An Overview of Engineering Education in the US under a Globalization Environment

Wangping Sun
Manufacturing & Mechanical Engineering & Technology
Oregon Institute of Technology

Abstract

This paper reviews the current trends of engineering education in the US under globalization environment. It summarizes the requirements for global engineers, and lists the available programs that educate these engineers. It recapitulates the benefits, challenges and efforts to establish a sound global learning environment for engineering students. It concludes that the current practices by various universities will help engineering educators to create more practical, scaleable, diversified and sustainable programs in a global context.

I. Introduction

Engineering is now practiced in a global, holistic business context[1]. It is common for engineers to work on multi-national teams designing products, which will be manufactured in one part of the world and sold in another part[2]. The ever-increasing trend of economic globalization necessitates dynamic and meaningful collaboration between engineers, designers and executives, transcending political and cultural boundaries[3,4].

Today's engineering students graduate in a world that is becoming highly competitive as geographical barriers are being eliminated[5]. The engineering profession is becoming increasingly global as it moves from domestic operations to global outsourcing (subcontracts), global offshoring (overseas divisions), and more recently, global teaming[6]. Globalization is expanding the engineering labor force both by becoming more internationally diverse and more internationally mobile. Ultimately globalization is impacting all engineering graduates[5,7].

The process of globalization has created an environment where the engineering educators must do more for engineering education to influence the US economy such that the US is able to retain its leadership position[8]. Globalization requires students in the US have additional knowledge to remain globally competitive and maintain that global leadership in engineering[9]. To remain competitive, the students must develop global skills and competencies to be participants and leaders in cross-cultural engineering teams[5]. The engineering educators must mold the students to be entrepreneurs, and spirited international adventurers[10].

Globalization has gained general acceptance in engineering programs. The commonly employed lecture-based pedagogy of the 20th century is being replaced by various experiential strategies[11]. More and more engineering programs are sponsoring activities that help the students to be global[2]. However, the most recent research indicates, the American engineering students are still largely in need of skills and experience in working on an international team[3].

Globalization continues to gain prominence in the discussions on engineering education for the 21st century and beyond[12]. While United States remains a leading source of high-quality global engineering talent[13], the question currently facing American engineering educators is "How can American universities do a better job in training the global engineers for the future?" To help answer this question, this paper for the first time in the public domain provides the most complete review on the current trends of engineering education in the US under globalization environment. It summarizes the requirements for future global engineers, and lists the available programs that educate these engineers. It recapitulates the benefits, challenges, and efforts to establish a sound global learning environment for engineering students. The current practices by various universities will help engineering educators to create more practical, scaleable, diversified and sustainable programs in a global context.

II. The requirements for global engineers

Global economy requires global engineers[12]. Without a global perspective, large corporations soon become outdated and unprofitable. More and more technical staffs are being called upon, as the global engineers, to assist in technology transfers, international design collaborations, and global manufacturing issues[14]. Even though there is no consensus on the definition of "global engineers"[12], some educators believe that a global engineer should have two sets of skills, soft and technical skills[8,15,16,17, 18].

The soft skills:

- Innovation that addresses the attributes needed for success in a changing global environment;
- Entrepreneurial experience to understand consumer needs, domestic and foreign markets, and market needs;
- Multi-disciplinary and inter-disciplinary team experiences;
- Global awareness in another culture and foreign language skills;
- Awareness of professional ethics and codes of conduct;
- Communications skills, particularly across international boundaries;
- Early involvement with industry through externships, internships, co-op programs;
- Transnational mobility;
- Team leadership.

Technical skills:

- Research ability on engineering in a global context;
- Analytical skills to gather, analyze and interpret data;
- Ability to use state-of-the-art software packages and design suites;
- Technical excellence with system design emphasis;
- Ability to be a life-long learner and self-teach the subjects that will have significant impact on future employment;
- Project management skills.

III. Available programs to educate global engineers

There are at least eleven formats available in engineering programs that educate global engineers[2,19,20,21,22,23,24,25].

1. Dual degree: students obtain two degrees - one from the home university and one from the university abroad. Students follow an integrated program, which includes substantial study at the university abroad.

2. Student exchange: students from the home and university abroad are exchanged and take regular courses. A parity of exchange is maintained so there is no net expense to either institution. In student exchange program, students receive an in-depth experience associated with learning a language, living and studying abroad.

3. Field trip: it involves a 1-3 week tour including visits to foreign countries, companies, and/or universities. This type of program enables the students to obtain a "snapshot" of the world via a broad exposure to numerous places and know what issues are associated with global engineering.

4. Extension: the home university operates a pseudo-extension campus in another country. These programs usually scale more easily and can serve as a good platform from which students can explore another country.

5. Internship or co-op: students work abroad at a foreign company or at an international branch of a U.S. company. These programs can include a lot of informal learning, particularly regarding business issues involving teamwork, communication, design, and manufacturing.

6. Partner sub-contract: the home university partners with a university abroad and contracts for courses to be taught to students of the home university.

7. Project-based learning/service learning through mentored travel: students travel abroad for four or more weeks and are immersed in another culture via a project that connects technology with the society abroad. The project may involve a senior capstone project or service learning in the community abroad (such as finding water and sanitation solutions for a community that is having a high incidence of waterborne diseases; health surveys and health education for the local people).

8. Research abroad: the student travels to a laboratory abroad and conducts research under the guidance of a faculty member or research associate.

9. Faculty exchange: the faculty member from the home university teaches, or co-teaches a class of the students in the university abroad.

10. Distance learning: internet technology (web-conferencing, list-serv, emails, etc.) is used to create a virtual community for learning across cultural and national boundaries.

11. International conference: the student travels abroad to attend competitions and workshops for a short period of time, normally less than two weeks.

IV. Benefits from a global learning environment

The value of an international cognizance, in context of engineering education, has been the subject of much research[23]. It is commonly accepted that for the US to remain the world leadership in engineering and technology, it needs an educated engineering workforce that has global awareness, namely the capability of operating in international engineering and research environment[26]. The universities and students can gain quite a few benefits from a global learning environment. These benefits can be categorized as follows:

A. Study interests

In a global learning environment, the students put their roles as future professionals in the global context. It blends study abroad programs, multinational projects, courses with international experiences, globalization and international research collaboration that help the students to develop abilities beyond the traditional analytical knowledge to be competitive in the global market[21]. The students show strong learning interests and can learn a variety of topics in a short time under such a different learning environment. Nothing brings the same kind of validation, motivation, or sense of urgent reality as effectively as living and working side by side with members of a community abroad[9]. To be involved in a global learning environment also provides the students with alternative views of engineering and modern technology from a global prospective[27].

Take Western Michigan University for example. This university established a three-week program, China Summer Engineering Trip, in 2006[27]. The program included lectures, engineering field trips and engineering demonstrations. Studies of design, business, manufacturing, problem solving, quality control, and supply chain management practices were conducted. In addition, students explored trade practices, copyright and patent protections, research protocol review boards, and political practices.

B. Awareness of societal and cultural dynamics

Through service-learning projects abroad, the students will gain substantial social and cultural awareness. These projects introduce the students to open-ended problems at the community level, help the students develop the skills to solve those problems and provide holistic engineering solutions that are sustainable and appropriate to the community being served. These projects also help the students work in interdisciplinary teams, give them the opportunity to reflect on the importance of their community service, and give them a professional work ethics[28].

In 2004, students from Tufts University have initiated projects in Ecuador, El Salvador and China’s Tibet Autonomous Region. In Ecuador, the students participated in the community-based natural resource management project. In El Salvador, the students were involved in water supply and sanitation system establishment. In Tibet, the students helped the local community to build a composting latrine and a solar cooker. These international service projects aided the students in gaining an understanding of global issues that they will face in their lifetime [9].

C. Improvement of personal skills

International hands-on experiences play a key role in the development of future global engineers who can navigate the complexities of global market forces[12]. These engineers have a better understanding of the global community and the role of engineers in improving the quality of life for the people around the world. From the global learning environment, the students can obtain the following skills[12, 15,27,29,30] to:

- Work in multi-cultural teams in an international setting;
- Work in virtual teams around the world by using internet technology;
- Develop cultural awareness and understand the importance of diversity in the design and development of new products;
- Acquire, apply and strengthen the design methodology and other high-level skill sets in a global context;
- Establish an international collaborative network;
- Explore global engineering career opportunities.

At Stanford University, a capstone project in mechatronics was designed to involve international collaboration with Royal Institute of Technology, Sweden[31]. The collaboration project was found to promote:

- Disciplinary learning skills;
- General skills, such as teamwork, team management and presentation techniques;
- Awareness of cultural differences and different educational systems;
- Self-motivation to meet the challenges internationally.

D. Other long-term benefits

There are some other long-term benefits can be generated after the global learning environment is set up:

- It has been reported that the integration of global perspectives in sustainable development projects attract women and underrepresented minorities into engineering[12].

- The Accreditation Board for Engineering and Technology (ABET) requires that an engineering program must give an ability to understand the impact of engineering solutions in a global, economic, environmental, and societal context; as well as a knowledge of contemporary issues [9]. The global learning environment is seen as an opportunity to significantly strengthen the engineering program, improve ABET outcomes[5,32]. It is helpful to enhance the international reputation and quality of the university in engineering teaching, learning and research[27].

- Sustainable development is an especially important aspect of international engineering education because it is a critical element in improving the quality of life of people worldwide. Connecting international technical education with service learning enhances the understanding of societal and economic conditions in the developing world. It allows students to develop an in-depth understanding of the costs and benefits of sustainable development and globalization to communities [12].

V. Challenges from a global learning environment

Even though the global awareness is beneficial for the students to develop themselves professionally, there are many challenges to set up, sustain or survive in a global learning environment. The challenges come from five aspects.

A. Communication

Communication is the key of effective global collaboration. It is also the biggest challenge[3]. Though language courses are included in the curricula of many schools throughout the US, few students achieve any degree of fluency[33,34]. Because of the language barriers, less information is gathered, translation is required and misunderstandings are more possible[28]. The meager lingual abilities prevent a typical American engineering student from being able to discuss the work with others around the globe[33]. Aside from language, differences in thoughts and opinions are another obstacles in communication as well[3].

B. Limit of resources

Even though globalization makes international experience important, it is often difficult to achieve it as a part of engineering curriculum[35]. In recent years, there has been a movement among American universities to offer students a global experience. However, this movement has been stagnated by lack of available resources[3,11]. The high cost, which is the major factor of resources, prevents many students and faculty from participating in the international projects[25].

C. Obsolete mindsets

With the old mindsets, globalization is often related to the loss of domestic jobs and influx of international competitors and products. To change these obsolete mindsets is needed urgently and is a tough job in engineering education. Globalization should be envisioned not as a threat, but an opportunity. To meet the challenges of this new opportunity, many changes will be necessary in engineering community[5]. For example, outsourcing of some technical responsibilities to overseas should be regarded not only as an accepted practice, but also as the only way for a company to stay competitive and profitable[17].

D. Institutional constraints

At present, few universities have been intentional about integrating global, cross-cultural education into the engineering curriculum[5]. There is a lack of infrastructure at the institution level to address the following issues in the establishment of a global learning environment[3,7,21,23,24,34,36,37,38,39]:

- Scaling: The concept of globalization has not yet had widespread impact on undergraduate engineering curricula and the size is of global learning is normally small (for example, in the 2003-2004 school year, 5,548 engineering students participated in some forms of study abroad programs; in 2005-06, fewer than 7,000 American engineers went overseas for study or professional development);

- Destination restriction: most American students go to Europe and other English-speaking countries.
- Time constraint: the students are constrained by time of graduation, timing of the semester, length of internships, or credit transfer difficulty;
- Incentive for faculty: participation in these programs may not count for much in rank promotion or tenure evaluation.
- Cooperation with other departments: to set up a global learning environment involves close cooperation and adaptation of programs among various departments, such as among language programs and engineering programs. Flexibility from all departments is often required. But, departments are not always willing to bend their programs' requirements. For example, the current engineering curriculum is rigid and offers little "wiggle room". Many of these programs do not emphasize an understanding of globalization as an economic, political, or cultural phenomenon.
- Program assessment: there is no standard teaching practice in internationalized education, and it involves a whole new set of variables and experiences. There is neither enough data nor formal assessment practices in place to formally evaluate the effectiveness of these initiatives in reaching the desired objectives. Additionally, the multinational and multicultural nature make more challenging the evaluation process due to the demanding time and resources.
- Management challenges: to design and build an engineering project with the participation of multiple companies or teams from a variety of universities in the global learning environment is difficult to manage and easy to cause chaos and confusion.

E. Safety issues

Safety is always an important and sensitive issue that arises in the discussion of travel and the realization of a global project[9]. Social stability, contagious deceases and travel safety in the abroad country must be considered before any international program can take place.

VI. Efforts to build a sustainable global learning environment

A lot of universities are working hard to build a sustainable global learning environment for the engineering programs. These efforts are taken in the following seven directions.

A. Curriculum change

Some universities are integrating global issues into all years of a student's educational experience[40]. Global preparation is moved beyond "add-on" programs; knowledge of the fundamentals and dynamics of globalization as well as opportunities to be immersed in study, work, or research abroad are becoming the key elements integrated into engineering programs[41]. At John Brown University, the university core curriculum requires every student to take at least one three-hour global studies course in fulfilling degree requirements[5]. The Department of Industrial Engineering of University of Pittsburg first implemented in the U.S. an international requirement that includes an out-of-the country experience for its undergraduate students. All students in the department are required to obtain an international experience and two globally focused Humanities or Social Science courses beginning with incoming 2007-08 industrial engineering sophomores[42].

At some schools (such as Lafayette College), the educators are thinking about changing the focus in the curriculum. The areas that are not likely to be outsourced to other countries are going to be strengthened. The focus of the areas that are most likely to be outsourced is going to be minimized[17].

Some educators are advocating strengthening foreign language education. They believe that although English has spread throughout the world as an almost universal second language, the mono-lingualism and narrow focus of American engineering students does not help the students in the global setting. Brigham Young University designed an education model to teach foreign languages in the four-year's education of the engineering students[14].

B. Infrastructure and assessment process establishments

Universities have increasingly expanded their mission statements to include a commitment to producing globally competent graduates who are able to function effectively in the global marketplace and provide leadership in the international arena[34]. Many universities have had international offices or designated staff members in place to organize, facilitate and assess the globalization activities. At Virginia Tech, an international department at the Dean's level in the College of Engineering has been established in an effort to raise the percentage of engineering students to study abroad[42].

Assessment of globalization activities is being formalized as well[21]. At Georgia Tech, the Director of Assessment of the school is responsible for managing the assessment process of international internships. The assessment items include application/hiring process, students' performance on the job (pre and post internship assessment), and the job content/experience[43].

Research on assessment of globalization activities is also being undertaken. Pennsylvania State University and Florida Atlantic University proposed six steps to evaluate the learning effectiveness [21].

Step 1. Identify the need or opportunity
Step 2. Create a Faculty/Industry focus group
Step 3. Define the initiative.
Step 4. Create the Overall Assessment Design Matrix: define the goal, tasks, competencies, and outcome metrics.
Step 5. Design of assessment tools.
- a. Pre-survey
- b. Formal evaluations
- c. Post-survey

Step 6. Analysis of data and recommendations

C. Financial support from the university

Some universities provided financial support and made ambitious plan to prepare the students for globalization. At Georgia Tech, a program was launched in the fall of 2005 with a $3 million commitment from the president. The goal is to enroll 300 students per year by the year 2010. The International Plan is part of Georgia Tech's strategic plan to have 50% of its baccalaureate students graduate with international experience[41].

Some universities believe that industry leaves and sabbaticals would both promote awareness of the global practice of engineering and provide invaluable international exposure[41]. More flexibilities have been added to engineering programs for faculty to help faculty members gain international experiences and to forge partnerships at international universities. Pennsylvania State University provides faculty travel grants. These travel grants are used for a number of purposes, including supporting activities and exchanges, helping faculty acquire further funding for international programs, and assisting faculty who want to develop material for courses that have international components[23].

D. Collaboration within the university

Inter-college collaboration within a university has been shown to be successful in creating further international opportunities for engineering students[23]. University of Michigan combines a traditional undergraduate engineering curriculum with courses in business and international culture through the business and literature, science, and arts schools, respectively. Iowa State University offers programs that allow their engineering students to concurrently pursue majors in engineering and a foreign language.

E. Collaboration with industry

Industry must take the lead in developing opportunities for students to practice engineering in a global context. Universities should initiate more collaborative activities with industry, such as research, educational projects, and transnational internship programs[12,41]. Funding from private donors is the key driver of the program's potential success[44].

In 2005 – 2006, General Motors Co. and PACE (Partner for Advancement of Collaborative Engineering Education) sponsored the first international vehicle collaboration project, a senior capstone project that demonstrated how global-scale projects effectively prepare students for future exposure to large-scale collaboration projects in industry[3]. Thirteen universities around the world (including Brigham Young University) participated. Through these projects, the students learned firsthand experiences and lessons that can be effectively applied to other global collaboration projects, both industry and academia.

F. Partnerships with foreign institutions

Partnerships with foreign institutions are established to seamlessly combine the curricula and educational opportunities[45]. Some examples are[46]:

- Northern Arizona University set up a Global Engineering College where a virtual engineering college spans multiple countries and cultures.
- Iowa State University structured a Global Academic Industrial Network to create multi-organizational, international partnerships of academic and industrial organizations that emphasize collaborative educational programs and research.
- Oregon State University has International Degree Program that allows students to earn a concurrent bachelor's in International Studies associated with an engineering degree.

G. Collaboration with funding and other professional organizations

Several organizations provide financial support opportunities to help set up the global learning environment. For example, REU (Research Experience for Undergraduates) program of National Science Foundation funded University of South Florida build a 10-week summer program in computer science[47]. NCIIA (National Collegiate Inventors and Innovators Alliance) provided grant to University of Colorado at Boulder to build the course Engineering for Developing World [28].

Other professional organizations could also be helpful. For example, International Federation of Engineering Education Societies (IFEES) was launched in 2006. IFEES' mission is to foster collaboration and learning among the world's engineering education societies. Some of the resources provided by this organization include international engineering-education newsletter, annual publication profiling engineering colleges from around the world, Engineering for the World Initiative network, virtual engineering-education magazine that focuses on issues raised by globalization.

VIII. Conclusions

Globalization drives the necessity for evolution of the engineering education system. All major engineering institutions in the US are undertaking a number of approaches to develop global competency of their students. There have been eleven programs established in the US so far. A diverse, internationally competitive and globally engaged learning environment for engineering students is forming its shape in many American universities. This environment provides opportunities and challenges to the engineering students. They must work hard to be competitive globally.

There is a long way to go to establish a good global learning environment for engineering students. More fundamental research is needed to be done on student motivations, learning behaviors, learning models, organizational processes, and management methods. Change of mindsets toward globalization is important. Support, especially financial support, from the industry, university administration, faculty, students, students' parents, professional organizations and other public domains is crucial. The participation of industry in the assessment and evaluation of international experiences is also vital. Only with these necessities can the global learning environment be created and developed in a scalable and sustainable way.

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