AC 2007-2962: GLOBALIZATION AND ENGINEERING EDUCATION FOR 2020

Michael Mariasingam, University of Wisconsin - Madison
Research Associate, College of Engineering, University of Wisconsin – Madison

Sandra Courter, University of Wisconsin-Madison
Director, Engineering Learning Center, University of Wisconsin - Madison

Thomas Smith, University of Wisconsin - Madison
Faculty Associate, Engineering Professional Development Department, University of Wisconsin – Madison

Gregory Moses, University of Wisconsin-Madison
Professor, Engineering Physics, University of Wisconsin - Madison.

Globalization and Engineering Education for 2020

Introduction

The emerging global trends in business have a great impact on the workforce needs, and the education and training of the workforce. The engineers of tomorrow will be expected to function differently from today as they face new ever changing work environment that includes globalization, outsourcing and emerging technologies. What do these emerging changes and challenges mean to the employers, the institutions that prepare engineers, and the organizations that assure quality? What should be their response to these trends as they unfold? In this paper the authors answer these questions. In particular they investigate what the nature and focus of engineering education of the future should be so that the discrepancy between the professional practice and professional preparation could be at least reduced. The following issues are discussed: emerging global trends in engineering, trends in the developed economies, impact of global trends on engineering enterprise, implications for engineering education, features of engineering education for 2020, other institutional requirements, and some existing models of engineering education for the future. The authors point out that the engineering enterprise is responding to the emerging trends and it is time educational institutions that provide the workforce to the enterprise begin the transition to a new relevant form of education and training.

Background

> Globalization is not a new phenomenon. Carthage, Rome, the Ottomans, several European powers, and mercantile city-states had multicontinental trading networks….. The globalization we are experiencing today is unprecedented in its magnitude and reach. The whole world has become a market for the economies of many countries, and globalization is transforming not only the location and organization of production and services, but also social and economic patterns. The long-term consequences are still unfathomable.

These emerging global trends, as noted by the National Academy of Engineering (NAE)[1] above, have transformed businesses and have a great impact on engineering workforce needs as well as the education and training of the workforce. Purdue Engineering Dean Katehi[2] observes:

> The engineers of tomorrow will be faced with a world much different than today. As technological advancements continue to erase our globe's geographical borders and the world population continues to balloon, our students will be asked to solve pressing issues dealing with economic development, poverty, the environment, healthcare, and energy—to name a few

Stephen Director, provost at Drexel University, speaking at a workshop on engineering curriculum reforms said in his message: "The world has changed…Globalization will dramatically impact what engineers do. A lot of routine engineering we've been teaching is likely to be subject to outsourcing." [2]

> Small and mid-sized enterprises are following the lead of their larger counterparts in establishing branches overseas. Industry requires a workforce that has been prepared for and can adapt to changes in this expanding global market

Even the Accreditation Board for Engineering and Technology (ABET) [3] asks:

> What does this mean for employers at these companies, the institutions that prepare their future hires, and the organizations that assure that their educations are of quality?
>
> Similarly, institutions of higher education are tasked – both by their students and by their students' future employers – to prepare their graduates to evolve with emerging technologies and with the ever-changing economic, political, and cultural landscape that characterizes the international marketplace. How can technical programs ensure that they are instilling this multifaceted education in their students?

These questions have not been answered yet. In this paper, the authors attempt to find some answers to these questions to minimize the discrepancy between the professional practices and professional preparation that Simo Lehto [4] of Helsinki Polytechnic mentions below.

> These [fundamental] changes [created by globalization] force the organizations and people in the industrialized countries participating in the global market to make a qualitative transition from the maintaining (routine) mode of operation to the development (creative) mode of operation. In global companies, this transition is almost completed. *In professional and academic education organizations, the transition is still at its infancy* [emphasis added]. This has led to a discrepancy between the education organizations and their customers in professional and work life.

Emerging global trends in the engineering enterprise

Korhonen-Yrjänheikki [5] identifies the important trends, phenomena and business areas during the next10 –15 years. On the top of the list is deepening globalization. Globalization has transformed the workforce trends globally and particularly in the emerging economies. Some of these trends in the emerging economies follow.

- The availability of a trained workforce is growing in emerging economies like China and India. [6]
- The number of engineers graduating in most countries as a share of the degrees in higher education is far greater than the same in the USA. [2,7]
- The great interest among the students in India to choose careers in science and engineering is mainly because of better prospects for employment both in the developing local companies and the growing multinational organizations. [8]
- An increasing presence of multinational R&D facilities is in countries like China and India. [8]
- The level of R&D in the India and China is growing. [8,9,10]
- Of the growing trained workforce in the emerging economic environments, a large number of them would prefer to stay home and work for a multinational firm than move overseas. [11]
- Even those who are already in the developed economies may move back home because of the changing work environments. [11,12]
- The global competition for S&E workforce is growing. Countries like the UK, Ireland, Germany and Australia are actively in the pursuit of trained workforce from the developing economies. [7, 13]
- While the number of students coming to the USA for higher education is declining, the number of students going to countries like Australia is increasing. [14]
- A huge market potential is in the emerging economies like China and India. [15]

- The USA has a declining interest and proficiency among the young in science and engineering. [2, 16, 17]
- Costs of education and training are escalating in the developed economies. [17]
- The developed economies face the problem of an aging population. A large percentage of the current trained and experienced workforce is due for retirement. [16]

Impact of global trends on the engineering enterprise

Impact on the nature of businesses

Globalization has changed the nature and character of businesses. Director [18] observes that 1) companies are employing engineers who are multi-national, geographically distributed, conduct business globally, and must deal with diverse business cultures and governmental regulations; and that 2) designs need to take account of both local and global cultural perspectives (e.g. environmental impact). He asserts that the impact of globalizations is that engineering practices have changed. These variations in engineering practice are due to different languages, cultures, customs, laws and legal systems, environmental regulations, and customer preferences. The emerging engineering practice demands that engineering teams must be increasingly diverse in terms of culture and language and an increase of engineers with international perspectives.

Impact on workforce

The developed economies will experience a shortage of talented and skilled workforce and the shortage will only increase in the future. Between 1980 and 2000 the employment of engineers has grown from about 1.3 million to 1.9 million, while science and engineering employment has grown from about 2.0 million in 1980 to about 4.7 million in 2000. This represents an average annual growth rate of 30,000 for employment of engineers, and 135,000 for science and engineering employment. But, enrollment in engineering at both undergraduate and graduate levels has remained fairly constant between 1983 and 2003 with marginal variations. Consequently, the number of jobs requiring people with engineering and science training will grow, while the number of US persons with the skills and training in S & E will not match the growth. [16]

A decline in the availability of people trained in science and engineering from other countries is anticipated [16]. There are a number of reasons for the anticipated decline. Although as mentioned above, China and India are graduating students in S&E in hundreds of thousands only a fraction of them – about 15 percent of the Chinese and 30 percent of Indians, on an average about 17 percent - have the global mindset required to work in a multinational environment

> 17% of engineering talent in low-wage countries is suitable for work in a multinational company. [McKinsey & Company , "The Emerging Global Labor Market" (2005), cited in Gabriele (7)]

The other reasons are travel restrictions imposed for security reasons; the emerging global trend in the developing economies like preference among the trained workforce to stay home; the increasing shortage of trained workforce in the developing economies; and global competition for students and trained workforce from the emerging economies.

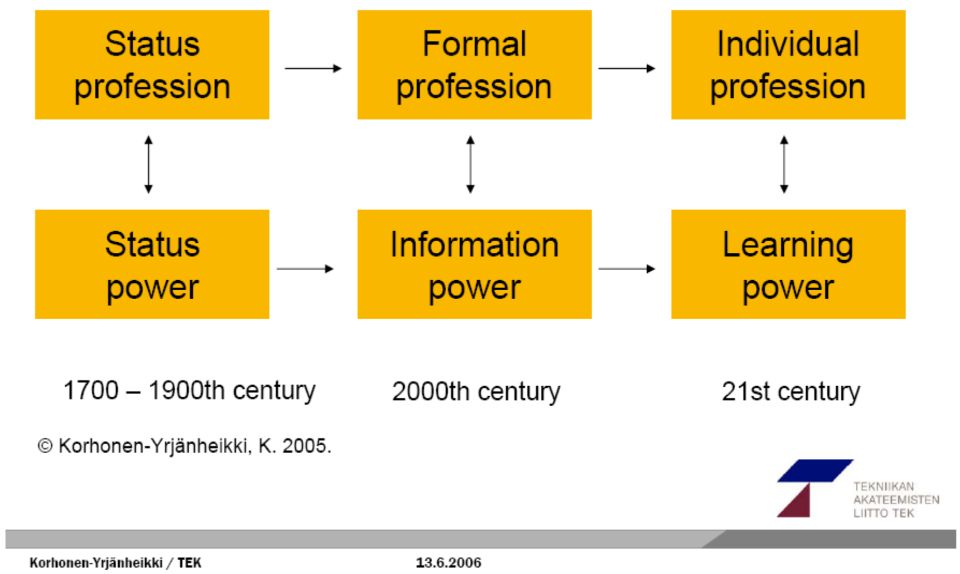
Consequently, many businesses would go for offshore outsourcing to use the best and talented workforce in business to be competitive. Alternatively, businesses in the USA might lose competitiveness in innovation, prominence and its global market share.

Implications for engineering education

Impact on the character of the engineering profession

The transition of the economy through the three industrial revolutions [19] has changed not only the nature of the businesses and the workforce but has changed also the nature of the engineering profession as shown in Fig. 3 according to Korhonen-Yrjänheikki [5].

Fig. 3 Changing character of the engineering profession [http://nordtek2006.tkk.fi/seminarium/Korhonen-Yrjanheikki_120606.pdf]



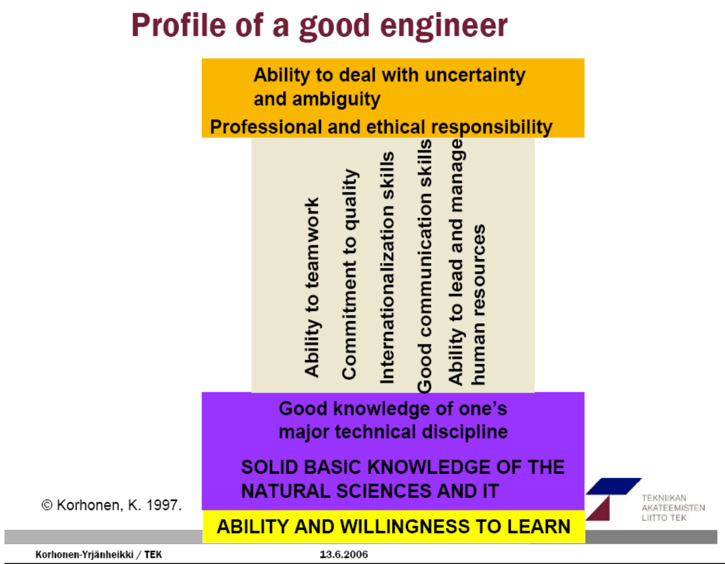
Impact on the profile of an engineer

The challenges of the emerging global trends and the consequent changes in the nature of businesses and character of engineering profession have changed the profile of an engineer. Engineers of the future have to be different from those of the past and even today. According to Director [18] engineers of the future need to be:

- Well grounded in fundamentals of physical sciences and mathematics
- Knowledgeable about the biological sciences
- Capable problem solvers and innovators
- Able to understand the role of customer needs in product design
- Be cognizant of social trends and have a grasp of environmental concerns
- Be integrators of technology across multiple disciplines
- Capable of working on diverse teams
- Be skilled in oral, written, and visual communications

Korhonen-Yrjänheikki [5] frames these qualities with the abilities to deal with ambiguity, ethical dilemmas and willingness to learn. He illustrates the profile of the engineer of the future in Figure 4.

Figure 4. Profile of the engineer of the future



Impact on academic content

All these changes such as in the character of the engineering profession and in the profile of an engineer have broadened the academic core of the profession to include interdisciplinarity and lifelong learning. Korhonen-Yrjänheikki show this change in Figures 5 and 6. [5]

Fig. 5 Core of the engineering profession traditionally [http://nordtek2006.tkk.fi/seminarium/Korhonen-Yrjanheikki_120606.pdf]

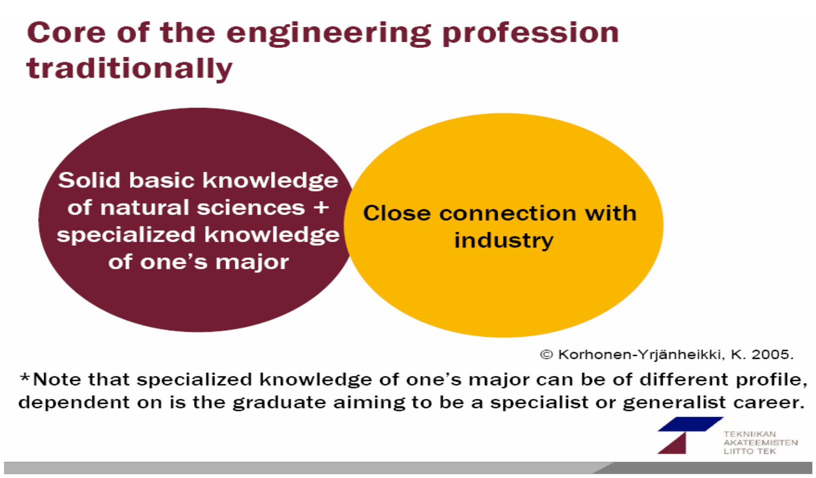
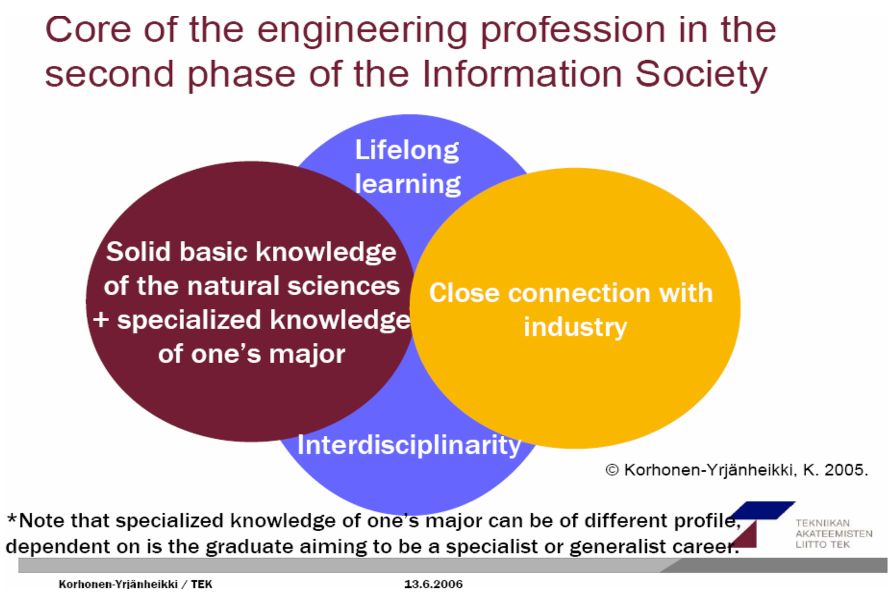


Fig. 6 Core of the engineering profession in the second phase of the Information Society [**http://nordtek2006.tkk.fi/seminarium/Korhonen-Yrjanheikki_120606.pdf**]



Engineering education for 2020

To function effectively in the emerging global environment described above the engineers of 2020 should have the knowledge, skills, and character that fit the new character of the engineering profession and profile of an engineer. Director[18] says: **"**Engineering education must change to better prepare engineers to work in global environment". Lucena and Downey [20] ask:

> By defining problems in mathematical terms and problem solving as the appropriate application of equations, do engineering curricula prepare students adequately to work with engineers trained in distinct national traditions? How might engineering students be trained better to work in environments where the need for negotiation and compromise in the definition of problems is more the rule than the exception?

National Academy of Engineering President Bill Wulf speaking in August 2005 at Purdue Engineering at a 3-day discussion on the direction of engineering education in the United States and the attributes of the future engineer "emphasized the need to focus on what an engineer will be doing 20 years from now and then determine the education needed to prepare that engineer for the future"[2].

To provide engineers with such education and training, engineering education of today should undergo both broad structural changes and transformation of disciplines in addition to curricular redesigns. Before looking at the specific features of the engineering education for 2020, the broader issue of the global economy calls for an innovative approach to workforce development strategies and education in general.

A broader issue - Implications of globalization for education in general

Alan Blinder[19] in his article entitled *Offshoring:The next industrial revolution* in *Foreign Affairs* magazine says that the world is experiencing the third industrial revolution. According Blinder the first industrial revolution shifted the focus of business from agriculture to manufacturing. The second industrial revolution moved the focus from manufacturing to services. The world is now going through the third industrial revolution. Blinder says services can be classified into impersonal services, which can be packaged and offered offshore, and personal services that cannot be packaged; have to be physically personally offered locally. The current [the third] industrial revolution is moving the focus from impersonal services like manufacturing to personal services. Such [personal] services would need skills different from mainly technological skills required for impersonal services like manufacturing. People in such services need to be more creative, innovative and have the skills to respond effectively to emerging environments. Providing such skills would require a different kind of education from the purely science and technology focused education of today.

General requirements for global engineering education of 2020

Within such a new system of education, engineering education should assume a new format and structure to meet with the requirements of the new character of the engineering profession and the new profile of an engineer.

Transformation of traditional disciplines to interdisciplinary approaches

Globalization has intensified the growing complexity and demands of the societal needs and consequently engineering education of the future demands transformation of disciplines. The traditionally defined disciplines have gradually changed by losing their distinct identities. Increasingly programs have become interdisciplinary to meet the global trends and emerging new needs and requirements of the society. ASEE[21] states:

> The profession of engineering and the teaching of engineering are undergoing a transformation driven by a number of external forces. The rise of the new biology and the nano-sciences is having a profound impact on society and on engineering practice and education. Similarly the growing complexity of socio-technical systems and the increasing sophistication of product development are shifting our understanding of the profession and its work. As a consequence the traditional engineering disciplines (e.g. Civil, Mechanical, and Electrical) formed in the industrial age of the 19th century may not be appropriate in the knowledge age of the 21st century.

According to the *Alumni e-Newsletter* of Purdue Engineering[2],

> And the newest technology areas—biotechnology, nanotechnology, materials and photonics, information and communications technology, systems engineering, and logistics—require bridging disciplines in ways that challenge traditional discipline-centered curricula.
>
> [Wulf] suggested, along the lines of the NAE *Engineer of 2020* report, that we'll have a global economy and a growing need for interdisciplinary, systems-based engineering. Engineers will better represent the world's population, and be involved in public policy at greater levels as technology is integrated into infrastructure and individuals' lives.

Structural changes: Operation and Organization

The transformation of disciplines calls for structural changes in engineering education and the engineering schools. Lehto[4] observes that the societal needs also demand structural changes in engineering education. He says,

> Until now, the profound changes in societies and dramatic developments of technology have had relatively little effect on the structure and mode of operation of EE [Engineering Education]. The new requirements of EE in the global environment can only be met by reengineering the present EE by incorporating a new structure. This transition requires qualitative changes in the mode of operation and organization of EE organizations

To facilitate and advance this transformation of disciplines and structural changes of engineering, schools have to undergo extensive reorganization. According to ASEE[21]

> Engineering Schools retain very conventional organizational structures based on the traditional disciplines, albeit with transformed course content. In contrast, industry and the broader society are undergoing dramatic changes in where, when and how work is organized.

The new organizational structures and institutional environment should facilitate interdisciplinary teaching and learning and new ways of educating the engineers of the future for engineering education to be in tune with demands of the emerging engineering enterprise. The new ways include common first-year curricula with design experiences and multi-disciplinary capstone design courses as well as alternative delivery approaches and collaborative partnerships,

<u>Alternative delivery approaches</u>: Alternative delivery approaches will not only change the mode of operation and organization of higher education but also provide access to education, an important element of quality education. The American Council on Education[22] says,

> All members of society have the right to access learning opportunities that provide the means for effective participation in society (p.11).

But the demand for higher education particularly professional education is so high. Lehto[4] observes,

> Social changes during the past decade have also directly influenced engineering education. EE has shifted from elite education to mass education. The changes of the society have also had a profound effect on the attitudes of the youth towards higher education and the know-how level and heterogeneity of the students entering EE. At the same time, modern ICT provides large possibilities for developing EE.

Also, the demand for education is increasing around the world, especially in the emerging economies, as indicated earlier. This growth is mainly the result of globalization and the resultant fast growing economies of these countries. Especially, the demand for professional education is growing at such a phenomenal rate that it is impossible to meet the demand through on-campus education only. Only distance education would allow wider access to education. Especially continuing education to working professionals is possible through mainly distance education. But, the ability of those countries in the emerging economies to meet this demand for professional education is very limited. This situation has two implications for engineering schools in the developed world.

First, in the future, in spite of lack of opportunities for professional education in their own countries, students from the developing world, particularly from China and India, migrating to countries like the USA and UK for education, will decrease significantly. One main reason is that in the past the main motivation for most students from Asia to go to the developed world for education was the hope of making a better future in the country of their choice after getting the education. That situation has changed now. As mentioned earlier, those students now find well paying jobs locally in multinational companies and do not find the need for going overseas for better living. However, they would still like to have higher education, preferably from the developed world, and would look for providers in the developed world who are willing to take the education to them. Many for-profit corporate educational providers are willing to do that. Consequently public and research institutions bent on traditional campus-based classroom education will find it very difficult, especially with the dwindling public funding, to survive for want of sufficient student numbers. For those institutions there is no alternative but moving toward providing education at a distance.

Second, there is a great opportunity for the universities in the developed world to capitalize on this situation. Indeed countries in Europe like the UK, and Australia have begun doing it. Particularly Australia has taken great initiatives in responding to the global demand for professional education. It has responded in different ways like: setting up off shore campuses; entering into collaborative arrangements with local universities in different countries; and offering programs at a distance. For instance, RMIT University has set up RMIT International University in Vietnam, has offshore campuses in Malaysia, and partnerships in China, Singapore, Indonesia, Thailand and the Philippines. It offers its program through flexible delivery. RMIT is also the only university that responded to the call by the African Virtual University to offer an undergraduate degree program in Africa. In these efforts RMIT is responding to the global trends like the multinational companies do. Universities in the US, with the exception of a few, are yet to capitalize on this gold mine of opportunities available not only for increasing their student numbers and the possible increased funding but also for taking their preeminent education and their influence to those regions, following the Australian example.

Collaborative partnerships: Collaboration can bring many benefits and may help institutions achieve more than they could on their own, with higher quality, and at a more rapid pace. While effective collaboration requires organization, common vision and agreements, and effort from all parties, it also adds varied and rich resources such as shared vision, knowledge, experience, human resource, funds, market for delivery, and a number of intangible assets like goodwill and credibility. Collaboration is, therefore, often desirable even when it is not required.

In the case of engineering education for 2020, many of the educational objectives discussed above would need collaborating partners to realize them. For instance, offering engineering programs at a distance is the need of the day. Very few engineering programs are offered at a distance currently. One of the main difficulties in offering engineering programs, especially undergraduate programs, is the difficulty in offering hands-on experience at a distance. While simulation and other technology based efforts are being tried, they are not an ideal substitute for real-world, hands-on training. But this problem could be solved effectively by entering into collaborative arrangements with local institutions in other countries. In many emerging economies, for instance in India, there are many institutions with excellent facilities and also quality faculty to provide the required hands-on training. Collaboration with such institutions would provide an effective way to overcome the problem. Collaboration, in addition, will bring in many other additional benefits. For instance, it would help to have the benefits of offering blended education by making it possible to offer part of the program in an in-class, face-to-face environment. There is a need for institutions to actively consider forming collaborative partnerships. ABET[3] observes:

> Institutions are cultivating the comprehensive education of their students and others to a degree by establishing partnerships with other schools, often beyond their nation's borders. These collaborations run a gamut that includes study-abroad programs, student and faculty exchange opportunities, consultations for foreign programs, and even the establishment of satellite campuses in other countries.

Globalization in engineering education, Director [18] suggests, could be addressed through, with several other steps taken, "university partnerships" that would include cooperative degree programs and joint research programs.

Collaboration with industry too would be required to respond effectively to the emerging global trends and changing business environments. The National Academy of Engineering[23] notes, "Reinventing engineering education requires the interaction of engineers in industry and academe. The entire engineering enterprise must be considered so that the changes made result in an effective system".

Among the many new possibilities globalization offers, Chang [24] mentions the following:

- International internships
- Joint and/or dual degree programs
- Technology-enabled faculty & curriculum development
- Multinational design teams & competitions

Additionally collaboration offers opportunities for outsourcing content. Faculty should be encouraged and facilitated in international curriculum development efforts and collaborative development of global engineering programs. Gerhardti [25]gives an example of faculty involvement in international collaboration in program development and offering:

> We also have strongly promoted faculty involvement not only implicitly through advising but explicitly through international curriculum development. Supported by FIPSE funding through 2000, seven pairs of international university teams reviewed and analyzed curricula offerings at their universities emphasizing compatibility of programs. This was done in 6 different disciplines in 5 countries. … a sufficient amount of compatibility was found to consider the future establishment of joint course offerings between these international universities using distance learning technology. This has already begun between the Technical University of Munich and Rensselaer Polytechnic Institute.

Curriculum for global engineering education of 2020

The curriculum for global engineering education includes content and methodologies that help students learn a global perspective, broader social awareness, lifelong learning, and business and personal skills. Curriculum, therefore, includes learning outcomes and assessment strategies.

<u>Curriculum: Global perspective</u>

The increasing globalization of business has created organizations where colleagues are very likely to come from different countries and different cultures. Lucena and Downey [20] observe:

> Globalization challenges US engineering students to prepare for work in a culturally diverse environment where they will encounter non-US engineers defining and solving problems.

This challenge Lucena and Downey mention would come in two forms. First, this would be a challenge at home. Every year at least 65 000 H-1B visas are issued to people from other countries with different cultural background. To work harmoniously with colleagues in such an environment, global perspective with a clear understanding of the cultures of people working with is becoming essential not only in organizations that are multinational but also in every organization.

Second, it would be a requirement for any engineer working in a global environment outside her/ his country. To be able to work in other cultures, engineers need a global perspective. It is claimed that although China and India graduate many times the number of engineering graduates produced in the US [China about 300, 000, India about 200 000, and the US about 60 000] only a small percent of the graduates from China and India have the global perspective to work in the US. According to McKinsey& Company ["The Emerging Global Labor Market", 2005, cited in Gabriele, G. A. [7]] on average only "17% of engineering talent in low-wage countries is suitable for work in a multinational company". This shows the importance of global perspective for success in the emerging economy. Because of globalization of the engineering enterprise, there is a case to make that every engineering student should develop global perspective.

William Wulf, President, US National Academy of Engineering, observes,

> Engineering is global, and engineering is done in a holistic business context. The engineer must design under constraints that include global cultural and business contexts -- and so must understand them at a deep level. They too are new 'fundamentals' [in engineering]. [cited in Director [18]]

Banks [26] claims, rightly, that in the emerging global environment such education is required for all students. Banks also defines elegantly the nature of such global education:

> Cultural, ethnic, racial, language, and religious diversity exists in most nations in the world. … Because of growing ethnic, cultural, racial, language and religious diversity throughout the world, citizenship education needs to be changed in substantial ways to prepare students to function effectively in the 21st century. Citizens in this century need the knowledge, attitudes, and skills required to function in their cultural communities and beyond their cultural borders. … Citizenship education must be transformed in the 21st century. Several worldwide developments make a new conception of citizenship education an imperative. … A new kind of citizenship is needed for the 21st century, which Will Kymlicka calls multicultural citizenship. … It should also help them to develop clarified global identifications and deep understandings of their roles in the world community. … Students should develop a delicate balance of cultural, national, and global identifications.

Sometimes it is claimed that the line managers do not care about global perspective; all they want is that the engineer can solve differential equations. This claim may be true for now but may not last very long. A comparable situation existed with communication skills many years ago. The importance of communication skills for engineering graduates was neither acknowledged by line managers nor addressed by engineering schools. The situation is very different now. Now it is hard to find an engineering curriculum, which does not explicitly emphasize developing communication and other interpersonal skills of graduates as an important goal of engineering education. With globalization of the engineering enterprise the importance of global vision and perspective will assume similar status very soon. Even with the line managers of today it would be interesting if we conduct an experiment. Give them two engineering graduates [of different cultural backgrounds from her/him] both with the same level of expertise in solving differential equations, but one with global perspective and because of that perspective has the ability to get along well with people of different cultures, and the other without these qualities of global perspective, and see after sometime whom the line managers prefer. It is hard to believe that any line manager would prefer to work with an engineering graduate of the latter type just because the graduate is an expert in solving differential equations.

Curriculum should be designed to facilitate developing global perspective in engineers. Such a curriculum would include education and training that would provide the engineering graduate several non-engineering skills sets. Osorio, Satzinger, & Mete [27] say:

> The globalization of engineering education means providing students with an enlarged set of knowledge and skills required to address the situations encountered in this large domain..
>
> This includes inculcating foreign languages skills, knowledge of foreign laws, practices and customs or knowledge of foreign environments, resources and needs.
>
> The reason for needing language skills, for understanding foreign customs and laws is to be able to better conduct business in an efficient manner, recognizing opportunities and avoiding obstacles.

Osorio, Satzinger, & Mete ask, "Can engineering skills which have been developed in the context of practice within a single culture be applied to global problems?" and Lucena and Downey [20] describe a course in *Engineering Cultures* to teach "a more developed understanding of the dominant American approach to engineering problem solving amidst other approaches" "where the need for negotiation and compromise in the definition of problems is more the rule than the exception" [20]. Courses in foreign languages and cross-cultural communication may be useful additions to the list of courses that could be included in the curriculum to impart global skills.

<u>Curriculum: Broader social awareness</u>

Engineering curriculum of 2020 should produce socially conscious engineers who are concerned with emerging social problems of the world. *Alumni e-Newsletter* of Purdue Engineering [2] observes,

> As technological advancements continue to erase our globe's geographical borders and the world population continues to balloon, our students will be asked to solve pressing issues dealing with economic development, poverty, the environment, healthcare, and energy—to name a few.

According to the Committee on the Engineer of 2020, Phase II [23] "The steady integration of technology in our public infrastructures and lives will call for more involvement by engineers in the setting of public policy and in participation in the civic arena."

Byron Newberry [28] quotes *Josep Xercavins i Valls* who rightly observes,

> If…our generation will be judged by History for its ability to confront the two fundamental problems of our times: soul-destroying and socially destructuring poverty and the increasingly worrying environmental

> problems…then…universities should not only adapt to 'market necessities' but also to the main necessities of people on the whole earth.

and [Newbury] asserts, "Producing graduates capable of addressing pressing global socio-technological problems" should be an important educational objective of "humanitarian" engineering education.

Also, as Osorio, Satzinger, & Mete [27] observed that engineering skills acquired in a single culture enable graduates to work well within the culture but they may find it difficult to apply them in a different culture or in a different economic environment. According to them,

> Engineering education in the United States and other technologically advanced nations prepares students to work in advanced industrialized economies. … It may be difficult to effectively apply this set of knowledge and skills back at home. … The kind of education required to prepare graduates for a high tech industry is not the same as the kind required to meet the needs of the developing world.

Two fundamental global problems are poverty and environmental problems. A global engineering education should seek to answer these questions while adapting to market necessities. Therefore, we also need a "new type of engineering program" which is "broad-based education, both technically and non-technically, targeted toward basic human needs, rather than the engineering job market and requires a more divergent and global perspective than traditional engineering" [28].

<u>Curriculum: Lifelong learning</u>

The curriculum for global engineering education also should include knowledge, skills, attitudes about lifelong learning. According to the American Council on Education, [22]

> Learning is a lifelong process, important to successful participation in the social cultural, civic, and economic life of a democratic society … (p.11).

Engineering practice is changing rapidly. Engineering knowledge is becoming obsolete at a phenomenal rate. According to the *Alumni e-Newsletter* of Purdue Engineering [2] the half-life of engineering knowledge averages five years.

> It's not only the demographics that are calling out for change. Current estimates place the half-life of engineering knowledge—the time interval in which half of what an engineer knows becomes obsolete—at between 2.5 and 7.5 years, with an average estimate of 5 years. Engineering curricula are faced with the challenge of developing students who are learners for life.

The Accreditation Board for Engineering and Technology (ABET), [29] in its Criteria for Accrediting Engineering Programs, stipulates, "Engineering programs must demonstrate that their graduates attain a recognition of the need for, and ability to engage in life-ling learning" (p. 2).

The NAE Committee on *Educating the Engineer of 2020* [23] has included in its suite of recommendations the following:

> That, in addition to producing engineers who have been taught the advances in core knowledge and are capable of defining and solving problems in the short term, institutions must teach students how to be lifelong learners.

Therefore, the learning outcomes of engineering curriculum should include engineering students developing the motivation and capacity for life long learning. Specific skills such as the following from the United Kingdom [30] should be cultivated and nurtured by the engineering curriculum:

- developing the skills necessary for self-managed and lifelong learning (eg working independently, time management and organization skills);
- identifying and working towards targets for personal, academic and career development;
- developing an adaptable, flexible, and effective approach to study and work.
  (QAA, 2001, Biosciences - Academic standards section, para. 3.9.)

Some engineering schools are attempting to redesign curricula to include this learning outcome. An example of such attempts is a research project in Finland which is "aimed at developing and implementing a new structure for engineering education (EE) and for EE institutions." [4] In describing the project. Lehto [4] says,

> The new EE model developed in Finland is based on the definition of the competence requirements for the modern engineer working in the global environment. These requirements can be summarized as the capability to do efficient engineering work (in a selected engineering field) by using modern concrete and abstract tools within the global economical, environmental, legal, and human constraints. This level of professional competence can only be achieved through a life-long process of learning and professional development. The new EE is designed to be a natural first part of the life-long engineering work process. The four-to-five year learning period makes it possible to learn the basics of these skills.

Curriculum: International Business and Communication Skills

The final curriculum issue examined in this paper is the need for modern engineers to have additional skills to practice efficiently in the global environment. ABET [3] describes these skills:

> A good education in applied science, computing, engineering, or technology no longer concentrates on imparting only technical competence; it also instills teaming skills, the capacity to communicate effectively, an understanding of other cultures and perspectives, and awareness of societal, political, cultural, and economic issues.

Lehto [4] says "the competence requirements for the modern engineer working in the global environment' would include the following "international business" skills and "personal" skills.

> *International business*: product, product life cycle, market economy, principles of business, customer-focused business, marketing.
>
> *Personal skills and specialization*: continuous learning, verbal and written communications in native language and in international English, creativity, teamwork, project work, control of personal life, time management, specialties in engineering and technology, capability to specialize, team management, knowledge of foreign cultures, foreign languages, personal networks, personal goals. [emphasis added].

In the changing global environment engineers of the future have to have good education and training not only in business but also in the global business culture. They should have the knowledge and understanding of how business enterprises in other countries operate. Particularly an understanding of the business culture of China, India, Japan and other Asian countries, where the business culture is very different from the Western way of doing business, is very important.

A number of skills on this list, such as in foreign cultures, foreign languages have been discussed earlier. The objective here is to highlight the importance of the international business skills, personal management skills and communication skills.

Also, the engineer of the future should have general purpose operational ability in addition to their specialist expertise. Engineers in the emerging economies are normally required to do all kinds of non-specialist jobs as part of their work.

Exchange and study abroad programs, overseas internships, and other educational programs

While study abroad programs provide an opportunity to gain global experience and an understanding of other cultures and perspectives, they have a few limitations: First, only a small percent of students go on those programs. Gerhardti [25] observes: " …with about 15 million native born Americans annually in higher education, only about 130,000 annually engage in an international experience abroad, with only 3,000 of those in engineering programs." Such programs are expensive and have other constraints. It is not a possible option for all students. Second, in study abroad programs normally students go to a particular country and their experience is limited to the culture and other aspects of that country. Their experiences may not be truly global in nature. Students need a broad global perspective – understanding and appreciation of diverse cultures and perspectives. Third, students on study abroad programs gain, usually, exposure to only general cultural traits and educational environment in a different culture. Their experience may not include exposure to and experience in the business culture of the country or region. Engineering students need, in addition to the knowledge and experience of the general cultural aspects - such as customs, language etc, a good knowledge of the business culture. Hall [31] observes:

> An understanding of national and corporate cultures and the dynamics involved in managing them is becoming essential in business and career effectiveness. Whether managing cultural differences will be the latest fad or will drive a fundamental change in the way we run our businesses, only time will tell. I hope and believe it will be the latter.

Students do not normally get exposure to business culture in study abroad programs, unless they go on internship to companies overseas.

Overseas internships in multinational companies are another way to provide students global perspective by exposure to diverse cultures and perspectives. In addition to engineering education with a global perspective and cultural exposure, internships in companies [both US and other local companies] in different parts of the world particularly in the emerging economies would be needed. Internships overseas can give students better global perspectives than study abroad programs because the exposure would include also exposure to and experience in the business culture of the county or region, and would give students an understanding of how an American company can successfully conduct business in a different culture, in an environment socially, politically and economically different from their own.

Another way of giving global perspective to students is here at home as part of their education and training. It can be done by making "preparing students for success in the emerging global age" as part of the mission of the institution and goal of engineering programs. As described above engineering curriculum should be designed to include global education and training to develop global vision in students. As mentioned above, many institutions seem to be doing it. Another example: The mission statement of Florida Community College at Jacksonville [http://www.fccj.edu/friends/president/mission.html] includes the following:

> The mission at Florida Community College at Jacksonville will be fulfilled, in part, through achievement of the following Collegewide goals:
>
> 1. Prepare students for distinctive success, and as outstanding citizens, in the global knowledge economy. Faculty, curricula, teaching methods, technology, learning environments and academic resources will provide students with relevant and rigorous preparation for success in a global knowledge economy. …

Some existing models of engineering education for the future

Finland, Michigan State University, University of Texas Pan American, University of Michigan, Purdue, and University of Wisconsin – Madison are some good examples of attempts to redesign and/or create new engineering programs that would produce the new breed of engineers who would perform well in the globalized economy. This section gives a brief description of these four efforts.

Helsinki Polytechnic Finland

An ongoing research project in Finland involves the design, development and implementation of a new structure for engineering education. According to Lehto, [4]

> The work is driven by the fundamental changes created by globalization on the global, national, and education system levels. … The work in Finland uses the engineering approach based on systems and model thinking. … The mode of operation and the organization of large, medium-sized, and small global corporations have been used as the main analog models in the development of the new EE model. … The new EE solution is based on the requirements for modern engineers and the learning goals derived from them for the whole study period. A sequence of real-world learning projects is used as the vehicle for achieving an effective learning environment … The new model is being pilot-tested since August 2001 in the Program of Industrial Management of Helsinki Polytechnic … The development work has shown that the new EE solution offers potential advantages for the EE institutions, regions and nations. The new mode of operation of the EE organizations closely corresponds to the organization and operation of the companies operating in the global competitive environment. This fundamental change eliminates the discrepancy between education and work life.

International Networked Teams for Engineering Design (INTEnD) program

The International Networked Teams for Engineering Design (INTEnD) program – a joint project of Michigan State University (MSU) and the University of Texas Pan American (UTPA) aimed at meeting the challenges of globalization "through a multidisciplinary, collaborative and innovative effort in global engineering education programs" is a good example of international collaboration in engineering education innovation. The project is also a good model for implementing many of the requirements for global engineering education such as communication skills and cultural perspectives discussed earlier in this paper. Lloyd, et al [32] describe the project as given below:

> This engineering education curriculum innovation … was initially created in 1998 by a multidisciplinary team of educators from MSU and a group of international engineering educators from Technical University Delft, University of Utrecht, Eindhoven University, and Kaiserslautern University. The team included educators from Mechanical Engineering, Electrical Engineering, Manufacturing, Anthropology, Sociology, and Telecommunications. The INTEnD program has linked multidisciplinary research groups at participating institutions around the world: Tsinghua University (China), TU Delft (The Netherlands), KU Leuven (Belgium), St. Petersburg State Technical University (Russia), Carlos III University (Spain), Kaiserslautern University (Germany), and ITESM (Mexico).
>
> The INTEnD program is a multidisciplinary research and education program aimed at educating future engineers and professionally-oriented social scientists as to how the engineering design and manufacturing process can meet the challenges of globalization of engineering practice. Under grants from the National Science Foundation, most recently the Partnership for Innovation program, the course imparts transcultural communication skills and multi-media communication skills to engineering students working in engineering design and manufacturing teams that are industrially-sponsored, geographically-dispersed and culturally -disparate.
>
> Engineering designers from the Colleges of Engineering and transcultural observers from Anthropology work together on the teams.

University of Michigan

The University of Michigan has taken three initiatives to address globalization in engineering education: the Engineering Global Leadership Program, the Global Product Development Course, and the University of Michigan, Shanghai Jiao Tong University Partnership. According to Director, [18] the global curriculum includes three core areas: engineering, business, and culture. The cultural core has two years of a foreign language, and twelve credits of history, art, political science, customs on a student-selected region.

Purdue Engineering

Purdue University's College of Engineering has initiated programs that would make engineering education relevant to the needs of the global engineering enterprise of 2020. Cynthia Sequin [33] writes about the programs:

> Purdue's Global Engineering Programs, created in 2005, focuses on preparing students for the global economy. The program offers new courses, integration of global perspectives into existing courses, distributed design team projects with students from international partner universities, international internships and coursework abroad.

University of Wisconsin – Madison

The University of Wisconsin has introduced a new Certificate in International Engineering, piloted a course for future faculty, and initiated an international design experience in the Department of Civil and Environmental Engineering (CEE). The certificate program now in its second year consists of six credits of a specific language, nine credits of area studies, five weeks of study or work abroad, and a new course titled, "Current Issues in International Engineering." The Department of Engineering Professional Development piloted a three-credit course titled, "Teaching Science and Engineering: International Students and International Faculty." This course is part of the Center for the Integration of Research, Teaching, and Learning, an NSF sponsored program. The CEE international design experience includes students from three disciplines (architecture, geology, and civil engineering) and several places including Stanford.

Faculty Development

Faculty too should have a global perspective, an exposure to cultures of other countries, and knowledge of the global business culture. Faculty development efforts in this regard are necessary.

The need for learner-centered education is all the more now as education becomes global reaching learners of varying learning styles, learning strategies, and learning needs. For instance, the learners in the emerging economies in Asia are less self-directed than the learners in the developed world. Education designed to suit the needs of learners in the developed world, as it becomes global, may not suit learners in Asia. Research evidence of this diversity is central to faculty development. Faculty should be made aware of these learner characteristics and cultural variations. Faculty may also need experience in learner-centered education, problem-based teaching, and the development of learning communities. The University of Wisconsin course for future faculty described above is an example of a faculty development program.

Distance education will be a prominent mode of education of the future in the globalized economy. Faculty need to learn how to function effectively in distance teaching and learning environment. Opportunities for training in technology-based education and appropriate incentives for participating in such training and for initiatives in innovative teaching should be available to faculty. Finally, another University of Wisconsin course for future faculty provides an example; the course was taught by web-conference with students from six institutions. In the process of learning about teaching, students gained experience with distance education.

Conclusion

Globalization as it is happening now, as NAE has observed, is unprecedented and has transformed the whole world. It has transformed the way businesses operate and has changed the character of the engineering profession and the profile of an engineer. Businesses have begun to respond effectively to the impact of globalization through outsourcing and other means but, as has been mentioned in the very beginning of this paper, the academic and professional organizations have not reformed engineering education and the way engineers are educated to fit the needs of the engineering enterprise in the global economy. This paper gives some details of the impact of globalization on the engineering enterprise and the way engineering education has to change to enable engineers of 2020 to perform effectively. As we engage ourselves in this important task it will be helpful to keep in mind the following words of Charles M. Vest in "Educating Engineers for 2020 and Beyond" *Educating the Engineer of 2020.* [7]

> As we think about the many challenges ahead, it is important to remember that students are driven by passion, curiosity, engagement, and dreams. ...In the long run, making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details.

References

1. George Bugliarello (2005). Globalization and Engineering (editorial). National academy of Engineering, Vol.35. No 3. Fall 2005. Retrieved on August 19, 2006 from http://www.nae.edu/NAE/bridgecom.nsf/weblinks/MKEZ-6G6QZY?OpenDocument

2. Purdue Engineering. *Fall 2005 E-Newsletter*. (2005). Retrieved on August 26, 2006 from https://engineering.purdue.edu/EAA/Newsletter/Fall2005

3. ABET. (2006). *ABET Annual Meeting Overview*. Retrieved on August 22, 2006 from http://www.abet.org/annual.shtml#Meeting_schedule_for_Thursday__October_2

4. Lehto, S. (2002). *Transforming Engineering Education from the Maintaining Mode of Operation to the Development Mode of the Global Industry.* Retrieved on August 19, 2006 from http://www.iacee.org/newsletters/sefi-lehto.pdf

5. Korhonen-Yrjänheikki, K. (2006). *Quality of engineering education and changes in the societal and business environment*. The Finnish Association of Graduate Engineers TEK. Retrieved on August 30, 2006 from http://nordtek2006.tkk.fi/seminarium/Korhonen-Yrjanheikki_120606.pdf

6. Offshore Outsourcing World. (2005). *Where Should You Outsource?* (July 29, 2005). Retrieved March 29, 2006 from http://www.oobp.org/Learning+Courses/7+Lessons+on+Offshore+Outsourcing/398.aspx

7. Gabriele, G. A. (2006). *Future Directions for NSF Engineering Education Programs.* 2006 International Mechanical Engineering Education Conference Retrieved on August 20, 2006 from http://imeec.cmes.org/wenzhang/conference%20presentations/301%20Gabriele.pdf#search=%22Globalization%20and%20Engineering%20Education%22

8. Sharma S., & Green, J. (2005). *Multinationals are tapping into India's engineering prowess for a song*. Retrieved October 1, 2005 from http://www.businessreport.co.za/index.php?fArticleId=2891106

9. Normile, D. *Is China the next R&D superpower? Electronic Business*, 7/1/2005 Retrieved October 02, 2005 from http://www.reed-electronics.com/eb-mag/article/CA610433?pubdate=7%2F1%2F2005

10. Ramamritham, K. (1995). *Computer Science Research in India*. Retrieved September 25, 2005 from http://www.fas.org/nuke/guide/india/agency/krithi2.html

11. The Philadelphia Inquirer. (2005). *Multinationals setting up shop in Asian nations.* Retrieved October 1, 2005 from http://www.mercurynews.com/mld/mercurynews/news/politics/12504560.htm

12. Hu Y. (2004). *Drug firms bolster R&D facilities*. China Daily. Retrieved October 02, 2005 from http://www.chinadaily.com.cn/english/doc/2004-11/03/content_388276.htm

13. Kumar, N. R. (2006). *Indo-Australian ties getting into a new architecture.* The Hindu Online Edition of India's National Newspaper. Wednesday, March 08, 2006. Retrieved April 1, 2006 from http://www.hindu.com/thehindu/features/indiaaustralia/stories/2006030800110300.htm

14. Ramachandran, K. (2006). *More Indians eye Australian education.* The Hindu Online Edition of India's National Newspaper. Wednesday, March 08, 2006. Retrieved April 1, 2006 from http://www.hindu.com/thehindu/features/indiaaustralia/stories/2006030800190200.htm

15. Tan, W. A. (2005). *A Huge Market for Multinationals*. Retrieved October 02, 2005 from http://www.bjreview.com.cn/En-2005/05-21-e/business-3.htm

16. American Institute of Physics. (2004). *Future S&T Workforce Projections: Two Perspectives.* Retrieved April 03. 2006 from http://www.aip.org/fyi/2004/087.html

17. The National Academies Press. (2006). *Rising above the gathering storm: Energizing an employing America for a brighter economic future – Executive Summary*. Available at www.nationalacademies.org/cosepub http://darwin.nap.edu/execsumm_pdf/11463

18. Director, S.W. (2002). *Impact of Globalization on Engineering Education*. Retrieved on August 19, 2006 from http://ed.sjtu.edu.cn/attchment/present/EngineeringED/Director.pdf#search=%22Globalization%20and%20Engineer

19. Blinder, A. S. (2006). *Offshoring: The next industrial revolution*. Foreign Affairs March/April 2006. 85(2). pp 113-128. Washington D.C.: Council on Foreign Relations

20. Lucena, J. C., and Downey, G. L. (2000). *Engineering cultures: Addressing challenges of globalization to engineering education through human and cultural-centered problem solving.* Retrieved on August 19, 2006 from http://fie.engrng.pitt.edu/fie2000/papers/1455.pdf#search=%22Globalization%20and%20Engineering%20Education%22

21. ASEE Conference (2005). *Globalization of Engineering Education*. Retrieved on August 25, 2006 from http://www.gcee2005.com/default.asp?pageid=10.

22. American Council on Education. (1996). *Guiding principles for distance learning in a learning society*. Washington, D. C.: American Council on Education.

23. National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. *Executive Summary.* Committee on the Engineer of 2020, Phase II, Committee on Engineering Education.

24. Chang, D C. (20005). Globalization, Technology & Partnership in Engineering Education. Retrieved on August 25, 2006 from http://www.iaalab.ncku.edu.tw/iceer2005/Form/PaperFile/0203P1.pdf

25. Gerhardti, L. A. (2001). The Global Engineering Education Exchange Program – Its History, Progress, and Challenges. 31st ASEE/IEEE Frontiers in Education Conference. October 10 - 13, 2001. Reno, NV.

26. Banks, J. A. (2003). *Educating Global Citizens in a Diverse World*. Retrieved on Oct 09, 2005 from http://www.newhorizons.org/strategies/multicultural/banks2.htm

27. Osorio M.., Satzinger M., & Mete O. *The globalization of engineering education*. Retrieved on August19, 2006 from http://testbot.ieng.washington.edu/abstracts/Meggie-Mary-Onur.pdf#search=%22Globalization%20and%20Engineering%20Education%22

28. Newberry, B. *Engineering Globalization - Oxymoron or Opportunity*. Engineering Computer Science, Baylor University. Retrieved on August 25, 2006 from http://www.hmc.edu/admin/presoffice/EngineeringGlobalizationFall2005.pdf

29. Accreditation Board for Engineering and Technology, Inc. (2006). *Criteria for accrediting engineering programs: Effective for evaluations during the 2006-2007 accreditation cycle.* Retrieved December 15, 2006 from http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2006-07%20EAC%20Criteria%205-25-06-06.pdf.

30. The Quality Assurance Agency for Higher Education (U. K.). (2004a). *Subject benchmark statements Academic standards - Biosciences.* Retrieved on December 15, 2006 from http://www.qaa.ac.uk/academicinfrastructure/benchmark/honours/biosciences.asp

31. Hall, K. (2003). *Worldwide Vision in the Workplace*. Retrieved from on Oct 10, 2005 http://www.leader-values.com/Content/detail.asp?ContentDetailID=350

32. Lloyd, J. R., Hinds, T. J., David, K., Chung, M. J., Gonzalez, M., & Timmer Douglas. (2004). A Dispersed Design Team Approach for the Globalization of Engineering Education. Retrieved on August 19, 2006 from www.asme.org/education/enged/awards.

33. Sequin., C. (2006). *Purdue engineering program promotes global awareness, initiatives.* Purdue University News. October 27, 2006. Retrieved on Dec 20, 2006 http://news.uns.purdue.edu/html3month/2006/061027ChangGlobal.html