping the pipeline issue either. The percentage of engineering majors pursuing an MBA is close to 11.7 per cent according to data released by NSF in July 2006 [1]. At this time, many engineers will forgo use of their engineering expertise and move on to management functions in the service and business sectors. With this in mind, an executive engineering management programme (EEM) is being developed with the management programme on a parallel track within the College of Business at NIU. The EEM programme would enable engineers to continue in their engineering tracks and move into engineering management positions and be able to utilise their engineering skills.

CONCLUSIONS

It is evident that the engineering profession is here to stay. It fulfils an indispensable need for the society to innovate. At the same time, engineering programmes also must be innovative. Without innovation, the future of society and its capability to create new wealth is severely limited. With the change in demographics and change in student attitudes, it is important that the path of creating new methods to attract and retain young students into technical careers is continued. The CEET at NIU has undertaken several initiatives that are helping it sustain the pipeline to engineering careers. It is critical that summer camps be continued in order to enhance the exposure of the engineering profession. CEET intends to enhance the scope and impact of summer camps further. Several others have been successful but an international dialogue about the strategies and successes of sustaining pipeline is a needed endeavour. Let this paper begin that partnership dialogue for an innovative future filled with technical inventions and creations. Let the engineering profession lead the way to a technologically sustainable future for the world.

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