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Impact of Globalization On Engineering Education

Number 18
March 2014

WFEO/FMOI

Committee on Education In Engineering
World Federation of Engineering organizations

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WORLD FEDERATION OF ENGINEERING ORGANIZATIONS
FÉDÉRATION MONDIALE DES ORGANISATIONS D'INGÉNIEURS

COMMITTEE ON EDUCATION IN ENGINEERING

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IDEAS is a publication of the WFEO Committee on Education In Engineering, addressed to engineering educators, educational officers at Universities and leaders responsible for establishing educational policies for engineering in each country. The articles it contains reflect the concern of people and institutions linked to WFEO, to provide ideas and proposals with the object of improving formation of engineering education. All the issues of IDEAS were and will be partially financed by World Federation of Engineering Organizations.

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Editor: Abdul Menhem Alameddine, Chairman
Committee of Education in Engineering - WFEO
Federation of Lebanese Engineers – Beirut, Lebanon
P.O.Box 11-3118 Beirut Lebanon
Email: munim@wfeo-ceie.org

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Assistant Editor of this issue: Dr. Antoine Abche

Prepared for printing by: Denise Homsi

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E-mail: info@53dots.com
Website:www.53dots.com

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Editorial

Reflections on the 9th World Congress on Engineering Education

24 – 25 October 2013 in Beirut - Lebanon

Abdul Menhem Alameddine, Chairman
Committee on Education in Engineering
World federation of Engineering Organizations

This issue of IDEAS will reflect on the 9th World Congress on Engineering Education that took place in Beirut, Lebanon on October 24 and 25, sponsored by The World Federation of Engineering Organizations – Committee on Education in Engineering and The Federation of Lebanese Engineers together with the Federation of Arab Engineers. A proceeding was published containing 36 papers of which 27 were accepted and presented during the Congress. The Congress was the result of two years of planning.

What did take place, however, was an excellent series of invited keynote and paper presentations. The format of the conference which was a combination of panel discussions and paper presentations created an environment of collegial debate and discussion on matters related to quality assurance and accreditation of engineering programs in Lebanon and elsewhere. Subjects such as mobility of engineers and accreditation processes in EU and US as well as the Washington Accord were discussed and debated not only in sessions with a sole presenter and all attendees in the audience, but also in small groups during lunch and other breaks. This environment afforded the Congress participants a forum for exchange of ideas and sharing of best practices.

Keynote addresses were delivered by Dr. Ahmad Jammal, the Director General of the Ministry of Higher Education in Lebanon, Dr. J. P. Mohsen, the Vice Chairman of CEIE, on globalization of ABET accreditation and by his Excellency Dr. Isam Zabalawi, Previous Minister of higher Education in Jordan, on the effect of Bologna process and its impact on engineering education in the Arab world. The most significant and well received keynote, however, was delivered by the Vice President of WFEO, Dr. Peter Greenwood, on the subject of engineering mobility.

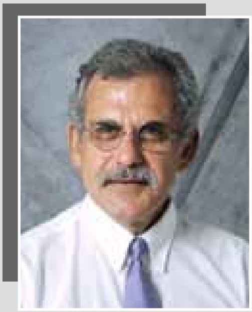
A panel discussion was presented the second day between the keynote speakers, His Excellency Dr. Isam Zabalawi, Dr. Peter Greenwood, Dr. J.P. Mohsen and Dr. Makram Suidan the Dean of College of Engineering and Architecture at AUB Beirut. It should be noted that all sessions were moderated by Deans of Engineering Colleges at various Universities in Lebanon. All papers will eventually be linked to the CEIE web page.

Quality Assurance In Engineering Education

J.P. Mohsen[1], W.E. Kelly[2], S. Harrington-Hurd[2]

1 University of Louisville, Louisville, KY USA

2 American Society for Engineering Education, Washington, DC 20036 USA



Dr. J. P. Mohsen is professor and chair of the Civil and Environmental Engineering Department at the University of Louisville where he has taught since 1981. He holds a Ph.D. in civil engineering from the University of Cincinnati. His area of research is non-destructive testing and evaluation of materials with a focus on concrete structures. He teaches courses and conducts research in the areas of structural analysis and design, pavement design, construction materials, and health monitoring of bridges using remote sensing. Dr. Mohsen is Past President of the American Society for Engineering Education. He served as ASEE President during 200910-. He has served on the ASEE Board of Directors previously as Vice President for Member Affairs and Vice President for Professional Interest Council. He has served as Vice Chair of WFEO Committee on Education in Engineering since 2012. Dr. Mohsen was named Engineer of the Year in Education in by the Kentucky Section of ASCE in1999 and received the University of Louisville Distinguished Service to the Profession Award in 1999 and the Distinguished Teaching Professor Award in 2003. He received the Robert M. Gillim Professional Recognition Award in 2013 and the Outstanding Contribution in Education Award from the Kentucky Society of Professional Engineers in 2014. He is also the recipient of the 2014 ASCE Computing in Civil Engineering Award.

KEY WORDS: *engineering, education, accreditation, quality, assurance.*

ABSTRACT

Engineering accreditation was initiated in the U.S. in the 1930s through the Engineers Council for Professional Development a joint effort of five engineering societies and the National Council of State Boards of Engineering Examiners; ABET is the successor organization. Engineering accreditation was from its beginnings in the U.S. closely linked to professional recognition for engineers. Today mobility for engineers means global mobility and new structures are evolving to support accreditation and quality assurance and the possibility of an international standard or standards is being discussed. The purpose of this paper is to present a brief history of quality assurance in engineering education and suggest some possible next steps where the WFEO could play a facilitating role.

1. INTRODUCTION

An important criterion for entry into many professions is appropriate educational preparation and accreditation of educational programs is one way professions ensure this. The assurance process typically involves setting a standard and assessing conformity to the standard. Conformity assessment is normally performed by an entity other than the program – a third party. In the context of this paper, accreditation is both the standard setting and conformity assessment processes. The accrediting entity is typically recognized by a government agency or an independent entity. Recognition is important to ensure that an education credential is recognized in other jurisdictions and can be the basis for mutual recognition and professional mobility.

What is today called ABET began in the early 1930s as a committee of the Engineers Council for Professional Development (ECPD). The American Society for Engineering Education (ASEE), then called the Society for the Promotion of Engineering Education, was a founding member of the ECPD. During its first year, the ECPD made three recommendation with the first being "a program for accrediting engineering schools."[1] The tagline of ABET the ECPD Committee's successor organization is "Assuring Quality- Stimulating innovation" and ABET is now accrediting engineering globally.[2]

One of the goals of the World Federation of Engineering Organizations (WFEO) standing committee on education in engineering is improving quality assurance.[3] In 2009, the WFEO approved a policy on mobility developed by the Committee that encourages development of a common framework for evaluating engineering education quality.[4] Issue Number 17 of IDEAS was entitled "Improving Quality Assurance and Miszalski suggests in the first paper that the time might be right for a world standard for engineering education and principles of accreditation.[5]

2. DEFINITIONS

There is no single definition of quality assurance.[6] Quality assurance has been defined by the International Organization for Standardization (ISO) as "part of quality management focused on providing confidence that quality requirements will be fulfilled."[7]

Quality assurance is defined by UNESCO as " the systematic review of educational programmes to ensure that acceptable standards of education, scholarship and infrastructure are being maintained."[8] A UNESCO glossary provides more detail.[9]

One of the first steps in developing an international standard for evaluating the quality of engineering programs would be to develop consensus definitions.

3. STANDARDS FOR ENGINEERING EDUCATION

The European Network for Accreditation of Engineering Education's (ENAEE) EUR-ACE system has what are called framework standards.[10] National agencies do the actual accreditation; the EUR-ACE label can be earned if the process followed by the national accreditor conforms to the EUR-ACE framework standards.

The Washington Accord is an agreement among organizations that accredit engineering programs. Some members of the Washington Accord are also members of EUR-ACE. These include: the UK Engineering Council; Engineers Ireland; the Turkish Association for Evaluation and Accreditation of Engineering Programs; and the Russian Association for Engineering Education. According to the International Engineering Alliance (IEA) web site a comparison of the Washington Accord Graduate Attributes with the EUR ACE Framework Standards is in progress.[11] There are 12 IEA attributes (outcomes) versus six for EUR ACE. The authors' side-by-side comparison of the EUR-ACE and IEA outcomes indicates substantial agreement.

The Latin American and Caribbean Consortium of Engineering Institutions (LACCEI) is supporting accreditation efforts in Latin America and the Caribbean. There are no countries in Latin America or the Caribbean that are members of either EUR-ACE or the Washington Accord at this time. There are programs accredited by Washington Accord members in Latin America and the Caribbean. ABET is a member of the Washington Accord and accredits programs outside the U.S.; at the present time, there are ABET accredited engineering programs at institutions in Chile (1), Colombia(3), Mexico(9), Peru(7), and Puerto Rico(8). ABET only accredits programs with a request from the institution, and for programs outside the U.S., " with explicit permission from all applicable national education authorities in that program's country or region.[12]

3. ASSURING CONFORMITY TO THE STANDARD

Quality assurance is in part a process of assuring that programs conform to a standard. Although the outcomes for EUR-ACE and IEA are very similar there are additional requirements in the standards that also must be satisfied for accreditation. For example, ABET Engineering Criterion four deals with continuous improvement.[13] The EUR-ACE framework standards call for "a management system able to ensure the systematic achievement of the program outcomes and the continual improvement of the programme."

Accreditation is a third-party process but there could also be first-party and second party conformity assessment. That is, a program could have and use its own internal quality management processes to ensure compliance with a standard. In any case, it is good practice and may be a requirement for accreditation to have a quality assurance system. There may also be a requirement for an internal system of continuous quality improvement. A robust quality management system has both.

4. GUIDELINES FOR ACCREDITORS

UNESCO has what are referred to as the "UNESCO/OECD guidelines for building capacity for quality assurance on its web site.[14] The United States Department of Education has a process for recognizing accreditation agencies.[15] Requirements are that recognized accreditors have an accreditation process that includes: setting and maintaining a standard; a self study, an on-site evaluation, publication of results, monitoring, and reevaluation.

EUR-ACE as part of its framework standards includes procedures for program accreditation. These include: submission of a report, an on-site visit by team, feedback to the institutions by the audit team, and report to the accreditation institution, a decision by a board of the accreditation institution. This process is very similar to the process outlined by the U.S. Department of Education and followed by ABET in accrediting engineering programs. ABET is recognized by the Council of Higher Education Accreditation a non-government entity for recognizing accreditors.[16]

5. MUTUAL RECOGNITION

Mutual recognition agreements (MRA) are common in trade in goods and services; and examples are the MRA between the US and the EU.[17] Less common are mutual recognition agreements for recognizing professional credentials; an example is for accountants.[18] ABET refers to mutual recognition agreements as "Accords."[19]

Mutual recognition can be done as a bilateral or multilateral agreement or by an agency. The Engineering Accreditation Commission of ABET and the Canadian Engineering Accreditation Board have a bilateral mutual accreditation agreement for engineering.[20]

The Washington Accord is an agreement among the agencies responsible for accrediting engineering programs in 17 countries.[21] An engineering graduate from an accredited program in one of the signatory countries is considered to have satisfied the educational requirement for entry into the profession of engineering in any of the signatory countries. EU-ACE is a mutual recognition agreement mainly covering countries in the EU.

Greenwood discussed accreditation in the context of mobility for engineering professionals and his paper provided the background for the WFEO statement on mobility.[22] The WFEO policy on accreditation and mobility is important to WFEO initiatives in capacity building and anti-corruption.[23]

6. ENGINEERING TECHNICIANS AND TECHNOLOGISTS

The International Engineering Alliance also has accords that cover the educational requirements for engineering technicians and technologists.[24,25] The Dublin Accord is for technicians and the Sydney Accord for technologists. For the Dublin Accord there are eight signatories. For Australian, Ireland, New Zealand, South Africa, and the United Kingdom it is the national engineering organization. For Korea and the United States it is the accreditation board and for Canada it is the Council of Technicians and Technologists. It is the same for the Sydney Accord with the addition of Hong Kong represented by their engineering organization and China Taipei as a provisional member represented by their Institute of Engineering Education. Engineering technologists and technicians are not covered under EUR-ACE.

Several of the engineering societies that participate in the Washington Accord admit engineers, engineering technologists, and engineering technicians as members. For example, Engineers Ireland admits technologists as associate engineers and technicians as engineering technicians.

There is an IEA agreement on mobility for engineering technologists with the six signatories being the same as for the Accord. The United States is not a member of the engineering technologist agreement and Australia is a provisional member.[26]

In most of the countries that are parties to the IEA agreement on professional engineers, there is no compulsory licensing requirement; what is available is voluntary registration typically through the national engineering professional society. IEA does not provide this level of detail for technologists and there is no agreement for technicians. The American Society of Civil Engineers (ASCE) is currently considering developing a certification scheme for civil engineering technologists.[27]

Certification is common for technicians and in addition to the Canadian Council of Technicians and Technologists there are other venues for recognition for certification; see for example the International Accreditation Forum.[28]

Kelly reviewed personnel certification and accreditation in the context of the different types of certification then common in the civil engineering workforce.[29]

7. DISCUSSION

The WFEO Committee has been leading a global discussion of quality assurance and mobility in the context of engineering education. This conversation should be continued and more countries and regions involved. There also appear to be opportunities to explore possible next steps and some are briefly discussed here.

Could a WFEO model standard for engineering education be developed? The EUR-ACE Framework standard and the International Engineering Alliance attributes could provide a starting point for developing a global standard for engineering education. The approach could be to develop a “model” standard one that could be adopted by countries or regions and adapted to meet local needs. The other approach would be to develop an international standard. Both approaches have merit and could be explored by the Committee.

A global standard for engineering technologists should also be explored. There is no EUR ACE standard for technologists so a reasonable starting point would be the IEA attributes. Since licensure does not appear to be an issue for technologists, certification could be explored in detail including mechanisms for recognition and mobility.

Finally, an appropriate structure for engineering technicians should be studied. For technicians, including engineering technicians, international structures already exist. These mechanisms may be satisfactory but could also inform a model for technologists and possibly engineers.

Most of the discussion so far has been for quality assurance for engineering programs and the Committee could lead in opening the discussion to engineering technologists and technicians. As discussed earlier engineering technologists are sometimes termed “applied engineers” and engineers “theoretical engineers”. The most immediate need in developing countries may be for high-quality engineering technologists and technicians and the most effective strategy for capacity building could be to build educational resources for engineering technicians and technologists with engineers to follow.

Continuous quality improvement is complementary to quality assurance and should be stressed as a necessary component of a robust quality management system. Accreditation of engineering programs is accepted as necessary to ensure minimum quality standards are met. However, a key part of quality assurance is building a culture of quality assurance and improvement at the institutional and program levels.

CONCLUSIONS

Two very strong accreditation systems for engineering education are in place: EUR-ACE and Washington Accord. There are important similarities e.g. outcomes but also some differences. The WFEO Committee could play a facilitating role similar to what has been done on mobility by beginning to explore a global standard for engineering education programs.

Education of engineering technologists and technicians and the recognition of these important components of the engineering workforce have received relatively little attention although these could be important parts of the engineering workforce in developing countries. A strategy for capacity building could be to build these capacities first with engineering education to follow. Again the Committee could lead this discussion.

Finally, quality improvement must receive more attention and the culture should be one of quality management to include quality assurance and quality improvement. The engineering community knows a great deal about quality improvement and this must be infused into the culture of engineering education. The committee could extend what it has already been doing for improving quality assurance to continuous quality improvement in engineering, engineering technology, and engineering technician education.

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Towards A Converged and Global Set Of Competencies For Graduates Of Engineering Programs In A Globalization-Governed World

Karim J. Nasr
Ph.D., Assistant to the President for Academic Advancement, University of Balamand, P. O. Box 100, Tripoli, North Lebanon, Lebanon

Prof. Nasr holds a Ph.D. (1993) and a MS (1990) from Purdue University and a BS from Oklahoma State University (1987). His technical background is in experimental and numerical heat transfer and fluid flow. Prof. Nasr served as a member of SAE, ASEE, ASME, ASHRAE, the World Energy Council, and also an EC2000 ABET Evaluator for the accreditation of engineering programs. Dr. Nasr published numerous journal papers in the fields of thermal engineering and sciences prior to assuming an administrative role at the University of Balamand as Dean of the Faculty of Business and Management in 2004. Dr. Nasr's educational research interests focus on the enhancement of students' learning experience and on the effectiveness of educational programs. Prof. Nasr is a recipient of SAE's Ralph Teetor Educational Award (1998), Kettering University's Outstanding Teacher Award (2000), Outstanding Applied Researcher Award (2000), CETL's Best Poster Award on Educational Research (2002), and TRW/CETL Educational Scholar Award (2003). Since 2007, Prof. Nasr is serving additionally as Assistant to the President for Academic Advancement tasked with mapping Quality Assurance and Control initiatives for the University of Balamand.

KEY WORDS *Attributes of engineering graduates, global competencies, convergence, globalization, engineering education.international, extracurricular, the engineer of 2020*

ABSTRACT

This paper deals with the notion of having a converged set of abilities of graduates from engineering programs for a diverse yet globalized world. It attempts to provide answers to questions like: What are the needed hard and soft

skills (abilities, attributes and competencies) expected of graduating engineers? What transformation do engineering education programs have to experience to accommodate advancements in technology and globalization? What is the role and scope of each of the constituencies of engineering education for a globalized world? What role does globalization play in the generation of modern and industry-ready engineers? What kind of educational reform is needed for engineering programs and institutions? What are the challenges of globalization in educating the engineers of tomorrow? What impact does globalization have on Quality Assurance systems and Accreditation processes? The paper concludes with a set of recommendations to the different constituents for the generation of responsive and globally-ready engineering graduates.

INTRODUCTION

Engineering is a profession that is concerned with the application of mathematics and science and whose objective is to provide solutions to complex problems for the benefit of mankind. With a knowledge-based economy in a globalization-governed world, engineering practice and Higher Education Institutions bear the responsibility of producing graduates who wear multiple hats and are equipped with a long list of hard (technical) and soft (professional) skills. In the past, an engineer was assigned a cubicle in an engineering firm and given the task to design a system or a component with the goal of meeting a particular need. The tools were simple gadgets and the expectations were limited in scope and bound by completing the assigned task. Nowadays, an engineer is a skilled applicator of science equipped with fundamental technical knowledge, versed with technological tools, and ready to take on problems never seen before in a world that is open and competitive. The integration of technology into our everyday lives and its presence in every little corner of the world has made the world a small place indeed and has allowed globalization to govern interactions across economies of the world.

Another major difference nowadays is the massification of education for learners having varying learning styles and preferences. Additionally, educational institutions are benefiting from globalization and the support of technology to reach students, previously and traditionally were not reachable. Engineering programs are faced with the need to diversify their instructional methods. In a student-centered environment, the emphasis is more on "learning" rather than on "teaching". Learning needs to be ensured via a number of assessment methods and through evidence exhibiting students' work and true abilities. Although a number of teaching methods have been utilized to deliver and convey knowledge, new and improved pedagogies for teaching have surfaced in response to the demand for better and deeper learning. In addition to the standard lecture method, a diverse set of methods such as the case method, the discussion method, active learning, cooperative learning, experiential learning, and problem and project based learning are being employed. New methods of teaching and learning often make use of technology via the internet and intranets and often involve engaging students in research activities.

This paper will attempt to provide answers to the following pertinent questions:

1 - What are the needed hard and soft skills (abilities, attributes and competencies) expected of graduating engineers?
2 - What transformation do engineering education programs have to experience to accommodate advancements in technology and globalization? What kind of educational reform is needed for engineering programs and institutions?
3 - What is the role and scope of each of the constituencies of engineering education for a globalized world?
4 - What role does globalization play in the generation of modern and industry-ready engineers?
5 - What are the challenges of globalization in educating the engineers of the future?
6 - What impact does globalization have on Quality Assurance systems and Accreditation processes?

Globalization has undoubtedly affected how and what Higher Education Institutions offer as formal and informal programs and how they engage learners of the 21st century. It has also given rise to the notion of having a converged (universally agreed upon but not necessarily uniform) set of qualities associated with graduates from engineering programs at H. E. Institutions across the globe.

1. GLOBALIZATION AND EDUCATION

Many write in defense of globalization and many see it as widening the divide between the rich and the poor. This view is especially true for developing countries and economies as they wrestle with the challenges of globalization. The International Monetary Fund confirms the opportunities linked to globalization but see its progress as skewed towards developed economies. Developed countries, leaning on strong infrastructure and investments in research, often set the course in terms of scientific discoveries, knowledge creation, and technology advancements and integration. Developing countries, on the other hand, are caught playing "catch-ups" and find themselves having to deal with self-defeating issues like the brain drain, political instabilities, societal injustice, and internal/external turmoil. In fact, developing countries find themselves in an inescapable position as consumers of knowledge with limited contribution to the creation and advancement of knowledge. Higher education institutions in developing countries, though manned by administrative and teaching staff often educated in developed countries, constantly attempt to play similar roles to their counterparts in the developed world with little, if any, contribution to the creation of knowledge. Due in part to their formal training and building on acquired knowledge, faculty members in developing countries often mimic what is done in the developed world and offer similar (copy and paste) programs and curricula. However and despite their noble intentions, these attempts are feeble as they ignore local issues and overlook regional contexts. This is in addition to the fact that the supporting infrastructure is quite different and there are differences across cultures. Most of all, the learning opportunities and experiences are lacking. In that regard, globalization widens the divide between developed and developing economies.

The globalized world is a knowledge-based world that is built on knowledge/information production and transmission. Production of knowledge is founded on the availability of high-technology industries and investments and correspondingly the contribution of highly-skilled workers (e.g. engineers). Transmission of knowledge and information requires the use of communication networks collaborating together using technology. An OECD report (1996) codifies knowledge as four different types: know-what, know-why, know-how and know-who. The know-what and the know-why are readily taught and acquired from reference books, textbooks, lectures and seminars. With the support of technology, they can be readily available and will continue to form the foundations of the learning process. The divide between developed and developing countries for those two types may not be significant. However, it is significant for the know-how and the know-who types which are based on practical experience and on the power of communication networks. To be a global player, the production of knowledge can not be expected to be done within the walls of educational institutions alone but rather within the context of shared responsibilities of both academia and industry. In addition, learning by doing is essential. Hence a partnership between industry and academia becomes an urgent need. The "information society" is rather supported by the digital revolution relying on extensive electronic networks, communication devices, e-tools, and digital libraries. In that regard, globalization presents an opportunity to be an active participant in the know-who type.

In a call for action on educating engineers as global citizens, Grandin and Hirleman (2009) offer a number of recommendations. As always, opportunities and recommendations are accompanied by challenges. There are a number of inevitable challenges due to globalization's impact on education. Naming a few:

- *Mobility for graduates*
- *Compatibility of programs and of graduates*
- *Recognition of degrees*
- *Benchmarks, standards, and metrics selection*
- *Agreement on terminology*
- *Institutional specifics and region-level contexts*
- *Emergence of non-traditional institutions and programs*
- *Internal/external QA systems/policies*
- *Reciprocity and mutual recognition of accreditation decisions*
- *Legitimacy of accreditation agencies*
- *Quality assurance in transnational education and across borders*

In lieu of restating what others have stated on the challenges presented by globalization, the reader is directed to a report prepared by Altbach et al. (2009) for UNESCO's World Conference on Higher Education. An excerpt is used here from the executive summary of their report: "Globalization, regional integration, and the ever-increasing mobility of students and scholars have made the need for internationally recognized standards among and between nations more urgent. The explosive growth of both traditional institutions and new providers raises new questions in regard to standards of quality….Mechanisms for establishing international comparability are still new and largely untested…… UNESCO has facilitated the elaboration of conventions that commitsignatories to common policy and practice to ease the mobility of students withineach region. The Bologna Process reflects enormous progress in regard to theintegration of higher education in Europe….UNESCO has partnered with the World Bank to create the Global Initiative for Quality Assurance Capacity that will include members of many regional and international networks…..It may be possible to ameliorate the most negative aspects of globalization, but it is not practical to opt out of the global knowledge system."

Thus, globalization has a noticeable impact in and on world's societies and particularly education. However, the author tends to agree with a statement made by Nayyar (2008): "We should not allow markets and globalization to shape higher education. Instead, we should shape our agenda for higher education so that we can capture the opportunities and avoid the dangers unleashed by markets and globalization."

2. ATTRIBUTES AND COMPETENCIES OF ENGINEERING GRADUATES

Much research has been carried out for the purpose of defining the attributes and competencies of future engineering graduates. In a study conducted by the U.S. National Academy of Engineering in 2004 - "The Engineer of 2020: Visions of Engineering in the New Century" - The report stated that "technology has shifted the societal framework….. [with] new developments in nanotechnology, logistics, biotechnology, and high-performance computing. The impact will be seen in medical breakthroughs, new energy devices, materials with characteristics not available today, remarkable light sources, and next-generation computers and telecommunications developments. The economy in which we will work will be strongly influenced by the global marketplace for engineering services, a growing need for interdisciplinary and system-based approaches, demands for customerization, and an increasingly diverse talent pool. The steady integration of technology in our infrastructure and lives calls for more involvement by engineers in the setting of public policy and in participation in the civic arena." In another study carried out by the UK's Royal Academy of Engineering (2007) - "Educating Engineers for the 21st Century" - Industry and academia emphasized that "university engineering courses need redesigning for the modern economy". "Industry wants graduates with more experience of problem solving, group ‹design and make› projects, and applying theory to real industrial problems. Students need opportunities to work in genuine industrial environments through work placements and projects and university staff need to be able to develop new teaching material with input from companies, learning from the success of academic-industrial research links."

3.1 GRADUATE SKILLS AND READINESS FOR EMPLOYMENT

Crebert et al. (2004) emphasized that higher education programs must find different ways to integrate transferable skills that can be used in a variety of situations in the workplace. Because of the unpredictable nature of the workplace, graduates must acquire skills that would be useful to them outside of the classroom and in the field. Atkins (1999), in a study of the employability skills of British university graduates, found that a gap existed between the requirements of employers and the skill sets of university graduates. He claimed that undergraduate educational programs could do more to better equip university graduates for employment. Laker and Powell (2011) promoted the notion of acquiring soft skills. They defined soft skills as «intrapersonal skills such as one's ability to manage oneself as well as interpersonal skills such as how one handles one's interactions with others» (p. 111). This contrasts with hard skills which are more technical in nature. They posited that soft skills are a necessary component of any employee›s skill set and form an integral part of an employee›s training process.

In attempting to provide a global model for engineering competence, Lohmann et al. (2006) stated that»many new competencies needed by engineers today are professional skills (sometimes called the 'soft skills')» (p. 119). They claimed that these soft skills had become necessary for engineers to be able to function in a globalized environment and to succeed transnationally. Additionally, in their review of the skills of modern engineers, Shuman, et al. (2005) stated that while technical skills remain a prominent component of the engineer›s skill set, soft skills have become equally important.

On the expectations of American employers, Back and Sanders (1998); Beder (1999); and Balaji and Somashekar (2009) to name a few found that employers were more likely to recruit applicants who showed a higher level of soft skills as opposed to those who only exhibited a high level of technical ability (hard skills). Sharma and Sharma (2010), on a study on Indian engineers, claimed that soft skills had become an increasingly important part of success in the engineering field in particular and that these skills could be successfully instilled in students during the education process.

Riemer (2002) pointed out that language and communications skills form an integral part of an engineer›s abilities. The list of important communication skills includes, but may not be limited to, verbal, written, and presentation skills. Engineers must be able to utilize new technologies to communicate, particularly when the communication must occur on a global scale. Furthermore, multilingual skills have quickly grown into a requirement in the globalized work environment. Firms operating on international levels require that their engineers be able to communicate across cultures. While strong English skills remain an integral part of international communication, multilingual skills are viewed as an asset in the modern workplace. In an Australian review, Greenwood (2007) stated that employers and employees had been placing an increased importance on the ability to write and speak effectively. Also, engineers must be able to communicate their ideas in a variety of ways and relay important information in manners suitable to the situations they may find themselves in.

Additionally, Lohmann et al. (2006) formulated a conceptual model for the success of engineers on a transnational basis. They claimed that ability to speak a second language constituted an important component of an engineer›s skill set. Their model placed proficiency in a second language in a prominent role and highlighted the importance of cultivating engineers› multilingual capabilities during their undergraduate studies.

Farr and Brazil (2009) found that team skills and leadership skills played an important role in American engineers› career. Engineers must be capable of working not just on an individual basis, but also as members and leaders of teams. Leadership and teamwork skills relate directly to an individual›s ability to deal with other people.

The global and competitive workplace requires an engineer that is able to work in a multicultural, multidisciplinary environment (Nair et al. 2009). Educational programs have much to contribute to equipping engineering students with the necessary tools to operate on such teams. This places unprepared engineering graduates at a disadvantage in the modern workplace (Nair et al., 2009).

Additionally, in a study of Irish engineers› skills, Wallen and Pandit (2009) found that engaging engineers in community-related activities helped bolster a variety of soft skills. Engineering practice looks for engineers with up-to-date skill sets and the ability to succeed in the workplace. Engineers in the modern workplace must be able to prove that their skills are current and that they are able to update their skills knowledge to better suit the evolving work environment (Greenwood, 2007).

3.2 ENGINEERING SKILLS AND EDUCATION

In his paper on the international standards of engineering educational programs, Fuchs (2006) claimed that, while engineers have recently become more specialized in their work and education, modern engineering curricula have not produced graduates with well-rounded skill sets. He asserted that an indirect effect of the increase in the specialization of engineers' education was a reduction in the amount of social sciences and humanities coursework in modern engineering curricula. This has supposedly resulted in the production of graduates who may not have the appropriate skills to perform their work effectively within (and across) social, ethical, and economic boundaries. Fuchs (2006) recommended that educational institutions should re-focus the coursework required of engineering students to allow them to work more effectively within social and global contexts.

Design makes up an important part of the engineering education process (Dym et al., 2005). Additionally, Conlon (2008) stated that social and environmental responsibility had increasingly become an important part of the engineering profession. Engineers must be aware of the impact of their solutions, not just on their employers and their clients, but also on the environment and society as a whole. This means that engineering students must be taught to focus both on designing systems and on attaining a broader understanding of their work›s impact on their communities and their surroundings (Sheppard & Jenison, 1997).

Problem solving skills and experimental design are key components of overall design skills. The ability to identify and solve problems contributes significantly to an engineer›s ability to design effective systems. The ability to design and perform experiments plays an integral part in the scientific approach to problem solving (Dym et al., 2005). Additionally, data collection and analysis skills, which complement experimental design skills, further aid engineers in nurturing their design skills.

In his review of the history of engineering education, Prados (1998) highlighted a shift in the paradigm of American engineering education in the mid-to-late 20th century, where curricula which were once based upon practice and design became more concerned with academia and theory. Further, he found that while contemporary engineering graduates showed adequate technical skills, they exhibited a lack of understanding towards practical manufacturing and project processes, low levels of creativity, inability to communicate effectively, and substantial deficiencies in teamwork and leadership skills. In addition, he observed that stakeholders in engineering education (e.g., accrediting bodies, educators, employers, and seasoned engineering practitioners) had begun working towards alleviating the issues presented by these narrow curricula whilst citing the modern rise in market competition as a key factor motivating the need for a fundamental change in engineering education.

Of particular relevance to the observed lack of soft skills in engineering graduates is the concept of emotional intelligence (Scott & Yates, 2002). In contrast to academic intelligence, which may govern aspects such as an individual's technical ability, emotional intelligence dictates the quality of an individual's human interactions. Emotional intelligence directly affects a person's leadership skills, teamwork ability, stress tolerance, and judgment. Among countless other factors which are fundamental to an individual's success in the modern, competitive workplace, the importance of emotional intelligence to an engineer's success places pressure on engineering curricula to foster this aspect in graduates and to produce engineers equipped with an adequate degree of emotional intelligence in order to perform effectively as professionals.

Finally, in an investigation on whether the "professional skills" could be taught and assessed (Shuman et al. 2005), the authors gave an extensive review of what is being done in the field of engineering education to respond to the challenge of acquiring the soft outcomes. The authors proposed the use of "service learning and its complementary component – global service learning".

3.3 ENGINEERS WITH BUSINESS SKILLS

Along with the relevant technical and soft skills required of a modern engineering graduate, research has identified the need for engineering professionals to function as businesspeople (Martin et al. 2005). Many engineers are now required to attain adequate business skills in order to sustain competitive advantage on a professional and corporate level. While engineers may have, at one point in time, been able to function solely as designers and technicians (i.e. to a certain extent, individuals having a set of hard skills), increasing global competition has translated into the need for more rounded engineering professionals who can function in global, social, financial, technical, and commercial contexts. From a European perspective, Birch (2007) stated that engineers must be able to connect the business world with the scientific community in order to drive innovation.

Many engineers find that their career paths naturally lead them to managerial and executive positions, requiring the ability to function with more than just technical skills. Engineers have transitioned from their traditionally purely technical roles to managerial ones that require a sense of business practices and leadership skills (Nguyen, 1998; Palmer, 2002; Goh et al., 2008).

Finally, in a Malaysian review of international engineering standards by Zaharim et al. 2010, it was found that several skills expected of engineering graduates existed worldwide. Utilizing a compilation of skills/abilities internationally, they built a comprehensive framework of the technical and non-technical skills required for employability in Malaysia.

4. GLOBALIZATION AND QUALITY ASSURANCE AND ACCREDITATION REQUIREMENTS

Various bodies and stakeholders have attempted to define the skills that are expected of engineering graduates. The US-based Accreditation Board for Engineering and Technology programs (ABET), for example, lists the following eleven skills as expected outcomes of accredited engineering programs (ABET, 2012). Criterion 3 lists what is called "Student Outcomes", also commonly known as Program Educational Outcomes. They are a mix of hard and soft skills each and every graduate must demonstrate having by the end of their undergraduate programs:

(a) "an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."

Other accrediting bodies, around the world (ASIIN, CET, EUR-ACE, etc.), have specified similar graduate qualities. The World Federation of Engineering Organizations (WFEO) has dedicated a publication titled "IDEAS" which featured themes and activities closely related to Quality Assurance and Accreditation. To name a few: 1994- Accreditation of Engineering Studies; 1996- Accreditation and Professional Practice; 1997- Accreditation, Engineering Education and Practice; 2000- The Necessary Basic Knowledge and Abilities for Engineering Graduation; 2002- Quality of Engineering Education; 2005-University Graduates' Managerial Knowledge and Skills- Way to Global Excellence. In edition 16 of IDEAS, Greenwood pointed out that "accreditation and assessment manuals include tables of attributes and competencies". In the most recent edition of IDEAS (edition 17), Nasr (2012) made the notion that it would not be worthwhile to re-invent the wheel in reference to developing a set of outcomes for engineering graduates that is too different from the sets developed by accreditation agencies worldwide.

1.1 The "exercise" of following procedures for Quality Assurance and Accreditation would, in principle, bring global views together on the issue of "graduate abilities and expected competencies". The International Engineering Alliance (IEA) developed a set of "professional competency profiles" and it could be concluded that graduate engineers (from any corner of the world) that are on the International Register of Professional Engineers (of the IEA) should be similarly *competent. The notion of "Qualifications Frameworks" may be worthwhile investigating if supported by verifiable outcomes, evidence of graduates' capabilities, and meaningful experiences.*

Therefore, accrediting bodies and engineering organizations around the globe have emphasized a set of non-technical attributes of graduates. One easily identifies the qualities and competencies linked to globalization. To name a few:

- "an ability to function on multidisciplinary teams
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- a knowledge of contemporary issues"

Furthermore, there are "constraints in designing systems" which are related closely to globalization: "economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability." This is particularly true for engineering firms which operate on the global scene. It is therefore suggested that globalization is driving engineering education towards having a converged set of abilities for engineering graduates who would be ready and equipped to hit the global workplace. The IEA has summarized a list of 12 broad categories of characteristics that are required of practicing engineering graduates worldwide through the Washington Accord, which represents a mutual agreement amongst international engineering bodies that recognizes the equivalence of engineering programs. The graduate attribute profile produced through the Washington Accord defines attributes that engineering graduates are required to display within complex engineering contexts and included the following major headings (IEA 2009): (1) Engineering Knowledge, (2) Problem Analysis, (3) Design/Development of Solutions, (4) Investigation, (5) Modern Tool Usage, (6) The Engineer and Society, (7) Environment and Sustainability, (8) Ethics, (9) Individual and Teamwork, (10) Communication, (11) Project Management and (12) Finance, and Lifelong Learning.

Similarly, EUR-ACE accredits European engineering programs and is supported by bodies such as Commission des Titres d›Ingénieur (CTI) in France and ASIIN in Germany. It has provided 6 main categories for engineering graduate skills as follows (ENAEE 2008): (1) Knowledge and understanding, (2) Engineering analysis, (3) Engineering design, (4) Investigations, (5) Engineering practice, and (6) Transferable skills. These are similar in nature to those provided by ABET and IEA.

In a recent study submitted to the European Journal of Engineering Education by Ramadi, Ramadi, and Nasr (2013), potential gaps between industry expectations and perceptions of engineering graduates› skill sets as perceived by engineering managers in the Middle East and North Africa (MENA) region were explored. Thirty six skills were identified. A Principal Components Analysis consolidated these skills into 8 distinct categories. These categories overlap to a significant extent with those grouped by IEA and ENAEE.

Therefore, based on the literature pertaining to the skill sets of modern engineers, accrediting agencies of engineering programs, engineering educators, curriculum designers, and the perspectives of the engineering industry, one may compile a list of skills which are essentially desired of engineering graduates. This list of compiled skills relies heavily on lists produced by accrediting bodies, such as ABET, the International Engineering Alliance (IEA), and EUR-ACE to name a few. These entities aim to structure global criteria for engineering graduates› skill sets and competencies to ensure substantial equivalence of engineering curricula worldwide (IEA 2009). That is, these bodies have attempted to define what skills may be required of professional engineers and, thus, what skills must be taught and communicated to engineering students in order for educational institutions to produce engineering graduates who are equipped for global mobility.

It should be noted that the emphasis should be placed on providing evidence that such outcomes had been acquired. Indeed, it would be highly useful and desirable to recommend a corresponding list of evidence-based activities for the engineering programs to ensure achievement of desired outcomes. Therefore, in addressing notions of quality assurance and accreditation for a globalized and interconnected world, the focus should be on authentic continuous improvement-driven assessment processes, on assessing whether these abilities have been acquired and on providing evidence for their achievement, while involving the various constituents of engineering education. This is especially relevant with advancements in technology and its infiltration into our personal and professional lives and with the undeniable presence of a globalized world that is founded on a knowledge-based society. Additional work is also needed to converge on answers to the challenges (listed earlier) presented by globalization.

5. RECOMMENDATION FOR THE STAKEHOLDERS OF ENGINEERING EDUCATION

Answering to accountability, customers' trust, and differentiation; engineering programs often define their constituents. A probable listing is as follows:

1. Engineering Programs themselves
2. Academic Institutions
3. Students
4. Parents
5. Support Foundations

6. Government
7. Industry/Profession
8. Advisory Boards for Engineering Programs
9. Accrediting Agencies
10. Professional/Licensing Bodies (Order of Engineers, Professional Engineer, etc.)
11. Ministry of Higher Education and related committees on initiation and certification of programs and institutions.
12. This paper offers a number of recommendations to the various constituencies as they each contribute to the making of the engineering graduate in a globalized modern world, a "global engineer" fit for the challenges of a globalized world:

a. To Engineering Programs Themselves and to the Academic Institutions

1. Form affiliations with other institutions worldwide and support the issuing of dual degrees
2. Engage and partner with global industries (engineering practice on a global scale) to introduce relevant and practice-linked courses
3. Work with accrediting bodies and industry to revise the list of graduates qualities and emphasize global aspects. In other words, upgrade and update the list of needed skills and competencies of graduating engineers
4. Carry out cyclic and assessment-based curriculum reviews to specify degree of achievement of program outcomes
5. Encourage and reward faculty members to carry out globally-relevant research
6. Offer programs and degrees which are compatible with the needs of a globalized world
7. Offer contemporary courses acknowledging the presence of a globalized interconnected digital world
8. Perform orientation sessions to students and their parents on the evolving expectations of the engineering profession in a globalized world
9. Incorporate a "mobility" program for students in the form of an international experience (study abroad experiences)
10. Integrate technology into the curriculum to match the needs of the digital globalized world.

b. To Students, Parents, Support Foundations, and Governments

1. Solicit answers from engineering programs on how they are dealing with the challenges and opportunities of globalization

2. Ask to see evidence of students' experiences and related abilities of the graduates which acknowledge dealing with globalization
3. Partner (support foundations and governments) with universities and industry and invest in creativity and innovation – the hallmarks of being competitive in a globalized world
4. Allocate funds (support foundations and governments) to support global sharing and exchange of knowledge and information
5. Support high schools in strengthening science and mathematics curricula and the professional development (training) of high school teachers.
6. Partner with universities in promoting the importance and relevance of engineering in making a difference in our everyday lives.

c. To Industry and Advisory Boards of Engineering Programs

1. Engage the global engineering practice (engineering industry) by making it available for visiting professorships, residencies, seminars, and internships opportunities for students
2. Partner with universities and government in promoting technology/innovation in sciences and engineering
3. Work with and contribute to professional societies in specifying global competencies as they spell out program-specific criteria and interact with QA/accrediting agencies
4. Make man-power available to assist accrediting bodies in the evaluation of engineering programs
5. Participate in lessening the effects of "brain drain" by utilizing technology and providing opportunities for graduates.

d. To Professional/Licensing Bodies, Accrediting Agencies, and Ministries of H.E.

1. Make becoming a "licensed engineer" a requirement for the practice of engineering everywhere in the world
2. Make holding the title of "an engineer" be based on some form of a standardized evaluation beyond that experienced to earn the degree from a HEI
3. Establish global standards in relation to accreditation and quality assurance
4. Adopt flexibility yet objectivity in dealing with the emergence of non-traditional institutions and programs. Hold such institutions and programs against objective criteria and standards.
5. Formulate a system for quality assurance in transnational education and across borders

6. Promote the concept of "substantial equivalence" in an effort to protect local and regional contexts yet open up to the world
7. Engage in the formulation of a "Qualification Framework" for each degree level
8. Explore the generation of a "ranking system" that is contemporary and does not necessarily favor traditionally ranked programs at the top – not an easy task
9. Form and contribute to the establishment of international networks concerned with overcoming challenges related to globalization.

5. CONCLUSION

Globalization has opened societies and cultures on each other. Firms and engineering businesses have turned global. Higher education institutions supply engineering firms with (supposedly) industry-ready graduates. However, the world we live in has become wide open and a world that is overwhelmed by technology. Therefore, the abilities/attributes/competencies of engineering graduates are no longer linked to the traditional roles of design and technical competence. Engineering accrediting bodies as well as world organizations concerned with the "making" of an engineer and the engineering profession are making progress in specifying the abilities of the modern and world-ready engineer. The global nature of engineering organizations, technology infiltration, multidisciplinarity of the problems, diversity in world's cultures caused the list of qualities of engineering graduates to expand. Naturally, the challenges remain as we wrestle with the ideas of evidence and true abilities. Engineering programs must equip their graduates with contemporary and modern technological tools. The various constituencies can play basic roles and functions so that the graduate is indeed global having a set of competencies that are transnational and can work across borders. H.E. institutions and accreditation agencies, along with other constituents, need to collaborate and share best-practices since globalization seems to be driving convergence of H.E. as well as QA systems and policies. In other words and to be active global players, H.E. Institutions can no longer play their traditional roles and should partner with other constituents in setting up programs which equip graduates with the "tools" to face global problems. In that regard, this paper concluded with a set of recommendations which aim to strengthen the possibility of producing an engineer with a global set of abilities, skills, and competencies.

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The Influence Of The Global-Scale Phenomena And Trends On The Evolution Of Engineering Education

Wlodzimierz Miszalski
Polish Federation of Engineering Associations, Czackiego 3043-00 ,5/ Warsaw, Poland,

Professor of the Military University of Technology (Warsaw,Poland) and Directorof Institute of Organization and Management. Before receiving M.Sc. degree in Computer Science and Operations. Research in 1972 worked as radar devices' engineer. In 1984 was awarded D.Sc. degree in Technological Science (Electronics) and in 1991 Ph.D. degree inManagement. In 1993 graduated from National Defense University (Washington, D.C.,USA). Prof. Miszalski has more than 30 year experience in postgraduate Education of engineers – particularly in Logistics and Management. Member of Polish Accreditation Committee (2007-2012). Representative of Poland in System Analysis and Studies Panel, NATO Science and Technology Organization. President of the Committee on Education and Professional Development of Polish Federation of Engineering Associations. Chairman of the Steering Committee of the 5-th World Congress on Engineering Education held in 2000 inWarsaw. Since 2005 to 2010 President of the Committee on Education and Training of World Federation of Engineering Organizations (WFEO) and Vice President of WFEO. Associate Member of Pan American Academy of Engineering. Prof. Miszalski participates in international engineering education programs. He advised Master and PhD students awarded outstanding graduate scholarship and doctoral thesis award. In 2011 Prof. Miszalski was awarded WFEO Medal of "Excellence in Engineering Education". Prof. Miszalski is author and co-author of more than 200 publications (books, academic manuals, scientific papers) on maintenance organization, decision systems engineering, disaster monitoring and relief systems command, postgraduate engineering education programs and curricula.

KEY WORDS: *engineering, education, global, international, technology, university, world.*

ABSTRACT

In the paper, different global perspectives of perceiving engineering education have been discussed with respect of the categories of key driving impacts and responses. The influence of particular global-scale phenomena and trends on the evolution

of engineering education have been considered. The paper ends with proposals of possible future institutional solutions in the area of engineering education and an invitation to further discussions on the presented proposals.

1. INTRODUCTION

The present status and future of engineering education could be discussed from different global perspectives among which the following seem to be particularly important (Figure 1):

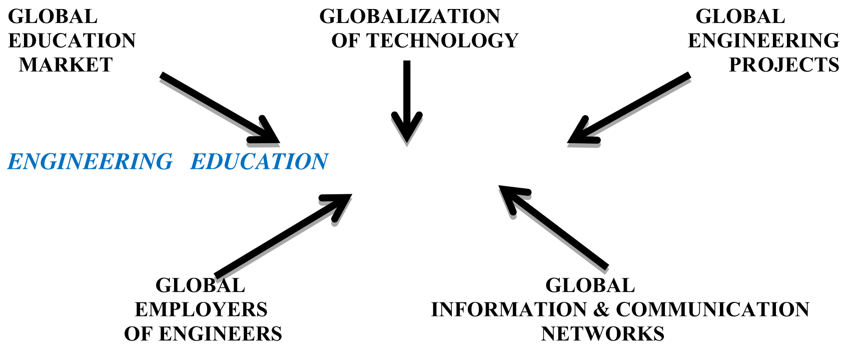


Figure 1. Engineering Education from different global perspectives

- **Global Education Market.** Engineering Education cn be perceived in terms of economy:
  internationalization of supply and demand for education services, export and import of the services, costs and benefits of providers and customers.
- **Globalization of Technology:** The antiquity technology has played important role in the convergence of societies. Presently, the number of globally spread technologies is increasing rapidly as well as the level of advancement of the technologies.
- **Global Engineering Projects:** Global Hi-Tech challenges exist in the areas of : energy, global transportation and logistics systems, space systems, environment protection, disaster monitoring and relief. However, Low-Tech challenges exist in the areas of facilitation and improvement the quality of human life (water supply and purification, sewage systems, roads) in the poorest regions of the world .
- **Global Information & Communication Systems:** Development of international distance learning and teaching, increasing the reach of education, possibility of worldwide publishing and availability of literature (textbooks, manual, research papers, lectures, presentations), access to databases, improved teacher - student

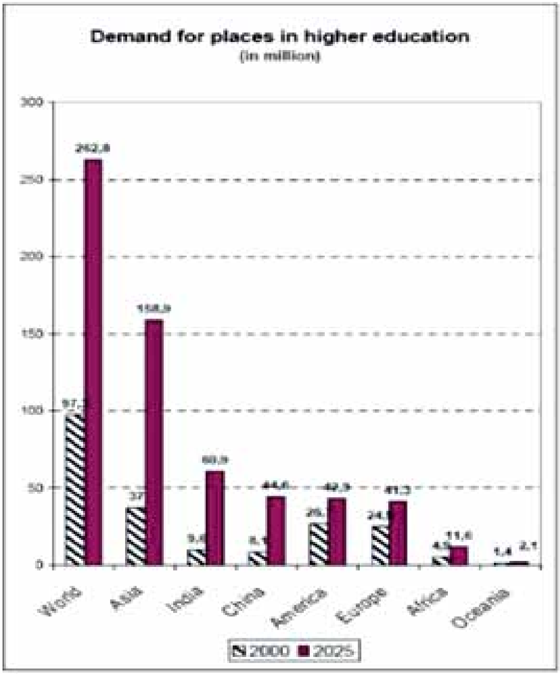
communication, development of virtual forms of education, facilitated lifelong learning.

- **Global Employers of Engineers:** Transnational corporations, global institutions and superstructures employing engineers but also providing supplementary education and training programs to meet the requirements of their global-scale activities.

2. GLOBAL EDUCATION MARKET

According to 2013 Global Industry Analysts Report [1] the global market for Education Services is projected to reach US $ 357 billion by 2018, and it is driven by the growing demand for Education and Training Services in developing countries.

The following key factors shaping the market could be distinguished:
- Supply and demand imbalance between educational needs and educational capacities, particularly in the developing world (Figure 2 shows the demand in selected regions and countries),



Source: Brandenburg, U., Carr, D., Donauer, S., Berthold, C. (2008) *Analysing the Future Market – Target Countries for German HEIs,* Working paper No. 107, CHE Centre for Higher Education Development, Gütersloh, Germany, p. 13.

- Mismatch in education quality (graduates knowledge and skills versus employers requirements),
- Growing competitiveness in the labor market,
- Appearing opportunities to take under control international flows of education services,
- Increasing needs for comparativeness and recognition of qualifications.
- Employers demand for cross-cultural awareness and international adaptability of graduates.

In response to the mentioned above impact factors, following solutions and trends have appeared:

- Organized exchange (ISEP, WISE, ASSE, ERASMUS Programme, SOCRATES Programme) as well as export-import trade of education services (Figure 3 shows the example of distribution of tertiary students in OECD countries),

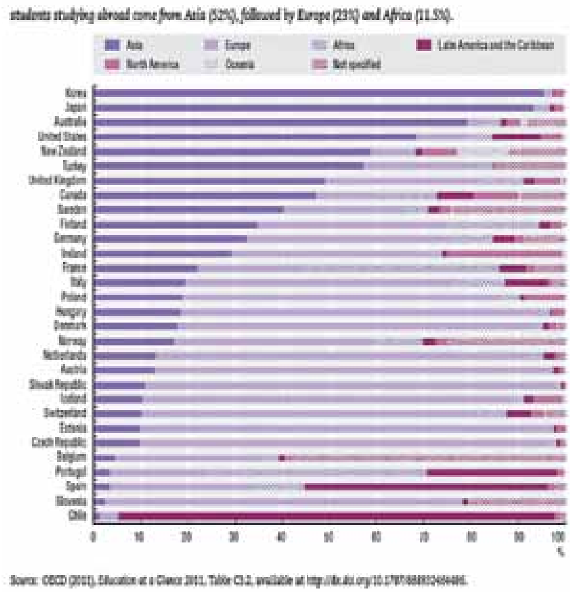


Fig 3. Distribution of foreign and international students in tertiary education, by region of Origin, 2009
Source: OECD (2011), Education at a Glance 2011,

- The rise of supplementary education and training to meet the
- demand of employers,
- Despite (or maybe as a result of) the economic crisis people tend to upgrade their skills or obtain additional educational qualifications in attempts to improve their employability,
- Emergence of the global superstructures and multi- national corporations in the education and training sectors (Apollo Group Inc., Cambium Learning Group Inc.,

Career Education Corporation, CL Educate Ltd., Daekyo Co. Ltd., ITT Education Services Inc., New Oriental Education &Technology Group),

- Establishment of international branch campuses overseas, expansion of international affairs offices in universities.
- Creating international accreditation systems enabling the validation of the education quality (e.g. EUR-ACE), worldwide rankings of universities, adoption of international academic credit systems (e.g. ECTS),
- Modifying the old and creating new programmes, courses and curricula oriented to international skills and competencies of students (cross-cultural communication and management, linguistic skills, personal and professional adaptability in international environment).

Global education market and global competition in education have reshaped many aspects of engineering education. To what extent the market orientation of engineering education and the training are influencing the mission, the personality and the professional profile of future engineer - seems to be one of the fundamental questions. Another important question is what changes in the functioning, the priorities and the resource allocation of technical universities have been driven by the global education market forces.

3. GLOBALIZATION OF TECHNOLOGY

Technology together with economy, politics and culture has been always mentioned as one of the fundamental driving forces of globalization. Today it seems interesting to discuss the feedback i.e. the influence of globalization on technology or the mutual interactions of globalization and technology.

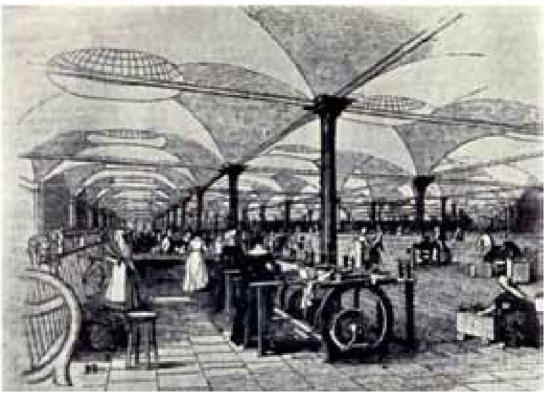


Figure 4. 19th century manufacturing technology

Source: **http://en.wikipedia.org/wiki/History-of-globalization**

Although historians differ in distinguishing particular periods of globalization, they generally agree that technology played a crucial role in every period. In the 19th century,the industrialization allowed cheap production of household items using economies of scale, while the rapid population growth created sustained demand for commodities [2]. 19th century Great Britain become the first global economic superpower because of a superior manufacturing technology and improved global communications such as steamships and railroads. The following factors driving globalization of technology could be distinguished:

- Globalization of trade, development of global market, mobility of capital,
- Multinational production, international fragmentation of production, foreign outsourcing,
- Development of international technical standards and regulations,
- Increased mobility and migration of people and products,
- Growing similarity of demand for household devices in different regions of the world

Figure 5. Mongolian yurts equipped with modern devices
***Sources:*http://www.xor.org.uk/travel/siberia2004/graphics/dcq_5547d.jpg**
http://www.lowimpact.org/blog/2013/Jan/yurts_in_mongolia.htm

The following tendencies have appeared as a response:

- Growing demand for new technologies of worldwide use required by global market,transmission of ideas for new products and new technologies around the globe.
- Increasing the number and the level of advancement of globally spread technologies, rapid transfer of technologies,

- Increased sales of licenses and patents, mutual recognition of patents,
- International servicing and spare parts logistics, cross-servicing, international logistic supply chains for spare parts, modules and maintenance media,
- Development of international R&D laboratories (within corporations and universities), internationalization of R&D publications,
- Students participating in international projects within university-corporation collaboration, international competitions for students in designing new technologies and innovations organized by transnational corporations,

Globalization of technology influences education programs, courses and curricula as well as research programs of most of technical universities and faculties making them more and more similar. From the perspective of globalization of technology, it seems not too early to discuss the globalization of engineering education. The important and urgent subjects of the discussion seem for instance in the knowledge and skills given to future engineers working in the area of service, maintenance and logistics as well as for those employed in the sphere of international sales of new technologies and products.

4. GLOBAL ENGINEERING PROJECTS

The term "global engineering" has been used in different contexts. In the names of companies, it has usually reflected the company's ability to a worldwide business activity; manufacturing products that compete in the global market, providing engineering services or conducting projects in worldwide scale (e.g. Global Engineering & Construction, Global Minerals Engineering, Global Engineering Construction Company, Global Marine Engineering, Global Engineering Services). "Global engineering" could be also interpreted as a human activity which meets the grand challenges of contemporary and future world of engineering. Those challenges - the phenomena and tendencies generating global problems are the key factors which are stimulating global engineering projects:

- Climate change,
- Natural disasters,
- Environment degradation, pollution,
- The running out sources of energy,
- Unequal quality of human life in different regions, poverty,
- Urbanization, population growth.
- Social unrests and threats to international security.

The responses are:

- Establishing international programmes oriented towards the mentioned above problems, e.g.: UN Environment Programme (UNEP), Transboundary Water Assessmment Programme (TWAP), UN Development Programme (UNDP), International Hydrologocal Programme (IHP), UN Human Settlements Programme (UN-HABITAT), Disaster Management Programme,

- Creating institutions for conducting projects associated with the programmes, e.g.: UN Office for Project Services (UNOPS), Global Environmental Facility (GEF), UN Office for Disaster Risk Reduction (UNISDR), International Committee on Global Navigation Satellite Systems (ICG).

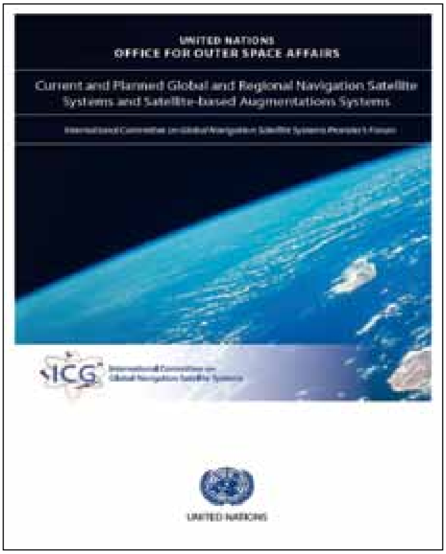


Figure 6. Publication of ICG on Global Navigation Satellite Systems Projects
Source:**http://www.oosa.univenna.org/oosa/en/about_PSA.html**

- Sponsoring, supporting and funding the global programmes and projects by institutions like United Nations, World Bank, OECD, regional international organizations, national governments, transnational corporations and companies,
- Sponsored international education and research programs conducted by universities and R&D institutions that are participating in the global programmes and projects.

From the perspective of global engineering projects, the new approach seems necessary in shaping the personality and the professional profile of engineering education graduates. Engineering projects that cover multiple countries, politics and cultures create special challenges for future engineers project executors and managers: project leadership, cross-cultural management, legal, conceptual and managerial responsibilities, project management contract laws, teams and inter-organizational relationship, conflict resolution etc. The subjects of education in this area would be also: international project phases, life cycle project management, tendering processes, risk evaluation, project realization, timing, casting, and planning.

5. GLOBAL INFORMATION & COMMUNICATION NETWORKS

In numerous opinions, global information & communication networks (I&CN) have constituted the essence of globalization – the core of globalizing society since the end of 19th century (Fig.7).

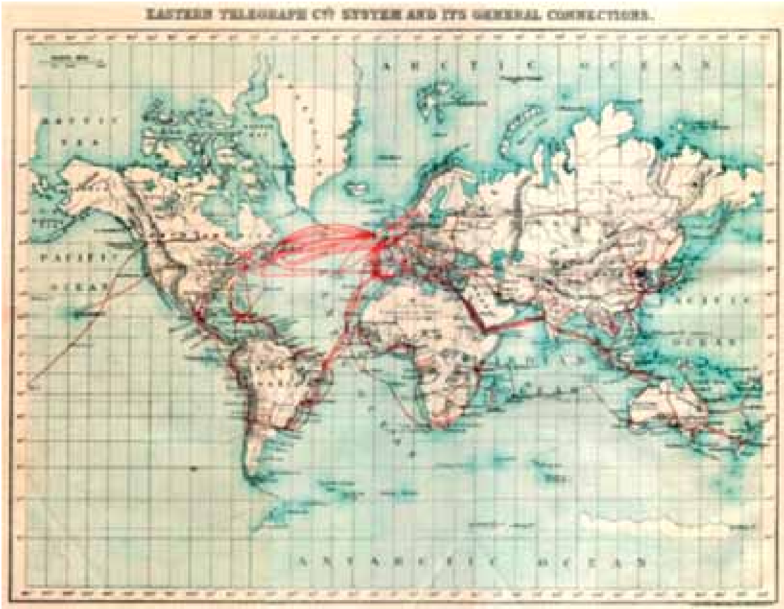


Figure 7. Eastern Telegraph cable network in 1901
Source: **http://en.wikipedia.org/wiki/Global_network**

Today, the following key factors influencing I&CN could be distinguished:

- Strengthening feedback between globalization and the development of I&CN.
- Increasing reach, density and traffic capacity of I&CN (expanding cyberspace).
- Rapid development of information and communication technology (ICT), the optoelectronics revolution.
- Continuous demand for enhancement of hardware (e.g. portability) and software (e.g. search engines) making the usage of I&CN in everyday work (business, banking ,management, education, research, engineering) easier, more efficient and effective.
- Appearance of crime and terrorism in cyberspace.

The responses are:

- Worldwide network-based virtual organizations in different areas of human activity (also in education and R&D).
- Social Networks – the new ways of sharing opinions, views and knowledge.
- Increased role of knowledge and innovation in world economy.
- Development of the so-called “Digital Economy”.

- Common using I&CN as a tool of self-education and getting knowledge outside the traditional education and R&D institutions as well as a tool of the lifelong learning.
- Development of the cyber security methods, tools and systems.

When considering engineering, the education from the perspective of the global information & communication networks, the following aspects seem important:

- I&CN as a subject of engineering education (e.g. the necessity of introducing courses on I&CN in education programs offer different engineering disciplines and specializations, taking into account the cyber- security issues).
- The influence of the I&CN development on the engineering education contents, methods, tools and organization (e.g. the scope of distance learning, the decline of traditional books, manuals, textbooks, creating virtual students' project teams).
- Bridging the barriers of time and distance in relations: professor-student, student-student, professor-professor.
- Creating international or global networks of technical universities and faculties.

6. GLOBAL EMPLOYERS OF ENGINEERS

The data from global labor market indicate the increasing demand for engineers and technicians despite the crisis and the growing unemployment in many regions (Fig. 8)

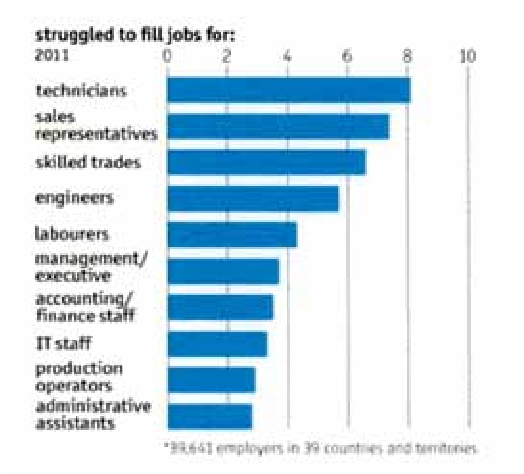


Figure 8. Demand for technicians and engineers on global labor market in 2011
Source: **Manpower Group, http://www.economist.com/node/21528434**

The biggest transnational corporations (TNCs) are technologically oriented (Fig. 9) and are the main global employers of engineers in all the areas of their worldwide operations (production, services, sales, R&D, logistics, education and training, management and even in public relations and marketing). Since long time engineers have been also employed in different international, regional and global organizations, commissions, committees, working groups - as experts, advisors, executives , leaders and managers . The following key factors influencing the behavior and evolution of transnational corporations could be distinguished:

- Increasing fragmentation and geographic distribution of production stages and logistic chains.
- Appearing opportunities to penetrate new markets (Central and Eastern Europe, Post- Soviet Asia, China, the post-local-wars stabilized regions in Balkans, North Africa, and Middle East).

Figure 9. Biggest transnational companies - global employers of engineers in 2011
***Source:* UNCTAD, http://www.economist.com/blogs/graphicdetail/2012/07/focus-1**

- Still existing and appearing new regions with political, social and economic instability,
- Demand for speeding processes of introducing innovations and new technologies,
- Growing needs for versatility, mobility and adaptability of the employed personnel.

In response, the following tendencies could be distinguished:
- Evolution from traditional, the head office centered structures of management to decentralized network centered structures,
- Decentralization of decision-making and growing self-determination of the corporations' overseas subsidiaries connected with the need for strengthening employees' awareness of corporation mission, goals, values and behavior patterns (appearance of the so-called "corporate culture").
- Appearance of "virtual companies" created for executing given project in given time.
- Ability to move jobs overseas in the cases of crisis or instability in the regions of operation.
- Simultaneous introducing innovations and new technologies in every unit of the corporation instead of the so far sequential steps (first in central company, then gradually in the overseas subsidiaries),
- Development of the internal (managed by the TNCs) education and training systems.

From the perspectives of global labor market and global employers of engineers, the fundamental issues for engineering education seem to be connected with the differencesbetween the requirements of the employers and the knowledge and skills given by universities. The main reasons of the differences or even discrepancies originate from the different assumptions or different views on the "specialization versus generalization" issues as well as from different opinions on the spectrum of positions and areas of employment (also on future professional career) of graduates. Most of universities are still preferring traditional narrow and professional profile (justified, among others, by the limited time of education) while the global employers (particularly the TNCs) require additional knowledge and skills, what results in creating by TNCs their own internal education and training systems.

7. CONCLUSIONS

From the considered global perspectives it seems not too early to start the discussion on future Global Engineering Education. First international engineering education programs appeared as a response to the needs of global education market rather than to the associated global challenges connected e.g. with the U.N. programs oriented towards solving the global issues (poverty, environment pollution, energy).

The following future solutions could be discussed:

- Virtual Global Technical University based on the distance teaching and learning, able to create international virtual teams for solving given R&D problems in given time,
- Global EE Network of the so far existing universities in different countries with synchronized and coordinated courses and curricula in selected areas of engineering, broad exchange of faculty and students (the international networks of technical universities have already emerged not only in education but in the R&D areas as well),
- Multi-campus distributed university (World University of Technology) with international chancellor's office subordinated to WFEO and with branch campuses located in different regions (mainly in the developing countries),
- Single-campus World University of Technology, subordinated to WFEO, located in one of the developing countries, totally oriented towards the U.N. global issues with the mission: "to educate humanity serving engineers".

The idea of the above mentioned options was presented by the author for the first time during the 7th World Congress on Engineering Education held in 2006 in Budapest has been developed in details in a series of papers published in IDEAS [3, 4, 5, 6, 7] and discussed during the following congresses.

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Engineering Ethics and Universities

Antoine B. Abche
Electrical Engineering Dept., University of Balamand, P.O. Box 100, Tripoli, Lebanon.

Antoine Abche received the BS Degree and MS degree in Electrical Engineering from the University of Toledo (USA) in 1984 and 1986, respectively. He received the PhD degree in Biomedical Engineering from Rutgers The State University (USA) in conjunction with the University of Medicine and Dentistry of New Jersey (Robert Wood Johnson) in 1996. Currently, he is a professor in the department of electrical Engineering at the University of Balamand. Dr Abche's research interests are: Virtual Reality, DSP, Image Processing, Analysis and Classification, Telemedicine, Image Registration, Neural Network, Fuzzy Logic, Modeling and System Identification. His interest extends to the improvement of the profession of Engineers.

KEY WORDS: *Ethics, Engineering, University, Industry, Critical Thinking, Communication, curriculum.*

ABSTRACT

In this modern era, engineers have to interact with persons, particularly professionals, to survive and to succeed in their professions as engineers. The interactions are becoming more complex due the tremendous advances in technology which is becoming an integrated component of their lives. The complexity is further compounded by the demands of societies in which engineers live as well as the societies› values, needs and expectations. Needless to say that engineers who are pursuing their studies in the universities or are working in industries have different social backgrounds, values, customs etc...., . Also, any professional action, activity or decision could affect and may have consequences and implications on the environment and the society. Besides, it has been observed unhealthy behaviors and practices in the academic institutions of higher education, research institutions and in the professional companies or industries. Thus, these interactions have to

be governed by a globalized code of ethics that is practiced by engineers all over the world. The ethical responsibility should be addressed by different entities: universities, industries, engineering associations, governments etc.... In this work, the ethical issue is presented from the university›s perspective. It can be achieved by introducing: i) a course (courses), ii) small modules in most courses and iii) in practical training. However, a platform for communication purposes should be in place and the engineers should acquire the ability of critical thinking, identify the ethical issue in a problem and provide the appropriate analysis to make sound decisions.

1. INTRODUCTION

The ethical issues can be faced by a person, and particularly by an engineer, almost daily. It can vary from a typical real life problem to a professional problem. For example, assume that you have a car that you need to sell and the transmission has a big problem. Also, you have been told that the transmission is going to fail within few months. The ethical issue becomes by addressing the following question: do you tell the buyer of the car's condition? or you pretend that your car works perfectly without any problem? As another example, assume that you are an engineer and you are studying a defibrillator that satisfies the «standard ANSI/AAMI DF2» for recommendation purposes to a medical facility that exists in a developing or under developing world. [1]. the battery is a crucial component of the design. It should be fully charged and should retain its full capacity at a temperature of 0o C. Under these conditions, the battery should be able to provide three discharges during a span of three minutes. However, the battery is expensive and its replacement may not be affordable by the facility [1]. The ethical dilemma will be the following: do you recommend the device even though you know the facility may not afford the replacement of the batteries? do you recommend a battery which is not expensive and can be afforded by the facility and does not work according to the standard? Similarly, an ethical issue can be addressed by an engineer working in an IT department within a certain company. That is, enormous, valuable and critical information might be under his finger tip. The question becomes: do you have the right to access the database and to extract such information for your own private interest? Can you transmit such information to another company in order to compete in an unfair manner? Can such information (personal and/or professional) be used for your own benefit and to become rich disregarding the damage that might be done?

Thus, the values and the ethics that are practiced by an engineer, graduated from his university, during the span of his life, particularly in the working place (companies, industries, and enterprise), are of great importance. They have become a mirror that reflects the values of the engineer, the society, the university and the professional industry in which he/she is working. If the ethics are taken into consideration in the design and the development of a particular system, in the advancement of technology (or any particular research in any field of engineering) or in bringing to light a given innovation, the outcomes through the reflections of engineers, their activities and their actions can be of great values (i.e. improve the quality of life) or of worst values (i.e. harmful) to people, the local society, the country and to the societies all over the world. Besides, the engineer has to be aware of the environmental context. The environment is for all human beings and not for a particular person. For example, the air that we breathe is not limited to one person or a group of people in a particular country or region. Thus, the pollution that is emitted in one area by industries is easily transferred to another area since there are no borders for air and its movement. Similar conclusions can be attained if it is looked at other issues such as water, sea, deforestation, acid rain and global warming. Also, the above ethical issues may be compounded by the fact that the industries, companies and organizations may have objectives (technical, profitable, economical, etc...) that contradict with the benefits and the welfare of the people who are living in a particular society and their needs [2-3]. Furthermore, the ethical issues have become crucial for accreditation institutions such as the Accreditation Board of Engineering and Technology (ABET). The latter institution requires the universities which are pursuing the process of recognition and accreditation, to incorporate ethics within their engineering programs. Some ABET criteria indicates that the student enrolled in an engineering program should acquire "*an understanding of professional and ethical responsibility" and should have a "broad education necessary to understand the impact of engineering solutions in a global and societal context*" [4]. Similarly, the Institute of Electrical and Electrical Engineering (IEEE), an organization that includes members from all over the world, emphasizes in its code of ethics the importance of the "*safety, health and the welfare of the public*" as well as the need to speak against abuses that are not in the interest of the public [5]. In the same context, the Australian engineering association emphasizes the concern of the interest of public above any other concerns such as the private or personal interests [6]. Besides, the emphasis on ethics, particularly professional ethics, can be observed in all professional engineering associations all over the world.

2. APPROACH

The ethical issues should be pursued by different entities such as the universities, engineering associations (federation of engineers....), industries, governmental agencies etc... In this paper, ethics are addressed from the university›s perspective. Actually, the student should be exposed to ethics (at least moral ethics) at an earlier stage i.e. preliminary schools and homes.

The university should look at the issue of ethical responsibility of the engineer as an integrated component of its engineering curricula. Ethics should not be observed as an independent and an isolated component in its engineering programs and consequently, they should not be perceived as an irrelevant component throughout the corresponding curricula (i.e. forgotten as soon as they are taken) and the engineer›s professional life in a company/industry at a later stage. Ethics should be emphasized as a valuable learning outcome to be fulfilled as a requirement to receive an engineering degree. Besides the related requirements of the accreditation agencies (national, regional and international) on the ethical issues, the implications and effects of engineering designs and implementations on the individuals, their societies and the environment, the university is also driven by the great concerns about the behaviors of engineers with respect to ethics during the years of their studies and during their professional lives. That is, this responsibility should address, if any, the academic dishonesty and integrity (such as plagiarism of the term paper, copying answers during an exam from other students who are sitting in his/her proximity, etc….) that have been observed in various educational institutions as well as in the professional institutions (claiming the work of another professional engineer as his/her own, relaying critical information to another company,....) without any remorse or giving credits to the appropriate persons.

The objective of such endeavor is to make a student aware about ethics and consequently to become sensitive about these issues when he is performing his job or is taking decisions, especially professional decisions. Subsequently, the knowledge about ethical issues and responsibility has to be increased through studying and analyzing more ethical cases as well as becoming aware of the ethical codes of his profession. In other words, the university should equip the student with the information, the knowledge and skills so that he will be in a position to make a sound (best possible) decision in solving the engineering problem under consideration within the context of the society and the environment.

The ethical issues and ethical responsibility can be addressed by various universities through different approaches: i) develop one (few) course (s) within the engineering curricula, ii) embed a small component of ethics within each course (or most courses) and in iii) practical training.

2.1 DEVELOP AN ETHICAL COURSE –

The development of such course (or courses) can be (are) easily accomplished. However, the faculty should not lose the broader picture and the final objective i.e. relates the ethics with the engineering curriculum that is developed at the university. He should be aware and consequently, make the student in his turn aware of the fact that the given ethical course (courses) is (are) not just a required component towards the fulfillment of the student›s degree. That is, a course in which he registers for one semester and completely is forgotten as soon as he receives his grades. In other words, each ethical course should not be treated as an independent component from any course in which he is enrolled or activity that he performs during his BS, MS and/or PhD programs and even from any activity during the span of his life. Therefore, the faculty should stress the ethical issues in its broader sense and urges the student to practice such responsibility during the remaining courses at the university.

2.2 DEVELOP ETHICAL MODULES

In this approach, the ethics are integrated in various courses throughout the engineering curriculum. They can be offered in few sessions during the span of the semester and each respective lesson could have a duration of about half to one hour. Also, they can be introduced in small dose that will require some amount of time within a particular session or/and are integrated in problems and exercises i.e. «Micro-insertion» [7]. That is, the conventional problem will be modified in order to reflect the ethical aspect which the engineer should be aware and would face in his professional carrier. The instructor should highlight the ethics which are related to the topics of the course. Then, he should provide examples (simple and complex) that will stress and highlight the practice of ethics with respect to the respective material. Consequently, this approach reiterates the principal idea that ethics are a valuable component throughout the student›s engineering education as well as in his profession. Consequently, the student should live with ethics every day and should practice it.

2.3 PRACTICAL TRAINING

The Ethical issue must be also integrated as an essential component in the training of an engineering student. Actually, the practical training has become a key component of any engineering program towards its fulfillment [8]. That is, a degree will be granted if the training within a company or an industry is accomplished successfully. However, it is not enough to expose the student to the workplace from the professional point of view i.e. apply and practice the acquired knowledge, skills, tools and information in his/her field of study. He/she should also practice ethics, including professional ethics, in the workplace. Consequently, he/she should learn and acquire the ethics that are practiced by engineers in the industry in which he/she is fulfilling his practical training. This practice should become a second nature to the trainee. In this context, industries and companies should be involved with the engineering students and their roles should be positive and highly required in preparing them for the new era and a bright future in their respective fields. The ethical issue is another reason for which both, the university and the industries, should work jointly effectively and efficiently for the benefit of the students. Similar to the acquired technical tools and knowledge, ethics should be practiced and not be kept as a moral theory that the student has to learn in a course or courses and are forgotten.

2.4. DISCUSSIONS

The university should have a code of ethics that governs the learning, the teaching, the research, the relationships and the behaviors between faculties and staffs as well as with the society, the actions and the activities within the institution. For example, the code should promote the integrity and addresses the dishonesty practiced by all parties (students, faculties, staffs ...) and the ethical actions/activities/behaviors within the academic institution of higher education. Thus, in the latter context, the integrity should involve the dissemination of corresponding information on academic and professional behaviors to all concerned parties such as the existing procedures and policies (as well as updates) that govern such issue, the appropriate behaviors, the responsibilities of each person and his duties in order to conduct in an appropriate ethical manner. The code should complement the codes that are practiced and put in place at the national and international levels as well as the professional codes that are practiced by engineers in their disciplines, industries, companies and engineering societies. If students become aware of such code of ethics at the institutional level and all parties abide by it and actions are taken accordingly with a high level of transparency in case of a breach by a student or a faculty or a staff, they (as well as all concerned parties) might become more attentive to the learning and the comprehension of the ethical issues during their studies at the universities.

The engineering student should be able to comprehend and understand through the materials and through his contact with the professors and staffs of the engineering's faculty (and with the whole university to a certain context) the ethical responsibility at large and the responsibility that comes with his profession. This responsibility should emphasize the proper conduct of engineers with respect to teaching, learning, and research, the appreciation and the respect of the works which are conducted by individuals or colleagues of the profession (research, teaching, professional...). This aspect includes several issues of great importance such as plagiarism, copyrights and patents even though it is a minor. There are no white lies in the profession of engineering. It could be costly in terms of human life. The engineer has to give the proper dues to the person around him even in the simplest interaction and yet a valuable one. The ethical responsibility should bring forth the awareness of engineers to various issues such as non-discrimination and equity within the educational community, the society and the professional community. For example, the gender, the religion, the background, the color and the region should not play a role in hiring an engineer by a company or accepting the student to a particular program. In other words, a system of fairness and equal opportunity should be put in place and advocated.

It should be pointed out that the university should address in its program the preparation of an engineering student to acquire the ability to identify the ethical issues that are associated with the task that he/she is performing or the problem that he/she is solving (for example with the design of a particular system that is requested by a company). In other words, the student should be able to understand the problem at hand and to recognize the impact of the outcomes of the proposed engineering solution on people, the environment, the society, the economy, etc… In this context, the student should present recommendations with his/her reasoning and the justifications that have led him/her to the particular ethical solution. This is very crucial in order to be able to make the best and the most appropriate solution. Always he/she should take into consideration "the good of the public" [9]. Thus, he/she should be aware of the current state of technology and of the technology that is being developed and its impact (positive and negative) on the society and the environment as well as on the future development and direction of the engineering profession.

Besides, the courses or the modules that are introduced should not be restricted to moral concept or theory. Even though, few lessons could be included along with the code of ethics respective to the corresponding field and profession, the presented lectures, the discussions and the information should be more concentrated on the analysis and the study of realistic cases. In this manner, the abstract concept can be related to real ethical problems that will be faced by engineers in their professions [11 - 12].

Furthermore, it will be worth to develop seminars during the span of the semester (for one credit- a seminar per week) in which professional engineers who are working in companies and industries are invited to present a lecture for one session. The lectures will be about a moral problem that was encountered, the analysis that is performed and the decision that is made. This should be followed by a discussion between the students and the lecturer to gain more insights about the ethical issues under consideration. Also, professors and lecturers (experts in the issue under consideration) from educational institutions can be invited for the same purpose.

3. COMMUNICATION

In this context and to gain the most, a platform for communication purposes among the students, between students and the professors, and between the university and the industries should be put in place [10]. This is very crucial in the process of teaching ethics because the platform will allow students to express well their ideas and opinions about an ethical issue orally as well as in writing. Thus, the student should not feel at all that he will be penalized for the open discussions i.e. express freely his opinions and suggestions. Subsequently, this open environment will allow the professor as well as the participants to discuss the various ideas and suggestions in order to make the appropriate decision in a given ethical situation. The communication can be achieved by dedicating sessions to discuss particular issues/case studies as a group or/and by submitting a written report followed by a presentation. However, it might be that some students do not express very openly their ideas and thoughts aggressively and effectively (i.e. they might be shy or little bit afraid to go to the limit). Thus, a dedicated internet site should be established and the discussions can proceed. The latter scheme can be a valuable tool to extend the discussions beyond the class and it might lead the students to actively participate in the on-going discussions without any reservation in expressing themselves. Furthermore, since the information can be stored during the offered semester, it will be available to the student and the professor to view how their discussions have been evolved during the span of the semester and to learn the appropriate lessons.

4. CRITICAL THINKING

The success of such endeavor requires the student to be able to think. In other words, the developed engineering programs at the university should provide the platform in which the student is encouraged to be active in the discussions in the class and on the internet and allow them to be an integrated component in the presentation of the course. He should not be passive students i.e. consume information and accept whatever his professors present without any discussions. That is, he should be guided and leaded to provide the information i.e. the ability of critical thinking. Having been equipped with such capability, he will be able to collect and analyze the information efficiently and effectively when he is faced with a problem, and will be able to grasp very quickly the theory (or theories) and insights of any complex problem and its impact on the people around him, his environment, his society, his country, his region and the world to a certain extent. Furthermore, this capability will allow him to acquire the ability to differentiate between facts that are based on sound theories, beliefs and opinions when he listen to his colleagues speaking in a seminar, workshop, conference or reading an article that is presented in a conference or a journal.

5. CONCLUSION

The ethical issue should be addressed by several parties: universities, industries, engineering associations, governments, secondary schools, elementary schools, homes, etc... The issue is complex and it is not easy to tackle. However, it should be addressed by all parties in order to reach a successful end. In this paper, the issue is addressed from the university point of view. The ethical responsibility can be achieved by developing dedicated courses or by inserting in almost each course a small component. However, it should be emphasized that the ethics should not be perceived as an independent component toward the fulfillment of a student›s degree. The ethics should become a second nature to the student and a «motto» that guides him in his activities. Also, a close cooperation should be forged with the industries in order to provide the student with professional ethics during his practical training. Besides, the success of such endeavor requires the creation of a platform of communication between the involved parties, the preparation of the students to acquire the ability of critical thinking and the ability of continuous learning in order to be current about the state of technology, tools and information.

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"Hand-Brain Alliance"

Xiao-Bing Song and Xi-La Liu
Civil Engineering Department, Shanghai Jiao Tong University, Shanghai, 200030, CHINA

Dr. Xila Liu, Chair Professor of Civil Engineering Department at Shanghai Jiaotong University (SJTU), is Executive Member (National Member of China) of the World Federation of Engineering Organizations WFEOand Executive Member of the Federation of Engineering Institutions of Asia and the Pacific (FEIAP). He is also the author or co-author of 5 books and about 400 articles in various technical journals, conference proceedings, and symposium volumes. His major research topics include: Constitutive Modeling of Concrete, Safety Analysis of Structures, Durability Modeling of Structures, Knowledge-based Systems for Structural Design and Damage Assessment. He was invited as the principal draftsman on «The Development Strategy of Structural Engineering in China» (1991) and «The Development Strategy of Engineering in China» (1999) by the National Natural Science Foundation of China (NSFC). In 2004, he was also invited as the first principal draftsman on «2020: Research on The Development of Engineering Technology in China». Since his outstanding contribution he received an honorary certificate by the China Association for Science & Technology (CAST). In 2006 and 2008, he was invited as Chair Scientist to write the 2006 and 2008 Annual Progressive Reports of Science and Technology in Civil Engineering for China Civil Engineering Society (CCES) respectively.

Xiao-Bing Song and Xi-La Liu

Civil Engineering Department, Shanghai Jiao Tong University, Shanghai, 200030, CHINA

Dr. Xiaobing Song From 1994 to 1996, Dr. Xiaobing Song was employed by Center Research Institute of Building and Construction (CRIBC) in China, he had opportunities to take part in several projects concerning diagnose, appraisal and repair of existing factories. In 2000, he received a P.H.D in Civil Engineering from Tsinghua University, and then he became a teacher in Shanghai Jiaotong University (SJTU).

Dr. Song is a teacher, he was elected as "The Most Favorite Teacher" by SJTU students in 2009. He is the coach of the student teams have won the first prize in National Structural Design Competitions seven times in succession. He is a researcher, his research interests include special structures and durability of reinforced concrete. He is also an engineer, his design won awards from the Ministry of Education and the Ministry of Construction for several times, he also won "Most harmonious Structure Award" and the "Advanced Achievement Award" during the China 2005 Award competition organized by IStructE. He not only has the National Registered Engineer Licenses (first class) but also have the Chartered Engineer Licenses.

ABSTRACT

Shanghai Jiao Tong University (SJTU) is one of the top five universities in China; its students are generally excellent with a high IQ. However, students majoring in civil engineering in SJTU tend to be uninterested in their major, which results in a lower quality of undergraduate education. To improve the situation many efforts have been made, such as to move the education from teacher-centered to students-centered, from knowledge transfer-centered to capacity building-centered and from classroom-centered to outside-classroom. Up to date, the students' learning condition has been improved obviously. Students become more interested in civil engineering and their teams have won six championships successively in the National Structural Design Competition. It is found that the most important in the education's improvement is to make engineering education programs more welcoming. The key point is to make students' "Hand-Brain Alliance" to explore students' potential.

1. RAISE A PROBLEM

Since the 80s of the last century, the steady economic growth of China has been commonly recognized in the world. By 2010 the gross domestic product (GDP) of China has the second GDP in the World. Following the process of industrialization and urbanization, China has become a largest construction field in the world. Under the developing background, however, young men in China are not very interest in engineering specialities, especially in traditional specialities.

As an example, in the civil engineering department at Shanghai Jiaotong University (SJTU), a considerable proportion of students are complaining.That is, the civil engineering is not their original choice.They actually are passively arranged in the civil engineering department This means that they like other specialities. Since their grades are low, they could not have more choices.

It is clear that the annual financial support for education from the central government of China is increasing.Various education promotion programs and students' creation plans are presented continuously. In the last century, due to the financial problem, many works could not be done.Now, the financial condition has been improved a lots and what has been done is still questionable. From the Global Competitiveness Report 2012-2013 of the World Economic Forum, about 81% of under-graduated students from engineering schools in the US can be competent for works immediately. However, in China the relative percentage is only 10%.

Some students present the following definition of examination on the web set: "What is the examination in the university? It is not a test on IQ.It is a test of physiological limit and EQ, the ability of collecting relative information, the ability of showing bosh, the ability of self-studying, the ability of quick recitation, the spying ability, the mental carrying capacity on bogus contents, and how much money to copy lots of examination papers.

Please take a look at a typical student's distribution in a classroom (Fig.1) which is given by students. There are some particular areas for sleeping, for game players, for unsatisfied students, ambitious students and overdue students. It is really questionable how many students in class are listening to their teacher seriously?

Fig.1Typical student's distribution in a classroom

In China you may hear "to build a creative educational system to train qualified students to meet the needs of the country" everywhere. It means that most people have recognized the importance of creation for the country, but it seems that there are many slogans without essential improvement in engineering education. Where is the sticking point?

2. ANALYSE THE PROBLEM

In China, it is often neglected that there is a very inherent concept, the engineering which is always connected with dry and monotonous works. If the word "Civil Engineering" is translated to Chinese directly, it means "Land and Timber" engineering. Some people treat it a yokels' job (Fig.2). Some students think that in civil engineering calculation and drawing are only needed. They do not understand the excellence and the sapience of civil engineering during the human settlement in the world. The problem is not from students. He is due to the civil engineering education.

Fig.2 some people in China treat civil engineering as yokels' job

It has been practiced for a long time that the theoretical training is overestimated and teaching in classroom is the most important. Most teachers have been accustomed to teach the theory in classroom. They aspire to the systematic and complete theory but forget that the reality is primary. In fact, engineering has two constraints from both nature and society:

I. The theory must be connected with the practice in engineering and
II. The individuality and synthesis must be emphasized.

In the new century with Information explosion and the technical globalization, the traditional education mode has been impacted seriously, the curriculum is expanding rapidly, the practical training programs are atrophying and the situation is getting more worse.

SOLVE THE PROBLEM

The innovation of engineering education in China is a very wide and complex plan. Many works should be done. From authors' view and experience, three key points have been addresed for more than ten years which can be presented as follows.

1. From teacher-centered education to students-centered education, the transition process should be done in class by every effort from teachers.
2. From knowledge transfer-centered education to capacity building-centered education, the transition from indoctrinization to heuristic approach, from school to society, from student learning to life-long learning should be done in school as quick as possible.
3. From classroom-centered education to outside-classroom education and the awareness on "All genuine knowledge originates in direct experience…" [1] and the principle of "creation must be proven by practice" [2] should be emphasized.

3.1 TO IMPROVE AND REARRANGE THE EDUCATION SYSTEM AND TO MAKE "THE FIRST CLASSROOM" MORE ABUNDANT

3.1.1 PAY MORE ATTENTION TO MOBILIZING STUDENTS' INTEREST IN SPECIALITY. THE STUDENTS' INTEREST IS THE FIRST OF FIRST THINGS TO ENSURE THE EDUCATION PURPOSE AND THE IMPROVED RESULT.

Since 2002 a course "Introduction of Civil Engineering" has been provided by Prof. Xi-la Liu at SJTU, in which many examples are shown to convince students to take civil engineering as their life-long job. A complete triangle knowledge structure (practice- theory – computation) and three knowledge levels (analysis-system-society) are mentioned. The requirements on capacities and quality are also presented. This course is designed as an engine, to excite students' interest (Fig.3).

Fig.3 The visit of a construction field with students at Pudong International Airport and Shanghai Center

3.1.2 INCREASE COURSES ON SYSTEMATICAL THINKING, SUCH AS "INCREASE COURSES ON SYSTEMATICAL", AND EMPHASIZE A MODE OF "THINKING IN GLOBAL AND DOING FROM LOCAL"

Since 1998, SJTU was the first school to provide a synthetical course "Conceptual Design of Structures", and the instructor is a chartered engineer. In this course, more contents are related to synthetically decision making. It is emphasized that the element analysis should be based on the structural consideration and the structural stiffness should be a mainline in structural design. The awareness of "thinking in global and doing from local" has been raised to the students.

3.1.3 MOVE THE EDUCATION FROM CLASSROOM-CENTERED EDUCATION TO OUTSIDE-CLASSROOM, CHANGE "WRITING HOME WORKS" TO BE "DOING HOME WORKS"

Since 2005, Dr. Xiao Bing Song added more practical training in the course "Fundamental of Reinforced Concrete". The students have to finish each step independently in the test, which starts from a concrete mix proportion design, reinforcement colligation, setting formwork, stirring, casting, and curing to each steps on setting specimens, sticking strain gages, setting sensors, loading and end up to write the test report. Every student gets involved and gains a lot (Fig.4).

Fig.4 Students with reinforced concrete beam test

Since 2006, in the "Fundamental of Reinforced Concrete" class the students have used gypsum wired to model reinforced concrete specimen and finished failure test on class for demonstration. Several student groups can be organized to start a competition. From the failure of specimens students can have a visual and a vivid observation and a strong perceptual knowledge (Fig.5).

Fig.5 Loading test of gypsum specimens in class

3.1.4 ACROSS THE BOUNDARIES BETWEEN DIFFERENT COURSES

Since 2008 Dr. Xiao Bing Song and Dr. Wen Bing Fang have provided a joint course "Architectural Design". It emphasizes the combination and penetration between architectural and structural fields. The connection between technology and aesthetics is so-called “Longitudinal and Transverse Connection” in SJTU.

In 2010, the students from both civil engineering department and architectural department can take the same course, which was attractive for students. In an International “Tower of Babel” Design Competition hosted by the Union of Seven engineering Schools, a joint student team from the civil engineering department and the architectural department of SJTU won “the Best Construction Award” (Fig.6).

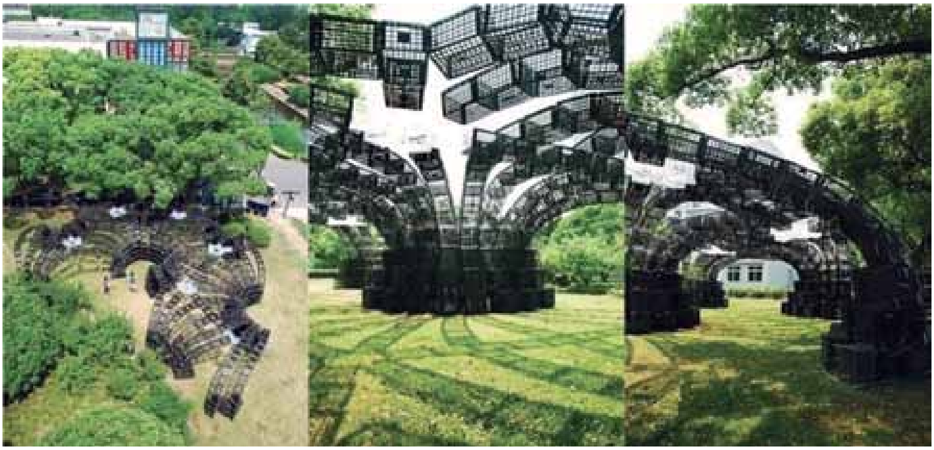


Fig.6 the “Tower of Babel” model at SJTU Campus

3.2 TO EXPAND “THE SECOND CLASSROOM”: TO EMPHASIZE THE AWARENESS OF PRACTICAL EDUCATION, TO FIND THE BEARER OF PRACTICAL EDUCATION, AND TO REDUCE THE TRACE OF PRACTICAL EDUCATION”

Since 2002, when the first Structural Design Competition at SJTU was held successfully, ten years have passed. During the past ten years, SJTU hosted ten competitions and the student teams from SJTU were invited to attend eight competitions and to host one competition in south-eastern China. Besides, SJTU student teams attended six National Structural Design Competitions. They have won 17 national or regional awards, and are called the best team in China (Fig.7).
The most important is not only the awards.But should be what the students really gained in understanding and sentiment during the competitions. One of the students, Mr. Xin-Rao Chen, who was the winner of the first class award in the first National Structural Design Competition, wrote that “…..hard working on it in five days, enjoying it in five minutes, loading it in five seconds, and collapse in 0.5 second….. It is our whole life in these days, in which it is full of sweat and hardship, setback and rough, especially choice, expectance and happiness.

Fig.7 Student team of SJTU in competition

3.3 THE TEACHERS MUST HAVE RICH EXPERIENCE TO GUIDE STUDENTS.

The practical training for many young teachers is not enough. They come from a school gate and go to another school gate. When the content of a textbook is very practical, some problems may happen. In China, no matter in engineering school or in science school, during interviewing new applicants may have to answer the educational background and published papers. It is hardly to show the practical experience. In the department of civil engineering at SJTU, the practical experience of faculty members is needed and to acquire a registered engineer license is getting more important. The license should be the same as publishing papers for promotion, and is an important step to improve faculty quality in civil engineering.

The authors, Dr. Song and Prof. Liu, have won awards from the Ministry of Education and the Ministry of Construction several times. They also won the National Outstanding Design Award in China and the China Award from the Institute of Structural Engineers (IStructE) in UK. They have the National Registered Engineer Licenses (first class) and the Chartered Engineer Licenses. Among The 25 faculty members teaching group of structural engineering in the Department of Civil Engineering at SJTU, there are 10 Chartered engineers and 6 National Registered engineers.

3.4 TO BUILD CREATIVE ATELIER OF STRUCTURES AS A PLATFORM FOR CREATIVE ACTIVITIES OF STUDENTS

In the “atelier”, the research on structural engineering including geotechnics, transportation, building structure, and bridge structure can be done. At present, it gives strong support to attend various scientific and technical competitions such as the structural design competitions between universities in Asia, the National Design Competition in China, and so on. Some students’ branches of civil engineering are very active in the “atelier”. The “atelier” area is around 250 square meters, and some loading facilities, small vibrometer, high-speed camera, and a laser cutting. The atelier opens seven days a week.Students can work on modeling, loading and evaluation. (Fig.8 and Fig.9).

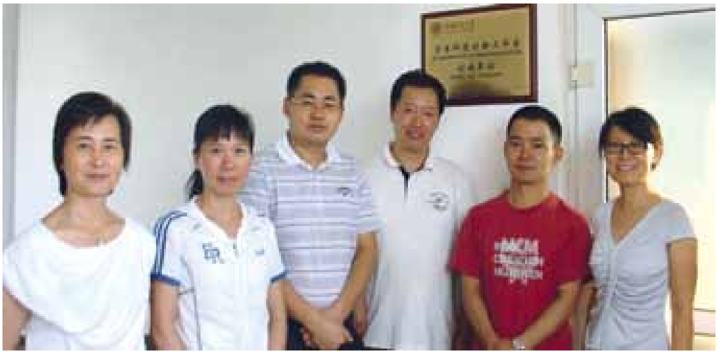


Fig.8 Instructors in the creative atelier of structures

Fig 9. Students in the creative atelier of structures

4. EDUCATION RESULTS

Considering the characteristics of engineering education some positive results can be obtained by ten years of hard work:

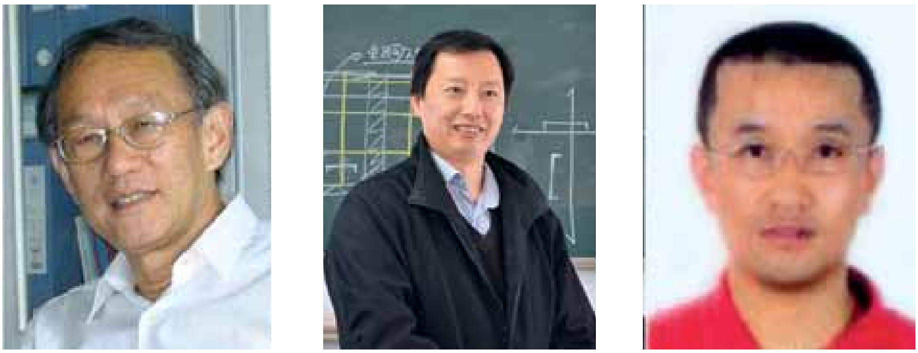
4.1 ATTRACTIVE EDUCATION IS THE MOST FAVORITE FOR STUDENTS

In SJTU, the topics for competition are always changing to keep them interesting, such as “Fishing” in 2009, “Cutting out” in 2011 (Fig.11), and “Crossing the barrier” in 2012 (Fig.12).

Fig.10 "Fishing" in 2009 **Fig.11 "Cutting out" in 2011**

Fig.12 "Crossing the barrier" in 2012

It seems that "interesting" is the best teacher, "to muster the student interesting" is the origin of education, which is also the most favorite for students. Prof. Xi-la Liu, Dr. Xiao-Bing Song and Dr. Wen-Bing Fan were elected as "the most favorite teacher" by SJTU students (Fig.13).



Prof. Xi-la Liu Dr. **Xiao-Bing Song** **Dr. Wen-Bing Fan**

Fig.13 The most favorite teachers in SJTU

4.2 THE AWARENESS ON "ALL GENUINE KNOWLEDGE ORIGINATES IN DIRECT EXPERIENCE..." [1]SHOULD BE STRENGTHENED AND THE PRINCIPLE OF"CREATION MUST BE PROVEN BY PRACTICE" [2] SHOULD BE EMPHASIZED.

To educate students to understand the importance of "working by hand" is not easy. It seems a common sense for students in high school and is not suitable for university students. In fact, it is lagging indeed. No matter how beautiful the theory is, no matter how clever the designed scheme is, they must be proven by practice. Through practice, the students can not only integrate the learned knowledge, but they can also be excited in their specialty (Fig. 14).

Fig.14 Happy learning from doing

4.3 CONSIDERING THE CHARACTERISTICS OF CIVIL ENGINEERING AND ARCHITECTURE, TO COMBINE THE TECHNICAL AND AESTHETIC EDUCATION TO CREATE SJTU STYLE

Mr. Huan Cheng Jiang, an academician of Engineering Academy in China, said that"the reasonable structure presents an architectural beauty". Another academician of Science Academy in China, Mr. Kang Qi said that "it is impossible that an architect becomes an artist completely, architect should be a combination of engineering technology with art".

In SJTU, the department of civil engineering and the architectural department are within the same school.There are many traditional exchange channels between the two departments. The faculty members from both departments have clear consciousness on how to keep the cooperation, which is an advantage of SJTU.

Wind generation (2008)

Disaster prevention of mudslides (2012)

Fig.15 Structural design competition on new topics

4.4 FOLLOWING ENGINEERS' REQUIREMENTS TO BUILD STUDENTS' CAPACITY

In class, the principle of "Teach one, Home work two and Examination three" will give students necessary training and by which students may have capacity on self-learning and long-life learning. The adoptability of students is the first requirement in capacity building, and had been recognized in wind generation (2008) and disaster prevention of mudslides (2012) (Fig. 15)

5. CONCLUSION

Under the developing background, young men in China are not very interesting in engineering specialties, especially in traditional specialties. Based on over ten years of effort made at SJTU, it is found that the most important in the education improvement is to make engineering education programs more welcoming. The key point is to make students' "Hand-Brain Alliance" to explore students' potential.

This is a very precious time to review what a great Chinese educator, Mr. Xing-Zhi Tao (1891—1946), have said. He mentioned that "The common fault in Chinese education is to teach brainworkers without using hands and to teach manual workers without using brains, and therefore neither of them can do anything."He also mentioned that "The only countermeasure is to make hand-brain alliance, which can bring both hands and brains with incredibly great power."[3]

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Extracracurricular Service Projects Prepare Engineering Students For Real World Problems

Christopher J. Lombardo1, Suvai Gunasekaran1

1Harvard School of Engineering and Applied Sciences, 29 Oxford St. Cambridge, MA 02129, U.S.A.

Dr. Lombardo attended the University of Maryland in College Park where he earned Bachelor of Science degrees in Electrical Engineering and Physics. After finishing his undergraduate work, he attended The University of Texas at Austin and completed a Master of Science degree and Doctor of Philosophy in Electrical Engineering where he studied charge transport and recombination mechanisms within organic semiconductors and other thin film photovoltaic materials. Throughout his education he became increasingly involved with Engineers Without Borders – USA, an international development organization focused on community-scale infrastructure projects, both at the University of Maryland as well as The University of Texas holding several local and national leadership roles. He has led or contributed to projects located in Mexico, Cameroon, India, Panama, Peru, Uganda, and most recently the Dominican Republic as well as several regional and national initiatives within the United States. Dr. Lombardo is currently employed at the Harvard School of Engineering and Applied Sciences as the Assistant Director of Undergraduate Studies for Electrical Engineering, Mechanical Engineering, and Engineering Sciences as well as a Lecturer in Electrical Engineering. He also serves as the faculty advisor of the Harvard University chapter of EWB-USA.

KEY WORDS *Engineers without borders, ABET, student outcomes, service learning, international, extracurricular, the engineer of 2020*

ABSTRACT

The number of engineering students participating in university-based international service projects has increased greatly in the past decade, reflecting evolutionary changes of what it means to be an engineering professional. While both curricular and extracurricular programs exist at many institutions, at Harvard University,

international service projects have yet to become a formalized part of the engineering curriculum. These international projects provide experiences that align closely with the ABET Learning Outcomes and attributes of NAE's The Engineer of 2020, which themselves share many commonalities. The Harvard University chapter of Engineers Without Borders – USA is an extracurricular student group that operates with faculty supervision, but is not currently part of the curriculum. Yet, the experiences that students obtain throughout the participation in Engineers Without Borders, as well as other engineering service learning organizations, can meet ABET Learning Outcomes and the foster the desirable attributes of The Engineer of 2020.

1. INTRODUCTION

Extracurricular service learning projects, implemented through organizations such as Engineers Without Borders, Engineers for a Sustainable World, and other programs, have seen large increases in student interest and participation over the past decade. Simultaneously, there have been major evolutionary changes in what is required of an engineering professional. The introduction of these programs has changed engineering curricula through senior design courses at a number of academic institutions [1], which meet ABET accreditation requirements [24-] and foster the desirable attributes of The Engineer of 2020 [5, 6]. Additionally, Project Based Service Learning and other hands-on learning methods have been shown to positively impact other outcomes, including increases in student self-confidence, self-efficacy, and self-esteem. [7, 8] The Harvard University chapter of Engineers Without Borders – USA (HUEWB) is an extracurricular student group that is not formally integrated into the engineering curriculum, though programs like these can still meet many of the ABET Learning Outcomes and foster the attributes of The Engineer of 2020. This article describes the interconnected nature of ABET's Learning Outcomes and The Engineer of 2020, and demonstrates how Engineers Without Borders projects, specifically those conducted by Harvard University's chapter, can meet these educational metrics for its own students.

2. DESIRABLE CHARACTERISTICS OF ENGINEERING GRADUATES

2.1 ABET STUDENT LEARNING OUTCOMES

ABET, formerly the Accreditation Body for Engineering and Technology, is an organization that accredits baccalaureate and masters-level engineering, engineering technology, computing, and applied science programs in the United States, as well as in 23 countries internationally. The ABET process is focused on what is learned rather than what is taught, as well as a methodology and process for continuous institutional and programmatic improvement.[9] For an engineering program to attain accreditation, it must meet at least eight general criteria, and many programs have shown an increased focus on effectively meeting the Criteria 3: Student Outcomes, which are:[4]

a) an ability to apply knowledge of mathematics, science, and engineering
b) an ability to design and conduct experiments, as well as to analyze and interpret data
c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d) an ability to function on multidisciplinary teams
e) an ability to identify, formulate, and solve engineering problems
f) an understanding of professional and ethical responsibility
g) an ability to communicate effectively
h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i) a recognition of the need for, and an ability to engage in life-long learning
j) a knowledge of contemporary issues
k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

2.2 THE ENGINEER OF 2020

The learning outcomes that ABET uses to qualify programs for accreditation were modeled after Engineering Criteria 2000 [10], which was published in 1997. Since then, several other engineering focused organizations have published their own characteristics of what makes a competent, employable, and successful engineer. In 2004, the National Academy of Engineering published The Engineer of 2020, which detailed the envisioned attributes of an engineer in 2020. In condensed form, engineers in 2020 will:[6]

1. possess strong analytical skills
2. exhibit practical ingenuity and creativity
3. communicate effectively orally, visually, and in writing while using modern virtual communication tools
4. understand and practice business, management, and leadership skills
5. possess high ethical standards and exhibit professionalism within their profession
6. demonstrate dynamism, agility, resilience, and flexibility
7. practice lifelong learning

2.3 CONNECTING ABET AND THE ENGINEER OF 2020

While there are many different methods to map ABET Student Outcomes onto The Attributes of the Engineer of 2020, Polok et al. have generated a reduced set of these points that share the most commonality.[3] Here, ABET Outcomes 3a, b, e, i, j, and k are omitted, as many engineering programs have either been successful at achieving these learning outcomes or they do not represent a fundamental change between traditional notions of the engineering profession and The Engineer of 2020. Figure 1 describes Polok et al.'s list, which has been subsequently modified to include a mapping from ABET Student Outcomes to the attributes of the Engineer of 2020.

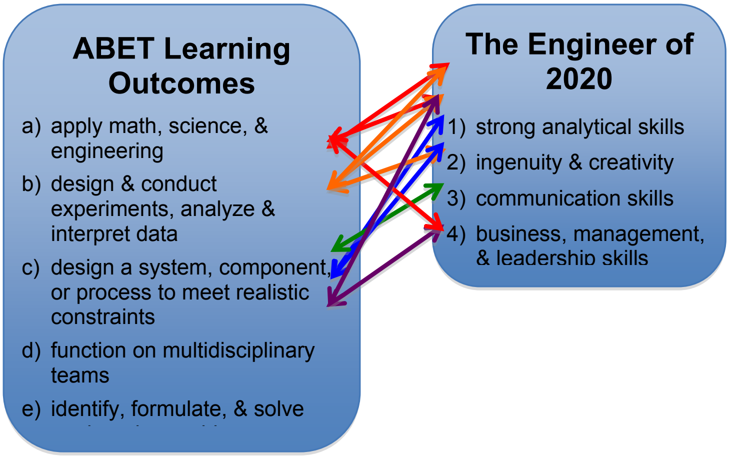

Figure 1: Mapping between ABET Learning Outcomes and Attributes of The Engineer of 2020. Modified from Poloket al.[3]

By examining the mapping described in Figure 1, it can be seen how ABET Learning Outcomes coincide with Engineer of 2020 attributes in a number of ways. ABET 3c describes how graduates should be able to design a system, component, or process within realistic constraints. The ability of an engineer to create this design should be directly related to the quality of his or her analytical skills. Ingenuity and creativity play an even more prominent role in engineering designwhen the product to be designed is new, innovative, or completely "outside the box". The presence of additional constraints, which may not normally be encountered, only increases the necessity for ingenuity and creativity within a given design, and reflects the agility, resilience, and flexibility of the designer.

ABET 3d describes functioning on multidisciplinary teams. It is the authors' assertion that to be a competent member of a multidisciplinary team, each individual member must be highly proficient in his/her own discipline, which implies that the team members possess strong analytical skills. Multidisciplinary teams are becoming commonplace within the engineering profession as the variety and magnitude of societal problems, like those being addressed by the Millennium Development Goals and The National Academy of Engineering's Grand Challenges, are increasingly being solved through engineering solutions. These large societal problems require collective ingenuity and creativity that can only be addressed by diverse teams. The success and profitability of businesses will rely on the ability of their employees to not only be functional parts of multidisciplinary teams, but also to manage and lead these teams. Similar connections can be made between ABET 3f, g, and h to the attributes of the Engineer of 2020.

3. ENGINEERS WITHOUT BORDERS – USA

Engineers Without Borders – USA (EWB-USA) was founded in 2002 by Professor Bernard Amadei of the University of Colorado at Boulder as a means to connect developing communities with infrastructure needs to engineering students who are able to design solutions to those needs.[11] Since that time, EWB-USA has grown to over 12,000 students, faculty, and professionals in over 250 chapters working on over 350 projects in over 45 countries.[12] EWB-USA engages its members though community-driven infrastructure projects where chapters partner with a served community, typically for at least five years. This multi-year commitment to a community is referred to as a program. EWB-USA programs allow for a holistic and integrated approach to community-based development and tend to consist of multiple infrastructure projects as well as assessment, education, monitoring, and evaluation of these projects. By managing these projects programmatically, the effects of multiple projects can be collectively monitored to determine the impact on the overall quality of life in the served community. For example, an improved sanitation system may have a measureable impact on water quality either independent of or in conjunction with an improved potable water supply.

Within each EWB-USA program, chapters implement individual *projects* that address a specific community infrastructure need, including: water supply, structures, sanitation, energy, agriculture, civil works, and information systems.[13] While every project is technical in nature, each project must incorporate non-technical aspects, such as cultural, social, environmental, and economic considerations in order to be sustainable long after the relationship between the chapter and the community has concluded.

3.1 EWB-USA PROJECT PROCESS

EWB-USA projects generally follow a five-step process, including project selection, assessment, design, implementation, and monitoring and evaluation. The project process is cyclical in that many elements of a given project inform subsequent projects within a partner community. Selection of an EWB-USA project is motivated by the needs of a specific partner community as well as the technical competency of the EWB-USA chapter. Once a specific project is selected, members from EWB-USA, with assistance from community members and in-country partners, must acquire all data necessary to perform an engineering design, including identifying and determining the appropriateness of multiple engineering solutions. Using the data gathered in the field, the engineering design is developed in the United States, typically at the chapter's university campus. Throughout the design process, community and in-country partner feedback is solicited repeatedly to ensure that the final product meets not only the community's technical needs, but is also acceptable within the local culture and can be maintained solely by the community for many years.

The final, collaborative engineering design is then reviewed by the Technical Advisory Committee (TAC), which is a group of practicing engineers that review the facility design and documentation in order to determine if the design is appropriate and meets applicable U.S. or other international standards. Upon approval from the TAC, the chapter can make plans to construct the project with the partner community. After the conclusion of construction and for some time after, the chapter, with the assistance of the community members and in-country partners, will monitor the effectiveness of the facility as well as its operation and maintenance in order to determine if modifications to the design are necessary to meet the desired outcomes. Additionally, this will inform the chapter and the community of how to determine and proceed with future projects. At all points in the project process, engineering students must be working with a professional mentor who has practical engineering experience in the relevant project field. Frequently, chapters have more than one professional mentor to achieve expertise across the technical areas within a given project.

3.2 HUEWB TIREO ABAJO WATER FILTRATION PROJECT

In 2007, the Harvard University chapter was contacted by physicians from the St. Jerome's Parish Constanza Mission to aid in the reduction of water-borne illness present in the community of Tireo Abajo, Dominican Republic. Members of HUEWB diagnosed the existing water system in Tireo Abajo to find a non-functional community-scale slow sand water filtration plant and contaminated distribution piping, while the groundwater source was relatively free of contaminants.

Over the next two years, HUEWB began to pursue two different options to address water-borne illness in Tireo Abajo: rehabilitation of the water filtration plant and designing a groundwater well which could be easily replicated at the household scale for those families who do not have access to the municipal water system. Rehabilitation of the water filtration plant would require collaboration with and consent of the local government water agency. After two years of little progress with the municipal government, this solution was abandoned, as it would not have been a viable short-term solution to water-borne illness. During the same time, HUEWB had made significant progress on family-sized groundwater wells with a functional prototype demonstrated in-country. Upon examining this solution further, the technical skills required to implement and maintain these well systems were beyond the capability of most members of the community, which raised the question of the long-term sustainability of family-sized wells.

As a result, the project team was forced to radically rethink the approach to providing clean water in Tireo Abajo. Since working with the local government for a community-scale solution would not be possible in the short term, the team needed to develop a point-of-use based filtration system that was inexpensive and could be easily maintained by households with few technical skills. After some initial research, several feasible possibilities arose for water treatment at the household scale: ceramic filters, solar disinfection, bio-sand filters, and chlorine. After exploring the various options within the project team and with the community, ceramic filters were selected, as they are inexpensive, long lasting, locally produced, and can be implemented on an individual household basis. This solution dovetailed well with existing practices because many households use standing water storage tanks, and any attempt to implement a clean water solution must either ask these households to renounce the convenience of these tanks, or else intervene between the "tanks and the tap".

In spring of 2010, HUEWB tested the feasibility of ceramic water filters for use in households in Tireo Abajo. Ten ceramic filters were purchased from AguaPure, a local ceramic filter factory, and were tested in five public and five private locations. The results from community residents were very positive, demonstrating the high potential impact of point-of-use ceramic filters. To facilitate greater adoption, HUEWB developed a microfinance model for a sustainable non-profit entity to sell the ceramic water filters in Tireo Abajo. HUEWB donated an initial capital investment to purchase filters from AguaPure. The filters were sold with an installment plan that would make it sustainable for the non-profit to purchase more filters. Two specific community members enabled the success, Rosana Duran, the neighborhood council president who was in charge of the finances for the group, and Dr. Saif Haider, a local physician, who stored unsold filters in the clinic where he was employed. Both individuals promoted the filter program and as of January 2013, 24 families were using the ceramic water filters and reported a reduced incidence of water-borne illnesses.

Throughout the partnership with Tireo Abajo, HUEWB was focused on strong community relations to enable the success of the ceramic filter project. Chapter members gave multiple, well-attended presentations about the water quality testing and their results. A school program was developed where middle school students educated community members on water quality and sanitary practices as part of their class. The community formed a health advisory committee, comprised of ten members, which allowed the chapter to remain more in touch with the community as a whole, even when not physically present. Furthermore, the team worked with Dr. Haider to collect health metrics related to water-borne illness not only within Tireo Abajo, but also in the surrounding communities.

3.3 HUEWB PINALITO WATER SUPPLY PROJECT

HUEWB then became involved with the neighboring community of Pinalito during a trip to Tireo Abajo in 2012, in which the travel team learned that the community water well and pump were not operational. The community knew of the chapter's involvement in Tireo Abajo through an in-country partner involved in the ceramic filter project and requested help from the chapter. During January 2013, the chapter again traveled to Pinalito in order to determine the cause of the pump/well failure through extensive pump and recharge testing of the existing well. In addition to these tests, the chapter performed water quality tests at several water sources used by the community, land-surveyed the community and surrounding area, met with community members as a group and with individual families, and began an education program in the local elementary school to teach children about clean water and hand washing (shown in Figure 2). All of these tasks were necessary to develop a working rapport with the community members, determine the history of water usage and water-borne illness, and develop a holistic approach to water safety and security within Pinalito, as opposed to designing a purely technical solution.

Figure 2: Education program implemented in three elementary schools in the Tireo region in January 2013. (Left) A student uses a water sample from a local source to test for bacterial contamination. (Right) Five students examine the results of bacterial tests from four local water sources.

Using the data collected in January of 2013, chapter members spent the spring semester of 2013 determining a path forward for the community of Pinalito. Using results from the well tests as well as knowledge from a local drilling professional, it was determined that the well was unlikely to be able to be repaired due to improper installation of the screened area by the original contractor. Based on this result and an analysis of the topographic and water quality data collected in the field, many alternative water sources were discounted due to either their water quality or the inefficiency of transporting water from the source to the community. The resulting solution to Pinalito's water supply would be a new well, which would be properly designed to meet the community's water needs. To prevent another well failure, this new well would be installed by a drilling professional who has extensive experience with wells in the area and would be unwilling to jeopardize the quality of the well and its groundwater in an attempt to cut costs. For the remainder of the semester, the project team designed a new well within the capabilities of the Dominican drilling professional, which will be added to an existing concrete water storage tank and the minimal distribution piping that currently exists in Pinalito. The complete design that will be constructed includes a new well with appropriate foundation and protection measures, a submersible pump with control electronics, a control loop connected to float switches in the water tank for automatic pump switching, a structure to provide environmental protection of the electrical elements, a piping network to connect the pump to the existing 3000 gallon concrete storage tank, and subsequent connections to several communal access points, which will be constructed in multiple phases. This design will include complete water system operation and maintenance manuals as well as a sustainability plan to be produced both in English and Spanish.. Before construction begins, the design, operation, maintenance, and sustainability plans will be presented to the community for their feedback, revisions, and approval. Currently, the community of Pinalito and HUEWB plan for the well to drilled during the summer of 2013.

4. CONNECTING SERVICE PROJECTS TO LEARNING OUTCOMES AND ATTRIBUTES

As extracurricular international service projects are examined like those engaged in by students at the Harvard School of Engineering and Applied Sciences, , various elements of these projects can easily be identified as meeting both ABET Learning Outcomes as well as encouraging the attributes of The Engineer of 2020. Most fundamentally, these projects typically address a community need, usually in the form of infrastructure. Students that participate in these projects not only have to design a facility (ABET 3c, Eng2020 1) that is acceptable by U.S. or other international standards (ABET 3f, Eng2020 5), but this facility must also be able to be constructed on location with materials that are locally available (ABET 3h), greatly reducing the portfolio of pre-made designs that could be used in the U.S. Within the Dominican Republic, HUEWB students only implement designs where the materials can be sourced locally (Eng2020 6). This was one of the motivating factors for selecting the clay pot water filter as opposed to using other "high-tech" methods that could not be sourced locally. This required the project team to look "outside the box" of solutions typically used in the U.S. to technologies that are commonplace in less developed parts of the world (Eng2020 2).

The clay pot filters were selected not only by the project team, but in collaboration with the community of Tireo Abajo and the in-country partners, which created a diverse group of stakeholders collaborating on this project (ABET 3d). The students on the project team are pursuing varied academic concentrations, which range from engineering sciences to evolutionary biology and social anthropology. In addition, the academic and cultural backgrounds of the community members and in-country partners were diverse, including several Dominican community members with little education past middle school as well as a local university-trained physician who is Pakistani in origin. Without this multifaceted group of stakeholders actively participating on a multidisciplinary team throughout the multi-year relationship, an effective, culturally appropriate solution that was also sustainable economically, socially, and environmentally in the long term would not have been possible (ABET 3f).

Further, HUEWB projects are wholly student-led, with some technical oversight given by faculty, professional mentors, and the national organization, EWB-USA. As a result, the students are the project managers that need to effectively manage the community relations, logistics, and fundraising necessary to achieve their goals (Eng2020 4). This mandates professional communication skills, both written and oral, not only to communicate with the project team in the Boston area, but also to work with other supporters and like-minded groups in the U.S. as well as project partners in the Dominican Republic, most of whom do not speak English (ABET 3g, Eng2020 3). To be successful in these international extracurricular service projects, students and practicing engineers need to already possess or have to ability to learn the skills and attributes enumerated in the ABET Learning Outcomes and The Engineer of 2020.

5. CONCLUSION

Extracurricular service projects at many academic institutions, including Harvard University, have been demonstrated to fulfill ABET Learning Outcomes as well as encourage the desirable attributes of The Engineer of 2020. Although the method in which these traits are learned is not institutionally formalized, as is the case with HUEWB students, the traits are evident within those individuals who participate in Engineers Without Borders or similar programs.

Engineering is a profession that utilizes both natural and man-made resources from the world around us for the advancement of society. The students who work on international service projects throughout their educational training will have the experience of working on teams with diverse groups of people throughout the world, and will be leaders in projects that have a direct positive impact on human life even before they graduate and enter the workplace.

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Developing A Globalized And Sustainable Mindset In 21st Century Engineering Students

Dr. Patricia Polastri
Texas A&M University, Frank H. Dotterweich College of Engineering, Industrial Management & Technology Department, Kingsville, Texas, USA
Mr. Todd E. Alberts
Indiana State University, College of Technology, Applied Engineering & Technology Management Department, Terre Haute, Indiana, USA

Dr. Patricia Polastri is an Assistant Professor at Texas A&M and teaches classes in the Department of Industrial Management and Technology within the Dotterweich College of Engineering. While specializing in the areas of technology management, supply chain, and sustainability, before starting her career in academia, Dr. Polastri worked for numerous years in Europe and enjoyed the complexity of multinational organizations in the area of advanced manufacturing. Her interest in global business prompted her to pursue a PhD degree in Technology Management. For her dissertation Dr. Polastri focused on the impact of globalization on the gas engine and parts manufacturing industry of Indiana. Now a resident of Texas, Dr. Polastri continues her research in sustainable business practices embracing the Eagle Ford Shale discoveries. She is an Internal Steering Committee member for the Eagle Ford Center for Research, Education and Outreach (EFCREO) recently established by the Frank H. Dotterweich College of Engineering. Dr. Polastri is also a supporter of the Reshoring Initiative, seeking to promote the importance of global competitiveness of the manufacturing sector of our nation. In that role, Dr. Polastri was a guest speaker at the Krannert School of Management Fall 2011 Conference at Purdue University. Dr. Polastri is a frequent speaker at diverse national conferences emphasizing sustainable practices and social responsibility. Dr. Polastri also serves as Co-Chair for the Information Tech, Computer Science & Business Division in the IAJC/ISAM Conference Executive Board.

KEY WORDS *Engineering, education, competitiveness, sustainability, curriculum, academia, industry, globalization.*

ABSTRACT

The globalization of education is undeniable in the U.S., where every year students from all over the world come to American Universities to pursue their Engineering and Technology degrees. However, the traditional engineering education model has invariably remained focused on purely engineering related topics, providing students with limited global and social content and lacks in the development of their view of globalization and sustainable practices. Engineering projects may extend to domestic and global environments usually requiring the acquisition of raw materials and the disturbance of local sites to complete their projects. Thus, engineers lacking a holistic view of the world may pose a threat to local or distant environments. Therefore, it is imperative to expose these students to the social, economic and environmental repercussions their choices may have for those living near and far. This paper proposes that to create engineers capable of dealing with global issues, their education should also comprise the understanding of economic, social, environmental and sustainable topics currently not included in their academic curriculum.

1. INTRODUCTION

Engineering education is extremely relevant for the competitiveness and economic development of any country. According to the U.S. government data, the manufacturing sector is accountable for around 20 percent of the gross domestic product (GDP) of the country [1]. In education the U.S. has experienced a continuous increase in diverse Engineering Bachelor's Degrees awarded throughout the years. At the beginning of the 20th Century, around 4,900 degrees were awarded in Engineering; by the year 2000 around 245,916 students received a degree in Engineering. During 20082009- engineering schools in the U.S. received almost 172,000 students from India, China and South Korea. These three nations were overrepresented in the area of Engineering, followed by Saudi Arabia, Nepal, Japan, Turkey, Mexico, Canada and Taiwan. Chinese and Indian students accounted for almost half (47 percent) of all foreign Science and Engineering students in December 2009. The amount of foreign graduate students still outnumbers the amount of foreign undergraduates. Chinese students prefer business and engineering education while Indian students remain mostly in engineering related areas [2]. American students on the contrary paint a different picture. They hesitate in their choice of academic major and usually abandon the engineering path. From those students who initially state Engineering as their main major, 40 percent end up switching to other academic subjects or fail to complete a degree [2]. Today in some universities foreign students outnumber Americans in engineering fields.

1.1. CURRENT DECLINE IN ENGINEERING EDUCATION

One of the many reasons for the change between majors for American students could be related to the negative perception of the engineering and manufacturing industry in the U.S. The media exercises great influence on the selection of majors and students are receptive to the negativism with which engineering and manufacturing is currently portrayed. As Miller states, parents and students are seeking viable educational programs that are capable of placing graduates in high paying positions with projected long-term growth [3]. Thus, manufacturing is portrayed, as an area of study with almost no future, since increasing production of goods is being offshored to low cost countries. The fact that the U.S. has never been more efficient and that U.S. output has undeniable increased is barely mentioned.

Another possible reason for students leaving engineering as a preferred area of study is the level of mathematical skills required in the engineering curriculum. Pisa studies conducted in 2009 revealed that American students are average and below average in mathematics and science respectively when compared with other OECD countries. Calculus, physics and chemistry seem to be the most difficult areas to deal with in engineering for American students. Wadhwa [4] mentions that students and parents alike are worried about the outsourcing of jobs while Kennedy states the routine, repetitive aspects of engineering have become commoditized and are being priced as a commodity, not as a profession.
In the end, engineering graduates accept job positions outside the engineering profession, mostly in business and management areas, offering them not only better opportunities but very competitive salaries [4]. It is noteworthy mentioning that today around 30 percent of U.S. workers with science and engineering degrees are age 50 and older [5]. Duderstadt explains that with just 5 percent of the world's population, the U.S. employs almost one third of the world's scientists and engineers, and accounts for more than 40 percent of its R&D spending and publish 35 percent of its scientific articles [6]. Despite this fact, reports show that 600,000 manufacturing jobs go unfilled because industry cannot find workers with the needed qualifications and skills sets [7].

2. REQUIRED SKILLS OF FUTURE ENGINEERING STUDENTS

In his Roadmap to the Future of Engineering Practice Research and Education, Duderstadt explains that "the changing workforce and technology needs of a global knowledge economy are dramatically changing the nature of engineering practice, demanding far broader skills than simple the mastery of scientific technological disciplines" [6]. His stance is also confirmed by recent surveys conducted in the engineering field that according to M. Jones et.al. confirms that skills in Lean Processes, Six Sigma and CAD/CAM are desirable for technical majors. The Association of Technology, Management and Applied Engineering (ATMAE) a recognized accrediting body in applied engineering, confirms the presence of a gap between skills needed and courses offered [8]. Those skills are not necessarily of a technical character but "soft skills". Duderstadt mentions skills in entrepreneurship value creation, leadership, innovation and global engineering practice. According to Ayokanmbi engineering students must acquire a "global perspective", what he calls multicultural intelligence skills that will enable them to communicate and appreciate other cultures around the globe. Ayokanmbi cites Patricia Galloway's statement that "understanding of globalization is key to an engineer's success in today's global society" [9]. The purpose of this paper is to emphasize not only the area of globalization as a requirement in engineering education, but also the addition of economic, social, legal and political, environmental and sustainable topics in the engineering academic curriculum.

2.1 GLOBALIZATION'S IMPORTANCE IN ENGINEERING

Although the term globalization is somewhat tainted with a negative tone, the free movement of goods, capital and labor have enormous potential for growth and development for those in favor of it. Multinational corporations (MNCs) thrive where local market conditions are favorable, and where knowledgeable workers are available. The reach of MNCs has changed in character and evolved from being a set of discrete subsidiaries under a common canopy to a well-integrated and dynamic set of synchronized global operations. These operations cover the whole spectrum of value creation from global procurement, management, and process design, R&D and even after sales [6]. The U.S. exports of manufactured goods are expected to top $1.3 trillion in 2012, as Moutray states, an all-time high. This increase could not be possible without the increasing significance of our business counterparts in foreign markets. [10]. The leading U.S. export products are all related to technical improvements in the areas of transportation equipment, computers and electronics, chemicals, and non-electrical machinery. The key word for this phenomenal achievement is "trade". Trade in general, and global trade in particular, are areas studied in business education and oftentimes not covered (or insufficiently covered) in engineering education. Thus, engineering students remain unaware of the country's major trading partners, the different free trade zones around the world, outsourcing, off-shoring, supply chains and their advantages for value creation, technology commercialization, and mutual economic development to name a few. Engineering education must add value to society by transforming engineering deliverables into marketable products and services.

2.2 UNDERSTANDING SOCIAL AND ETHICAL ISSUES IN ENGINEERING

Globalization shortens distance and time leading to a diverse array of engineering projects extending beyond national borders. This entails working with individuals of diverse nationalities and cultures in places that might not look, or work, like ours. Engineering students currently have less than optimal opportunities to practice, understand, even less appreciate, basic cultural differences. The opportunities presented within the American educational environment (i.e. the representation of so many different nationalities in the classroom) are not sufficiently exploited.

Thus, prejudices and assumptions lead to cultural imposition, mostly by the most dominant culture in the classroom. Kennedy states that engineering students need to be adaptable to the knowledge base that exists in other parts of the world, who also understand that our culture is not the "only one around" [11].

Understanding social issues within global markets are reflected in the various aspects of the product concept, product design, material selection and also in the respect for social norms encountered at the worksite. The unquestionable leadership of the U.S. in technology related areas has led to the misconception that what works here must work around the world as well. Engineering students are poorly prepared for the task of working in multicultural teams, and even less prepared for working in foreign environments. Ayokanmbi (2011) calls it "Global Competency" and he advocates for opportunities to study, work and conduct research abroad. He also suggests that learning a new language is paramount in developing a deep understanding of another culture and a way of reaching across cultural boundaries [9].

According to the National Association of State Universities and Land Grant Colleges Committee for International Education [12] students should possess the following skills:

a) Diverse and knowledgeable world view
b) Comprehend international dimensions in their area of study
c) Communicate effectively in another language
d) Exhibit cross cultural sensitivity and adaptability
e) Carry global competencies throughout life

International business has for long been conducted in the "unofficial" language of business: English. This has diminished the interest for American students to understand the importance of learning a foreign language. However, today engineering projects are conducted on a global basis, and the proficiency (or at least basic knowledge) of a second language would make them more productive and competitive in the global arena. Duderstadt notes, "an increasing number of companies already are searching for engineers with foreign-language abilities and industry experience in global management and team-oriented skills". This is an area in which the majority of our American engineering students remain at a disadvantage and uncompetitive compared to foreign students in the same field.

Ethics as a topic is frequently found in the business curriculum, but not so in the area of engineering. Ethics, beyond the understanding of moral principles that govern a person's or group behavior is closely related to the proper understanding of nuances in the verbal and non-verbal communication. Johnson states that the social responsibilities of American engineers as defined in the present system of engineering are ambiguous and weak [13]. Thus, it should be a priority in engineering education to form students with a solid foundation regarding the impact of their work in society. At present students are not sufficiently (if at all) exposed to the ethical and moral ramifications of the technical solutions they may propose to a given problem. It should be well understood among engineering students that the goal of engineering is not just delivering the best technical solution, but delivering a solution that is best for all, humans and nature included.

1.3 ENVIRONMENTAL SUSTAINABILITY

The U.S. with only 5 percent of the world's population controls 25 percent of its wealth and is responsible for almost 30 percent of its pollution [6]. The U.S. decision not to ratify the Kyoto agreement in 2001 could be interpreted as a disregard to environmental issues, but the U.S. is very much concerned with the wellbeing of the planet. The baby-boomers of 1946 -1964 created a society of wealth in the U.S., and any concern about the impact of their consumption on natural resources was inexistent. Today, we live in a time that condemns waste and the use and misuse of natural resources is constantly under scrutiny. In academia, sustainability issues are considered of extremely relevance for the preservation of our own life on Earth. Terms like global warming, greenhouse gases, CO2, and alternative clean energy are frequently used, but their reach, impact, and cost are not understood. It is undisputable that human activity, in particular the burning of fossil fuels, cement fabrication, clearing land for agriculture and urbanization has increased the inflow of CO2 to the atmosphere (IPCC).

Technology-based fixes concentrate on further reducing the already low emissions of developed countries, rather than reducing the increasing pollution of developing countries. For many students then, environmental concerns are frequently related to the area of clean energy, leaving concerns about soil, biodiversity, water consumption, human displacement and deforestation entirely unattended. However, these concerns are not included in engineering education and students do not learn the necessity to address the global problems that arise regarding pollution, regardless of its place of origin. Projects in engineering are mostly of technical content and do not include environmental decision-making issues or explain satisfactorily the interplay of eco-systems and their impact on human and wildlife.

1.4 LEAN MINDS IN ENGINEERING

People usually see Lean as a business tool, a technical fix, and a manufacturing thing. However, Lean is a philosophy, a way of thinking and a strategy for working efficiently and reducing waste. [14]. The philosophy of Lean can be applied to any industry as well as any area of academic studies. Many authors confirm the simplicity of this management philosophy, but they also express the incredible resistance to apply Lean concepts. Engineering students in the area of manufacturing cover to some extent Lean concepts but for the majority of other engineering areas, Lean remains an unexplored manufacturing tool.

Byrne laments that “Lean Manufacturing” as a term, has been detrimental for the acceptance of the Lean philosophy since many see it as a manufacturing tool and not as a management tool. However, Lean has an enormous wealth of knowledge to offer the engineering student. Lean stands for continuous improvement, problem solving skills, teamwork, creativity, innovation and respect for the individual. These are some of characteristics that the 21st Century engineer will need serve society in a global world. The simplicity of its main concept, reducing waste (all types of waste), is a great concept to start forming the mind of a sustainable 21st century engineer.

3. CONCLUSION

Duderstadt’s report highlights a concern stating that “we are attempting to educate 21th Century engineers with a 20th Century curriculum, taught in 19th Century institutions. Those involved in academia will certainly find his remarks well founded. We advocate for global sustainable minds, but the engineering curriculum is still of strict technical character and as Duderstadt explains in his report, there is not much difference in today’s engineering curriculum when compared with the one used a century ago. In order to create a competent workforce for the 21st century, academia must provide education above and beyond areas that might not be considered engineering related.

Engineering education could attract more students if the current curriculum offered a broader perspective to the profession than a restricted technical character it has today. Engineering professionals should not interpret the inception of “soft skills” as a reduction of value to the engineering academic program, but as a necessary improvement to it. To compete on a global basis, we need to open our minds to the skills needed in this century, and not hold on to a past that will never come back. If technology has so dramatically advanced, why not so the engineering education?
Engineering students are already at a great disadvantage compared to their foreign counterparts. All the nationalities represented at American institutions of higher education clearly demonstrate that foreign students are much more curious, flexible and adaptable to explore new environments than their American counterparts. These foreign students come with already a skill that American students lack: they speak a foreign language (and many times more than one).

American students lack of interest in learning or experiencing another culture, their fear of the unknown, and their reluctance to leave their comfort zone is making them, day by day, less attractive to global markets.

Therefore, it is imperative to give engineering students the tools they need to succeed in a global and challenging world. Their potential should not be restricted to only technical competencies, but extended to cover socio-economic, environmental, and ethical skills. It is only then, the engineering student will become the truly global and sustainable individual that our society in general, and industry in particular, is in need of.

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Regional Agreements On The Training Of Engineers Argentina In Mercosur And Latin-America

Authors: Daniel Elso Morano (1) and Marina Larrea (2)
(1) Coordinator of the Strategic Plan for Engineer Training 2012-2016 - Argentinean Education Ministry – Pizzurno 935 (C1020ACA) Buenos Aires
(2) Coordinator of Internationalization of Higher Education - Argentinean Education Ministry – Pizzurno 935 (C1020ACA) Buenos Aires

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ABSTRACT

Geopolitics has changed radically over the past two decades and has moved from a bipolar to a multi-polar world.
This has resulted in the formation of regional associations, and in our region were formed the Common Market of the South (MERCOSUR), the Union of South American Nations (UNASUR) and the Community of Latin American and Caribbean States (CELAC).
The education and practice of engineering must adapt to these circumstances and in this sense, regional or global agreements on training and quality assurance substantially equivalent are basic factors for the academic and professional recognition.
The integration of Latin-America engineering and thus the rising of the potential for development of multilateral projects is an obligation of engineers and their representative associations, because only then will the integration policies be technically viable and sustainable designed by the national states.

1. INTRODUCTION : MULTI-POLARITY AND REGIONALIZATION.

The transition from a bipolar world to a multi-polar one, the increasing incidence of world's economy on the emerging countries, the crisis in the developed world, the sustainability of the development, the environmental change and the problems with energy and natural resources among other things, are factors that have changed the geopolitics in the last two decades.

As a direct consequence, the world was arranged regionally, forming in our region the "Common Market of the South" (MERCOSUR) that has substantially advanced not only in the exchange of products but also in the services it provides.
More recently the "Union of South American Nations" (UNASUR) and the "Community of Latin American and Caribbean States" (CELAC) were created.

2. THE INTERNATIONALIZATION OF ENGINEERING

Professional practice and training of Engineering must be adapted to those circumstances and in that sense the regional or global agreements of training and substantially equivalent quality assurance are basic factors, to which the policy of academic mobility plan and the recognition of degrees for the professional practice must be founded.

From the 8th World Congress of Engineering Education, the Formation of the Engineer for the Sustainable Development (WCE) which was organized in the city of Buenos Aires on October 2010 by the Argentinean Center of Engineers (CAI) and the Federal Council of Engineering Deans (CONFEDI) and with the sponsorship of the World Federation of Engineering Organizations (WFEO), we can highlight the paragraphs below:

For this purpose, it is needed to train engineers in the required quantity, with standards of international quality and, with curricular strategies that favor the local and regional pertinence of their knowledge in order to assist with the urgent task of recognizing, identifying, and characterizing the priorities that allow the diagnosis, proposition, planning and contribution to the sustainable proposals in each of the areas that concern them.
Countries via their most powerful authorities and the multilateral organisms must be aware of it and must establish their increasing plans by education policies of Engineering and the search for early professional vocations.
Taking all this into account, we discover very convenient aspects such as the creation of spaces for Higher Regional Education, the creation of activities for research, the development and transfer of knowledge and experiences related to the necessities of the different regions, the articulation of these efforts and initiatives with social sectors, either state or economic related, the support of the quality education in its

different levels either starter or intermediate, and the introduction to the different programs for engineers' training such as the the promotion of entrepreneurial culture, the permanent reflection on the Engineer's social responsibility and the environmental and social impact of the practice of this profession.
This is a challenge that we need to take and it is a joint obligation for states, universities, social organizations and enterprises.

3. THE TRAINING OF ENGINEERS IN THE SOUTH COMMON MARKET (MERCOSUR)

3.1. HIGHER EDUCATION IN THE EDUCATIONAL SECTOR OF MERCOSUR

As an essential tool of the process of integration, it was generated in the higher education a regional academic space in the Education Sector headed by the Council of Ministers of Education.
Three major blocks of work were defined:

- Recognition: A career recognition system as a mechanism for the approval of the degrees to ease the mobility among the region; to motivate the process of evaluation in order to improve the quality of education and to ease the comparison between the training processes of academic quality.
- Mobility as a tool for the creation of a common regional space for higher education. This program is centered on projects and activities of academic and institutional matters, student mobility, a system to transfer college credits, and the exchange between professors and investigators.
- Inter-institutional cooperation: Implementation of joint actions between universities in order to develop partnership programs among undergraduate and graduate students in projects of joint investigation, in the creation of excellence networks and in the work with other levels of education in the training of professors.

3.2. CERTIFICATION SYSTEM OF UNIVERSITY CAREERS FOR THE REGIONAL RECOGNITION OF THE ACADEMIC QUALITY OF EACH DEGREE IN MERCOSUR AND OTHER ASSOCIATED STATES (ARCU-SUR SYSTEM)

ARCU-SUR is the continuation of a process with similar characteristics, called Experimental Mechanism of Accreditation (MEXA), which was applied on different careers of Agronomy, Engineering, and Medicine between 2003 and 2006 in Argentina, Brazil, Paraguay, Uruguay, Bolivia and Chile, with a total of 62 certified careers in which 19 were in Agronomy, 29 in Engineering, and 14 in Medicine.

After the experience with MEXA, it was considered convenient the installation of a permanent certification system for the quality of training in a university level among the region.

According to the Decision Nº 1708/ signed in San Miguel de Tucuman (Argentina) on the 30th of June 2008, the transcript was approved and it establishes the definitive basis of the System ARCU-SUR, according to the document *"Agreement on the creation and implementation of a certification system of university careers for the regional recognition of the academic quality of its degrees in MERCOSUR and associated states"*

These agreements are applicable to the careers of Agronomy, Architecture, Nursery, Engineering, Medicine, Dentists and Veterinary. In this case Engineering is applicable to the fields of Civil, Electricity, Electro nic, Industrial, Mechanic and Chemical.

Participants of the first call were Engineering careers from Argentina, Bolivia, Brazil, Chile, Colombia (Colombia asked for the integration to the system although it is not an associated member of MERCOSUR), Paraguay and Uruguay. On the second call, Venezuela and Ecuador were also incorporated.

On the first call of Engineering, there has been participation from Argentina with a total of 20 careers as follows: Civil (2), Electronics (5), Industrial (5), Mechanics (2), and Chemical (4).

3.3 MOBILITY PROGRAMS AND INTER-INSTITUTIONAL COOPERATION

The aim is to encourage not only the teaching and learning of the culture and the customs of the host country, but also the sense of community among students from different countries.

- Regional Academic Mobility Program for Certified careers (MARCA) – Engineering: This is the first mobility program for undergraduate students from MERCOSUR managed by its members and associated States. The aim is to exchange students from certified careers of the ASCU-SUR System, with the objective of strengthening the certified careers, encouraging inter-institutional cooperation, and reaching the target of regional integration. This came into force in the year 2006 (for Engineering careers in 2008)
- Teachers Mobility Program for partnership projects with universities among graduate courses that participate in the MARCA Project
- Pilot Mobility Programs in the European Union Support Program of Mobility from MERCOSUR in Higher Education. It is a project from the Education Sector of MERCOSUR (SEM) that emerges from a financing agreement between MERCOSUR and the European Union, signed the 16th of April 2008. One of

the outcomes of the project is the implementation of a Pilot Mobility Program in 2012, for 180 students enrolled in careers that do not integrate the ARCU-SUR System.

- University Association Program for the Mobility of Teachers of Undergraduate Courses from MERCOSUR: This is a program of mobility for teachers assembled in projects of the university association, for undergraduate careers, in careers that are not certified by the regional accreditation mechanism of Argentina, Brazil, Paraguay, Uruguay or Chile.
- Program for the Support to Joint Research Projects: The general aim of this program is to stimulate the exchange of teachers and investigators of the State Members and the members of MERCOSUR. It is linked to Excellency Doctorates Programs of Higher Education Institutions, and to higher levels of human resource training in different knowledge areas.
- Program for the Strengthening of Postgraduate Studies from MERCOSUR: The Partnership Program for the Strengthening of Postgraduate Studies is one of the strategic axes of this action. It is based on the principle of cooperation by a flexible outline of academic partnership, in which a postgraduate or a postgraduate network of academic excellence of major relative development strengthens a postgraduate or a network of postgraduates of minor relative development. This project aims to the decrease of regional inequalities that are found in Higher Education, to the support of human resource training at the level of postgraduates, to the support of research activities in deficient areas and/or vacancy areas, to the contribution of an increase of students and postgraduate teachers exchanges and to improve in this way, the quality of the offered courses.
- Program of Associated Postgraduate Centers in Brazil – Argentina (CAPG-BA): The program is aimed for the academic exchange of quality postgraduates in priority areas between High Education Institutes of both countries. The responsible entities for the coordination of the Program are: on the Brazilians side, Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and on the Argentinean side, Secretaría de Políticas Universitarias (SPU). The program promotes the exchange among postgraduate students and professors-investigators; it also seeks the mutual recognition of credits obtained in the associated institutions of this program by the co-ordination of the thesis and the co-bachelor, and encourages the exchange of integration experiences of postgraduate teaching between both countries.
- Program of Associated Centers for the Strengthening of Postgraduates in Brazil – Argentina (CAFP-BA): One of the weaknesses of the postgraduates system is the lack of homogeneity in its geographical distribution, either in qualitative or quantitative terms, generating an inequality situation in the university systems. The general aim of this Program is to create the necessary mechanisms to reduce these regional inequalities that are present in higher education, training and consolidation of research groups. Also, among its objectives include: to give support on the training of postgraduate human resources to the research activities

in deficient areas and/or vacancy ones, to increase the mobility of teachers taking advantage of the courses offered by the receptive and leading institution, and to improve the quality of the offered courses.

3.4. RECOGNITION OF UNDERGRADUATE DEGREES OF MERCOSUR

On May 2010, the meeting of the Work Group for the recognition of the undergraduate degrees from MERCOSUR was carried out in the city of Buenos Aireswith the presence of Argentina, Brazil, Paraguay and Uruguay.
To celebrate its Strategic Plan 20112015-, it was considered necessary to deep in the involvement of accreditation and join the recognition of the titles with the ARCU-SUR System.
It was defined as a goal the revalidation of undergraduate degrees in certified careers from the ARCU-SUR System and, as a purpose, the collective and regional construction of a mechanism in charge of that goal.

Together with the work referent to the construction of the mechanism for revalidation, the relative aspects to the specific professional exercise will be approached for each degree. In this way the revalidation of the degrees will be joined with the overcoming of asymmetries.

4. ARGENTINEAN ENGINEERING IN LATIN AMERICA

4.1. BILATERAL AGREEMENTS

In a bilateral basis, Argentina has signed agreements of degree recognition with Chile, Colombia, Ecuador and Mexico and in all of these cases, the recognition will be automatic for the certified careers by the national systems of accreditation, after the pedagogical panels agree and verify that the systems of training and accreditation of the signed countries are equivalent.

In all of the agreements, it is expected that the careers diplomas or degrees which count with the valid accreditation at the time of the validation request in their country of origin, will be granted for the effect of professional exercise the direct validation of the degree. In this case, the Bilateral Committee of Higher Education Experts will elaborate a list of certified careers, which will incorporate all areas of knowledge.

Thus, the governmental action, in the case of Argentina, counts with the technical support of the Federal Council of Engineering Deans (CONFEDI), due to the fact that it must be coordinated by the states, but analyzed and worked in detailed by the faculty associations of Engineering, the national accrediting entities and the professional colleges, in order to complement the national particularities with the regional vision and that the actions contribute to mutual benefits.

4.2. LATIN-AMERICAN AGREEMENT OF ACCREDITATION OF ENGINEERING (ALAI)

Although the region has similar cultural and social roots, the development of higher education had totally different realities that are now obstructing the integration.

To change this situation, it is necessary to develop a strong mobility among undergraduate or postgraduate teachers and students, along with the continuity of the official approval of careers according to the criteria and standards of each country, to encourage the diversity and the relevance of the training, and the creation of mechanisms that allow this exchange.

The Monte Alban's Declaration, which was signed after the First Latin-American Meeting about Accreditation of Engineering Programs in September 2001 in Mexico, by the representatives of Argentina, Bolivia, Chiles, Colombia, Costa Rica, El Salvador, Spain, Mexico and Paraguay, states that: "the current accreditation and evaluation systems of Engineering and the ones that are at different levels of development, in the national and international system look forward to the recognition of "substantially equivalent", such that they help the improvement of education, the professional mobility, the exchange of information and experience, and the actualization of professional and academic knowledge.

On May 2010, representatives from Argentina, Bolivia, Chile, Colombia, Guatemala, Central America, Mexico and Paraguay met in the city of Tlaxcala (Mexico) for the II Latin-American Meeting about the Accreditation of Engineering Programs and released the Tlaxcala declaration that states:

"That the activities pertaining to Engineering and Technology fields are basic factors for the sustainable development of the regions and countries that make up an important element for the improvement of the population's quality of life".
"That in most of Latin-American countries there has been a substantial progress in the implementation of accreditation processes of Engineering Programs in National and Regional levels".

"That this processes and accreditation systems of Engineering have as a common objective the improvement of the quality of Engineering's preparation, and they introduce common characteristics in the criteria and in adopted processes".
"That these national and regional efforts converge to a mutual recognition system in Latin-America that allows student's mobility and eventually enable the future bi-national or multi-national agreements of professional mobility".

"That these facts represent a great advance in relation to the obtained agreements in the I Latin-American Meeting about Engineering Accreditation Programs, expressed in Monte Alban's Declaration and that it is needed to keep working on the traced paths".

For all these reasons, it is stated that:

- It is needed to count on a structure that allows us to move quickly towards the proposed objectives in Monte Alban's Declaration.
- The richness of the diversity and pertinence in the training of professional engineers in Latin-America should be preserved.
- To achieve these objectives we commit to work in a joint way with the elaboration of a proposal for an entity, that allows to boost and reinforce the accreditation processes for the Engineering programs in the countries of the region, and at the same time it allows to facilitate the reciprocal recognition of certified programs based on internationally recognized criteria, standards and parameters of quality.

During the VIII World Congress on Engineering Education held in Buenos AiresIn October 2010, thirteen representatives of different countries signed the Latin-American Agreement on Engineering Accreditation (ALAI) which in 2011 formed its first executive committee at the meeting in Guatemala.

Members of this agreement (partners) are the organizations of Latin-American countries that have a public activity recognized by the Engineering accreditation programs in its own countries, either of governmental or private nature, whether academic, professional, or labor union organizations, and have signed the agreement by its certified representatives, which will give them the categorization of "ALAI Associates".

The most relevant areas that should be regulated by the ALAI will be, in their order of importance:

- Compatible Accreditation systems and recognition as "substantially equivalent".
- The establishment of Latin-American standards and parameters for the accreditation of Engineering teaching programs
- The exchange of pairs of raters.
- The exchange of accreditation experiences
- The participation in the recognitions of the professional mobility

The participants of ALAI are representatives from Argentina, Brazil, Chile, Colombia, Mexico, Paraguay, Central-America (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama), and The Caribbean, (Dominican Republic, Haiti and Jamaica).

The first Coordinating Committee was formed in November 2011 and it included the representatives of Argentina, Central-America, Chile and Mexico.

5. THE INCORPORATION OF LATIN-AMERICA AND THE CARIBBEAN

5.1 GENERAL SITUATION

The governments of Latin-American countries, have shown an advance in the inconveniences caused by the historical asymmetries and a stronger political decision on the achievement of integration.

Latin-America has common history, culture, deficiencies, dreams and challenges. If it acts as in union, it has an incomparable potential to take its own decisions in the search of its exclusive benefit and the benefit of its people.

Over the last decades, the institutional changes have been of a historic importance, of which we can mention:

- Consolidated democracies in every Latin-American country
- The enforcement of basic human rights
- According to the reports by the United Nations Economic Commission for Latin America (CEPAL), there has been an economical rising and a decrease of poverty and discriminationfor the first time in two hundred years of history.
- Consolidation of regional blocs as (MERCOSUR)
- Denial to the creation of the Free Trade Agreement (ALCA) in 2005.
- The establishment of the Union of South American Nations (UNASUR) aims to build a participatory and consensual area of integration and unity in the cultural, social, economic and political development among its members using a political dialogue, social policies, education, energy, infrastructure, finance and the environment, among others, leading to eliminate inequality, to achieve social inclusion and citizen participation, to strengthen democracy and to reduce the asymmetries within the framework of the strengthening of the States' sovereignty and independence.

5.2 THE ROLE OF ENGINEERING ON INTEGRATION

The development of multinational projects between Latin-American nations and The Caribbean towards achieving the essential goals for our peoples quality of life:

- Basic infrastructure and services,
- Energy sovereignty,
- Food sovereignty,
- Technology sovereignty in strategic and primary areas,
- Creation of more and better employments

It requires joint and compromised work from the Engineers of the region.
For this, it is indispensable to know each others and to trust each other in order to conceive, design, deploy and operate in multilateral projects.

6. CONCLUSION

Based on what it has been stated, it is a challenge for every country of the region to train engineers with a supranational and regional perspectives. Thus, it is necessary to consolidate and delve actions that are being developed by governments and national Engineering associations to cover every country of the region in reasonable deadlines and to incorporate this vision in the formation of future engineers and in the agenda of every engineering faculty of each university.

The general aims must be:

- To promote at a regional level a high level of convergence in the training of engineers, by common accepted definitions, of professional and learning results.
- To develop professional profiles, learning results and desirable competencies in terms of generic and relative competencies for each area of study including essential content, skills and knowledge.
- To facilitate transparency in educative structures and to foster the innovation by communicative experiences and the identification of good practices.

It is necessary to move further with the next actions:

- To increase the mobility of undergraduate or postgraduate teachers and students by the states (increasing their supports) and by the universities cooperation for making progress in reciprocal recognition agreements of academic matters. (Currently only 25% of motilities and exchanges are intra-regional).
- To increase the use of TIC's for the development of cooperative activities between universities of different countries, such as the creation of Communities of Practice, Virtual Communities of Consortium (CVC), and Virtual Working Teams.
- To keep moving forward on the mutual recognition of different accrediting agencies of each country; in a bilateral way and the evolution to a multilateral integration. These actions will allow the whole or partial recognition of studies depending on the different academic offerings of the region.
- To foster among students the learning of different languages of the region and the learning of different cultures in order to promote the professional performance on different cultural, social and political environments of the region. For this, it is needed to review the current curricula, from the perspective of the subsequent practice of the profession on the region, and to define the projects and programs that help students to understand other countries' reality.

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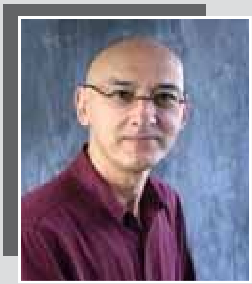
Engineering Education And The Bologna Process

Momir Djurovic[1] and Vlado Lubarda[2]

1 Montenegrin Academy of Sciences and Arts, R. Stijovića 5, 81000 Podgorica, Montenegro.

2 University of California at San Diego, 9500 Gilman drive, La Jolla, CA 92093-0448, USA.

Dr. Momir Djurovic (Ph.D., Imperial College of Science and Technology, London, 1973) is the President of the Montenegrin Academy of Sciences and Arts and Professor Emeritus of University of Montenegro. He was a consultant to leading electrical engineering companies, including Ferranti, Westighouse, General Electric, Crompton Grieves, and GEC Alhston, ISCU Asia, and organizations such as UNESCO and SMEITJ. Published numerous research papers and books, and delivered numerous invited lectures throughout the world. He is a foreign or honorary member of ten national and royal academies, European and World Academies of Sciences and Arts, doctor honoris causa,and a member of the Club of Rome.



Dr. Vlado Lubarda (Ph.D., Stanford University, 1979) is an Adjunct Professor of Mechanical and Aerospace Engineering and Senior Lecturer of Nanoengineering at University of California, San Diego. Published numerous research papers in the field of applied mechanics and four books widely used in engineering education internationally. He is a recipient of the most prestigious distinguished teaching awards from UCSD. Member of the Montenegrin Academy of Sciences and Arts, the Montenegrin Academy of Engineering, and the European Academy of Sciences and Arts.

KEY WORDS *accreditation, Bologna process, cycles of education, curricula, degrees, diversity, engineering, E-education, inflation of knowledge, life-long learning, outcomes, student mobility.*

ABSTRACT

A retrospective view on the introduction andimplementation of the Bolognaprocess in engineering education in Europe is given. The advantages and disadvantages of the Bologna process are discussed, with a particular referral to the Montenegrin experience. Several recommendations for possible improvements of engineering education within the Bologna process are suggested.

1. INTRODUCTION

Engineering education has a long tradition in Europe. A few rather different types of university engineering education could be recognized. The "German type" education was implemented in most European countries. The traditional German education system provided two distinct engineering programs having several features in common. One was offered by the technical universities and had a more theoretical orientation, while the other, taught at the Fachhochschulen, had a more applied profile. The former required typically five years of studying, enabling for research and in-depth development activities; the latter was a shorter cycle of typically four years and was meant to train production-type engineers. They were both implemented as one cycle programs. Students were supposed to get some insight into basic industrial manufacturing and develop engineering skills, as well as the appreciation for the work of others upon which they would rely on. Following the thesis work, which typically took one semester, the students would receive the *Diplom-Ingenieur* (*Dipl*.-Ing.) degree.

The engineering education in France was not much different but was more theoretical. In UK engineering education was organized mostly on the basis of three-year courses leading to the degree of *bachelor of science* or *bachelor of engineering*. Some four-year course programs have also been organized leading to M. Eng. which is equivalent to master degree. On the other hand, in some European countries, and at some point of time, the engineering education was organized in concentric cycles: two years of course work for the degree of engineer, with the continuation of another two or three years for the *Dipl. Ing*. degree (*diploma of engineering*). This practice was later abandoned.

The length of the actual study for the university degree in engineering departments was in practice much longer then the prescribed 4 or 5 years. Students were allowed to retake the exam many times, after failing the course first time, until they pass. Often, students would finish all required course work, but would remain students for much longer, even several years, to pass all exams for audited courses and complete their degree. Consequently, many argued that such a system was inefficient and expensive to run.

The master program lasted most commonly two years and was a prerequisite for the doctoral program. In Germany the *Dipl.-Ing*. was the prerequisite for the doctoral degree (*Doktor-Ingenieur, Dr.-Ing*.). The scientific work for the doctoral thesis was usually performed at the university within three to five years, and was conducted as part of research projects. In engineering sciences, the higher-degree candidates often worked on their theses as the paid departmental teaching or research assistants. In the former USSR, the graduate study was organized for the *candidate of science* (kandidat nauk) degree. This was recognized by other countries as an equivalent to master degree, but nowadays it is more commonly recognized as an equivalent to Ph.D. degree.

2. INTRODUCTION OF THE BOLOGNA PROCESS IN ENGINEERING EDUCATION

The engineering education in Europe has been greatly affected by the implementation of the Bologna Process, a major reform in the European higher education [16-]. This process is based on agreements between European countries aimed to achieve comparable standards and quality of higher education within Europe as it integrates, and to meet the growing needs for creative global competitiveness and quality assurance of engineering and other professions. The Bologna declaration was signed by the education ministers from 29 European countries in 1999. In an increasingly globalized world, the Bologna Process currently involves 47 (EU and non-EU) countries. As such, it is a global process of higher education in Europe, introduced with the expectation to facilitate higher exchange and mobility of students and academics among institutions from different countries, promote internationalization, enable less constrained employment after graduation within a broader region, continent, or the entire world, and thus contribute to overall economic growth. The Bologna Process is based on two main cycles, undergraduate and graduate. The prerequisite for the second cycle is successful completion of the first three-year cycle. The first cycle degree represents a preparation for the labor market, while the second is a graduate cycle leading to master and/or doctorate degree.

The implementation of the Bologna Process is to a large extent reflection of the modern globalization [711-]. University campuses are populated by students of diverse ethnical and cultural background, particularly in graduate schools. The faculty is increasingly diversified, as well. New international universities are being created, with large funding invested to attract the best faculty and students and compete in academic excellence with leading universities and technology institutes worldwide. Engineering education is greatly affected by the development of electronic data bases, open-access journals, and online citation indexes, such as the Web of Science, Scopus, and Google Scholar. Their availability within the countries participating in the Bologna Process significantly improves the effectiveness and quality of both education and research in these countries.

3. ADVANTAGES AND DISADVANTAGES OF THE BOLOGNA PROCESS

The first cycle, or the undergraduate engineering cycle of the Bologna Process lasts three years. It is characterized by more focused and shortened curricula, with more intensive faculty engagement in the education process. This new significantly shorter program resulted in larger number of graduates and faster graduation rates. The so-designed European higher education system became more attractive to non-European students, who are coming in increasing numbers to study at European universities (European Higher Education Area – EHEA). Furthermore, the system helps European integration, contributes to its economic and cultural growth, and thus overall prosperity. The Bologna process continues to be merged with political processes in Europe, although some education reforms, presented as part of the contemporary Bologna Process, were underway even before the Bologna declaration. The implementation of the Bologna Process has revealed numerous weaknesses. Notable among them is a diminished quality and quantity of engineering knowledge gained by students during their BS program (inflation of knowledge). This was recognized by industry and resulted in increasingly more difficult employment, as the graduates were not sufficiently prepared to successfully join the workforce. Shortening the 4 or 5 years of courses to only three years was not an easy task, and unfortunately in this process the quantity and quality of knowledge required for the work in industry was lost. Additional year of specialization offers some remedy. The M.Sc. program is most often designed as the preparation for the Ph.D. program, rather than being an enrichment of engineering knowledge towards the immediate industry needs. The loss of the old and well-conceived degree of the Diplom-Ingenieur has thus been a troubling issue for the industry from the beginning of the process of higher education reform [12]. At some universities in USA, UK, and Australia, the Professional Master of Engineering degree is comparable in its qualities with the Diplom-Ingenieur degree.

One of the major objectives of the Bologna Process was to enhance mobility among students and faculty throughout Europe, but this did not happen as expected. Within the ERASMUS program, which started in 1987, over 2.2 million students spent a term in a different country of Europe until mid-2010. More than 4,000 higher education programs from 33 countries now participate in this program. However, a study of the Higher Education Information Center shows that engineering students show the smallest interest for the study abroad, with only 16% of them studying abroad during 2009 [13]. More efficient processes are under consideration to achieve the high-mobility goals set at the beginning of the Bologna Process and to approach in quality the Anglo-Saxon system of education. Hearings in European Parliament have taken place in that direction (personal communication with D.P. responsible for higher education in the European Parliament).

The critics of the Bologna Process assert that the process does not offer the quality of the old Anglo-Saxon system of education, and that, to some extent, the Bologna Process transforms universities into "diploma factories". This is partly attributed to the fact that the Bologna Process originated from the political decisions and activities, without sufficient initial involvement of the institutions of higher education. The Bologna Process has led to student demonstrations during the Vienna conference of the European higher education ministers in 2010. Students questioned the acceptance of the bachelor in the industry, especially in small and medium-sized companies. They stated that the bachelor degree does not prepare well for the working world, that it demands too much learning matter per time, that it does not foster mobility, and that there are too few offerings for soft skill trainings[13].

4. BOLOGNA PROCESS AND ENGINEERING EDUCATION IN MONTENEGRO

Before introduction of the Bologna Process, the organization of engineering education in Montenegro was similar to German system: nine semesters of required lectures, each semester consisting of 15 weeks, plus one month for exams. The tenth semester was used for writing the engineering diploma thesis. The graduates would receive a Dipl. Ing. degree in the particular field of engineering, such as electrical, mechanical, civil, or metallurgical engineering. The actual duration of studying was on average significantly longer than five years. The Master of Science program consisted of one or two years of lecture work plus an unspecified time for writing and defending the M.Sc. thesis, which usually required one to two years. A doctorate degree did not involve taking any required lectures, but only the work on the doctorate thesis, which could take two, three, or more years.

The implementation of the Bologna Process in Montenegro began in 2007. Upon the adoption of the Process, the system of engineering education in Montenegro was radically changed. It is now offered in three cycles: 33+2+ years. The study for the Bachelor of engineering degree lasts six semesters (each semester consisting of 15 weeks, plus one week for exams). The degree of a specialist is obtained after completion of an additional year (two semesters). The study for the Master of Engineering Science degree lasts two years, after completion of the three-year Bachelor degree. This includes one year of required lectures plus the work on the master thesis. Master degree is in many ways equivalent to former diploma of engineering, but in many cases it provides a more theoretical background needed for the doctoral study. Specialist study attracts fewer students, but it provides lower level of professionalism than the old diploma of engineering. Consequently, the industry is still reluctant to employ students with such specialist degree. The doctorate program includes only the work on the doctorate thesis, which usually lasts three years after completion of the Master degree. It should be pointed out that in Montenegro, as in many other former socialistic countries which are in the process of transition, much of the industry has vanished. As a consequence, there is no much support from the industry to universities and their engineering education. For example, the contacts of students with real engineering through internships in industry have dramatically decreased or have been lost completely. The coordination or balance between the industry demands and the current supply of higher education remains to be a challenge. Further about the higher education in Montenegro can be found in [14] and [15].

5. RECOMMENDATIONS FOR IMPROVEMENTS OF ENGINEERING EDUCATION

There are many challenges facing the implementation of basic premises of the Bologna process, such as comparable or equivalent engineering curricula in historically and culturally diverse European countries. Several steps could be undertaken to improve the quality of engineering education. While the official lengths of various engineering programs are standardized, the actual contents of the courses and programs, as well as the criteria for their completion and established learning outcomes, may differ substantially. Similar or equivalent systems of quality assurance and program accreditation should be installed, preserving tradition and autonomy of universities. Specification of learning outcomes and their verification are essential for successful implementation of the Bologna Process. The comparability and equivalency of programs, with created proper interfaces, will result in easier mutual recognition of European programs. Such unification or harmonization of higher education should proceed without sacrificing the diversity, which is challenging by mere definitions of involved concepts. The success here may also prove to be instrumental for the enhancement of student mobility. Equal opportunities and accessibility of higher education must be imperative, regardless of the race, gender, social and economic background.

In addition to the M.Sc. program as a preparation for the Ph.D. study, a Master of Engineering program should be installed, providing a more in-depth engineering knowledge, emphasizing applications and skill-oriented capabilities, and directly linked to modern industry needs. Such programs have already been developed and are expanding in the engineering education in USA. The Bologna Process should incorporate additional measures to adopt other aspects of the American higher education system and establish closer relation to it [16]. For example, it would be desirable for students to give them the opportunity to study for a double-major, e.g., engineering major with a minor in mathematics, physics, biology, economics, or other field. Continuous feedback from students and alumni is a valuable source of information for the improvement of higher education. Finding adequate means to stay in contact with alumni (e.g., via email communications) is challenging but rewarding. Regarding engineering faculty, in addition to their creative research, they should be stimulated to work on the development and incorporation of innovative teaching and learning skills and methodologies.

Engineering programs should prepare students for rapid technological changes, making them able to continuously improve their skills in multi-disciplinary areas throughout their professional careers. The incorporation of various forms of life-long learning, for example through university extension programs, would provide the means for working professionals to keep track of modern engineering developments and remain competitive in the this era of fast changing and developing technologies. This could be achieved through evening or weekend classes, or through on-line interactive courses (E-learning). Engineering education must also ensure that students in their professional work deal knowledgeably and ethically with the impact of modern technologies on our society and on global issues.

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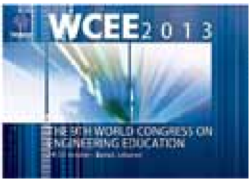

BEIRUT DECLARATION

The 9th World Congress on Engineering Education

On behalf of engineering professionals at the 9th World Congress on Engineering Education, titled “Impact of Globalization on Engineering Education”, organized by the World Federation of Engineering Organizations together with the Federation of Lebanese Engineers and the Federation of Arab Engineers, we consider that we should work towards:

1. Industry and universities establishing good relations to give students opportunities for practical training.
2. Universities emphasizing two types of research:

I. Research that can find solutions for local and regional needs.

II. Research that can advance the standing of faculty members and keep them marketable and competitive.

3. Universities and governments supporting the commercialization of innovations developed in university research laboratories, to create job opportunities for people in their own countries.
4. Engineering innovations receiving important investments to establish an industrial base. This would move the country towards wealth creation with associated engineering jobs as an alternative to a service-orientated economy.
5. Engineering ethics being ingrained in undergraduate engineering education to prepare graduates for their ethical responsibilities as professional engineers, and to help combat corruption in design, contracting, supervision and other fields of engineering.
6. An assessment of the need for a regional approach to improve accreditation and the quality of engineering education, by bringing together all the existing valuable contributors of accreditation systems.

Beirut, October 25th 2013

9th World Congress on Engineering Education

9th World Congress on Engineering Education

9th World Congress on Engineering Education
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