Changing Engineering Curriculum in the Globalizing World

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Abstract

Background: Under the impact of globalization and the coming of the Information Age, there is a paradigm shift occurring in the engineering curriculum and academic structure. Apart from the creation of new programs for the emerging fields in engineering, the approach and orientation have also been shifted from objective-based/input-based education to outcome-based education. The criteria for the new generation of quality engineering graduates have been much broadened. Engineering program structures are being revised to facilitate student mobility, and set to meet global recruitment needs.

Focus of discussion: This paper is divided into two parts: The first concerned with the general engineering education development and the second describes the developments in the European Union, the United States, and Japan.

Suggestions: To meet the new learning outcomes, approaches to learning, teaching, and assessments are revised and re-aligned. Not only have the graduates to update their professional knowledge, they should also have acquired various generic thinking and communication skills, the ethical sense of social responsibility, learning how to learn and life-long learning, knowledge of foreign language and other culture as well as authentic experience in doing research.

Conclusion: As engineering education is being internationalized, the government can keep in step with the international community by joining regional and international cooperation initiatives in engineering education. Students should be encouraged to participate in international research exchange programs. Institutions of higher learning must design new program structures, identify desired learning outcomes, determine ways to align and attain their outcomes through revising course content, provide pedagogical training for faculties, adopt a variety of teaching and learning methods, and devise appropriate assessment criteria and methods.

Keywords: Engineering curriculum, outcome-based education, globalization

全球化下的工程學課程

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摘要

*背景：*在全球化及信息時代的到來，高等教育的工程學課程和學術結構正經歷急劇改變。除了新的工程學系，工程學課程亦由過去的目標為本轉換成以學習成果為本。對新一代的工程學畢業生的要求更為廣闊。課程的改革促進學生的跨國流動性，滿足就業需求。

*討論焦點：*本文分為兩個部分：第一部分析整體工程學課程發展的情況，而第二部分則分析三個國家和地區的工程學課程發展情況，包括歐洲聯盟、美國和日本。

*建議：*在新的學習成果為本課程設計下，課程的學習、教學和評估都得重新調整。除了取得最新的工程專業知識外，學員亦要掌握各種共通能力，專業道德和責任感、學會學習和終身學習、外國的語言和文化，和實際的科研經驗。

*總結：*在工程課程步向全球化下，政府應該加強地區間和國際間的合作。學生應積極參與國際科研交流活動。高等院校則須要在課程規劃時，制定所需的學習成果和各種相關的教學和評估方法。

關鍵詞：工程學課程、學習成果為本教育、全球化

Introduction

Under the influence of globalization, international and regional cooperation among different countries, engineering education is moving towards greater mobility. Under various initiatives such as the Washington Accord, APEC, and Bologna Agreement[1] for the sake of mutual recognition of engineering qualifications, engineering curriculum is being changed accordingly. In the past, graduates in the engineering field mainly sought work in local engineering companies and expected to work in their home countries. With the range of new demands on engineering graduates, the previous engineering training is being replaced by a new one that offers a broader range of skills and knowledge, as well as a greater choice of programs and delivery mechanisms to address the changing personal and societal needs.

Much has been said about the impact of globalization, the coming of the Information and Communication Age (ICT), and how each country has prepared for these challenges. All these boil down to the production of a new generation of quality engineering graduates who are competent enough to meet industrial and national needs. So, there is a paradigm shift in the engineering curriculum and academic structure. Apart from the creation of new programs for the emerging fields in engineering such as nanotechnology, bio-medical technology, laser and information technology, to name a few, the approach and orientation have also been shifted from objective-based/input-based education to outcome-based education. The criteria for the new generation of quality engineering graduates have been much broadened. To meet these criteria, the course contents such as the program structure and graduation requirements have to be revised and the instructional design has to be made more active and interactive.

With new styles of teaching and learning, the assessment approaches are revised too. Not only are there subject level assessments, there are also program level assessments and institutional level assessments to ensure that the quality assurance is aligned and quality is maintained. Furthermore, to meet the target of becoming global engineers, engineering graduates should acquire authentic experience in doing research. They should have acquired the ability to update their professional knowledge, knowledge of foreign language and other cultures. They should have acquired various generic thinking and communication skills, the ethical sense of social responsibility, learning how to learn and life-long learning.

The engineering curriculum issue is not so country-specific and, in fact, under the challenge of globalization, engineering curricula tend to be internationalized. Engineering curricula in many countries are moving towards homogeneity. This study is divided into two parts: The first is concerned with the general engineering curriculum development and the second describes the developments in different countries/regions, namely European Union (EU), the United States, and Japan.

Development in Engineering Curriculum

In the field of curriculum, Schwab's (1978) has presented a well-known description of four key factors: Learners, teachers, content and milieu. At first glance, these factors are the players, the matter and also the scene where these two interact. The milieu, at any rate, is the ultimate driving force for curriculum change. In the following, some mega trends are identified:

Mega Trends in the Economy

In the new economy rapid, unrelenting change is the only constant. In that process of change we can identify, among other things, the following trends (Markkula, 2004):

a. Companies operate in an increasing extent in global markets.
b. More and more companies are knowledge intensive

and their business processes are based on operating within and through several global value networks in which effective knowledge sharing and collaboration are key success factors.

c. The labor market is more and more global and business operations are developed on the basis of the 24/7 worldwide concepts.
d. Knowledge work in particular is becoming multidimensional and network-based.
e. Top products and services are produced through complex systems.
f. Innovation is one of the few growing markets.

According to Peltola (2008), the following are some of the impacts of Information and Communication Technology (ICT):

a. ICT introduces new paradigms such as working clock-around, shaping own objectives, being responsible for own competence development, etc.
b. ICT introduces a possible danger for widening the digital divide and for information overload including information illiteracy and skills in filtering information.
c. Networks of universities, companies, and associations are becoming more and more important for collaboration, trust and sharing, etc.
d. Boundaries between working and learning are disappearing as engineers have to 'learn-from-work' and 'work-to-learn'.

These general trends have great impact on engineering education and working life, particularly on issues relating to changing work culture, knowledge management, ICT, productivity and innovation.

Changing Engineering Curriculum

The qualification requirements of engineering education.

The latest qualification requirements include: State-of-the-art knowledge of the related professional fields, a high level of professional competences in particular fields, the ability to accomplish scientific and R&D activities, good teamwork skills, including the ability to work as a member of international teams, the ability to perform creative engineering tasks, a capability for effective application of IT, expertise in logistics, economics, enterprise management and experience in quality assurance.

Changing concepts of core competence.

Core competence may be defined as: "knowledge (and skills) put into action in specific contexts". There are two basic types of core competences:

i. Cross competence: Innovation, management, quality, networking, customer, safety, etc.
ii. Specific competence: Identifying possible application contexts (products / processes, R&D / business administration, industry / services, Hard Ware/Soft Ware, etc.).

Constructivism as a dominant theory in learning.

A currently dominant theory in education is constructivism, which holds that knowledge is not merely a copy of reality but rather a construction built upon structures that learners already possess. Thus, the theory sees learners as active constructors of knowledge, developing their understanding through observation, reflection, experimentation and interactions with their surrounding environment that continually confirms, challenges, or extends ongoing theories or beliefs. Learning in this sense is far from what Clandinin and Connelly (1996) have described as "conduit' where knowledge is passed from the textbook into the memory system of the students.

Changing expectations of engineering graduates.

They include global outlook, generic competence, knowledge of other non-engineering subjects, and other cultures. In the past graduates of engineering courses would expect to work in an engineering company in their home country and have entrepreneurial skills. But this model of an engineering graduate is not suitable for the 21st century. Instead, modern engineering education focuses, among other things, on some generic competencies. Some of these competencies, such as teamwork, interpersonal skills, ability to work in an international team with students of different disciplines, nationalities and study levels, are of special importance. An engineer today must be able to cope with a broad scope of disciplines including economics, management, communication, languages and solid training in interdisciplinary and international teams. Many higher education institutions organize international teams of engineering students to carry out interdisciplinary projects.

Graduates also need to have a sound understanding of what is ethical in engineering, including ethical and social aspects of technology; corporate responsibility; social responsibility; environmental sustainability and human rights; development of attitude and understanding; knowledge of the foundation, properties and performance of key social institutions (including the legal and political systems) to safeguard positive exploitation and application of technology.

Important competencies in engineering.

Among the most important attributes required of an engineer graduate are ability to think critically, creativity, flexibility, assertiveness, pro-activeness, team playing, networking skills, leadership, ambitious, presentation skills, professional skills, tolerance, ability to predict, reliability, risk taking attitude, openness to new technologies, competitive spirit and knowledge.

Some basic knowledge in economics and management are important these days for engineers, as are presentation skills. Competence in foreign languages is a must, plus abilities like teamwork, good communication and leadership skills.

New criteria for engineering education curriculum.

ABET (Accreditation Board for Engineering and Technology), a major player in the accreditation in engineering education, has adopted Engineering Criteria 2000 (EC2000) in 1997. Some of these new criteria are reflected in the revised engineering curriculum.

Sustainable engineering.

Since the ABET 2000 criteria were implemented, attention has been focused on issues such as ethics, green engineering, community impact and sustainability. ABET in its 2004-2005 criteria advocates the integration and implementation of a broad education that enhances understanding of the impact of engineering solutions in a global, economic, environmental and societal context. Discipline specific criteria, such as in chemical engineering, further specify that engineers must have ``ethics, safety and the environment'' included in the curriculum.

Green engineering principles.

The following “green engineering” principles require attention in engineering education programs:

a. Environmental impact assessment in engineering processes.
b. Striving to prevent waste and use life cycle thinking in all engineering activities.
c. Conserving and improving natural ecosystems while protecting human health and well-being.

Measures to improve engineering education.

At departmental level, besides professional competence, the pedagogical competence of the professors is emphasized.

In industry, strategies can include offering real internships, paying students on internship, and collaboration with higher education institutions through seminars, workshops, and conferences at the university to approach students. The industry can also support students' ideas and projects, offering scholarships and funding research projects.

The government, on the other hand, can take initiatives in lowering taxes for industry in return for offering internships to students, more funding for research, lowering tuition fees, supporting junior enterprises, counting years of study as being equivalent to full time work, and providing free health care and insurance taxes when offering internship to students.

Changing instructional strategies in engineering.

The focus has been shifted away from the inputs--what content material is taught, to the outputs--what students can do. The following are some examples of problem- and/or project-oriented learning. An array of instructional strategies are promoted including problem-based learning, project-based learning, collaborative learning, scenario building and analysis, participatory modeling, focus groups, consensus conferencing, participatory decision analysis, gaming and simulation, etc. In order to facilitate transfer of experience, students have to move from on-campus problem-based learning to off-campus work-based learning, using ICT based platform for supporting the learning process in industry.

Internationalization of engineering education.

Since the end of the last century, higher education institutions throughout the world are busy in the realignment of their engineering programs due to the mutual recognition of engineering qualification. There are at least six international agreements governing mutual recognition of engineering qualifications and professional competence (International Engineering Alliance, n.d.). Among these agreements, three of them cover mutual recognition in respect of tertiary-level qualifications in engineering, including "The Washington Accord" (1989)," The Sydney Accord" (2001), and "The Dublin Accord" (2002). The other three agreements cover recognition of equivalence at the practising engineer level, i.e. it is individual people, not qualifications that are seen to meet the benchmark standard. These include the APEC Engineer Agreement (1999), the Engineers Mobility Forum Agreement (2001), and the "Engineering Technologist Mobility Forum Agreement (2003).

In Europe, similar mutual recognition is being undertaken through the Bologna process (Bologna Process, 2010). Under the Bologna Declaration (1999), which was adopted by ministers of education of 29 European countries, it proposed a European Higher Education Area in which students and graduates could move freely between countries, through "adoption of a system of easily readable and comparable degrees". Today, the Bologna Process unites 47 countries.

As a result of these agreements for mutual recognition and accreditation of qualification, major amendments are being taken place for all engineering programs. For each program, quality assurance, accreditation, mutual recognition, student mobility, curriculum integration and sustainability have to be re-evaluated and homogenized to one another. Linked to the internationalization of engineering education is the need to be flexible in the structure and nature of programs. Different models are promoted. For instance, there are joint degree program where degrees are issued by all higher education institutions involved. There also dual/double degree, multiple degree programs where degrees are issued by the same higher education institution. Furthermore, continuing engineering education (CEE) has become norm in the industry. Virtual university collaboration is also promoted in Northern European countries.

Research Findings in Different Countries

This section presents the key findings pertaining to the European Union, the United States, and Japan.

European Union (EU)

One of the major efforts in identifying engineering core competences developed by universities is the adoption of International Standard Classification of Education (ISCED), the classification is used by Organization for Economic Cooperation and Development (OECD), Eurostat and many other international organizations such as Teaching and Research in Engineering in Europe (TREE).

In teaching and learning, problem-based and project-oriented learning have become popular in engineering education. Over the years many very different approaches of Problem-based Learning (PBL) have been developed and are currently running with or without the PBL label (Teaching and Research in Engineering in Europe [TREE], n.d.).

In research activities in universities, a short comparison between the USA and the 'common' European educational systems, focusing on the research, showed that the American universities are more research oriented. This is due to the relationships between the industry and the universities, as well as the level of specialization. Another advantage of the USA is the fact that it is a single country, and that makes the establishment of laws and regulations easier for all the universities. Europe, on the other hand, is multi-national. So, a common framework of teaching and reaching activities is harder to implement (Wojewoda, 2006).

In doctoral studies, ministers in the Berlin Conference on 19 September 2003 considered it necessary to include the doctoral level as the third cycle in the Bologna Process and to promote the synergy between the European Higher Education Area (EHEA) and the European Research Area (ERA).The two basic models for doctoral studies in Europe are either mainly individual supervision and tutoring, or taught doctoral courses plus individual work. Graduates at all levels must have been exposed to a research environment and to research-based training in order to meet the needs of Europe as a knowledge society.

To enhancing European collaboration and increasing mobility at the doctoral and post-doctoral levels, joint doctoral programs are promoted as a further means of linking the EHEA to the ERA (TREE, n.d.).

In undergraduate research, it is agreed in general that students are probably not ready to do proper research because they lack some important skills that are only developed after some years of studies. However, it is believed that undergraduate research activity not only encourages students to continue later with PhD studies, but also provides them with technical, communication, group and research skills valuable for their career as tomorrow's engineers. The most popular ways of establishing the University Research (UR) is through a thesis, special projects conducted with the university research team, or an internship in one industrial company. The UR can be either basic theoretical studies or applied practical studies (Wojewoda, 2008).

In enhancing the attractiveness of engineering education, as with many of the technical and scientific fields taught in Europe today, engineering in general is facing a crisis in so far as the number of students opting for the subject is continuing to decrease. This appears to be a general trend across Europe, the USA, and Japan. To enhance the attractiveness of engineering for young people, especially women, the following issues should be considered: coordinated education programs, internationality of courses, research links, language support, academic support, etc. In addition, these information should be communicated to the target groups, such as local and foreign high school students (Höffer, 2008).

In promoting the pedagogical abilities of engineering teachers, university teachers are appointed based on research reputation (by research universities) or excellence in the professional field in industry (by universities of applied sciences). Pedagogical abilities are usually required in advertising a vacancy but in general these abilities are ignored in the process of appointment. To increase the pedagogical abilities of teachers in engineering education, the International Society for Engineering Education (IGIP) in its curriculum for International Engineering Educators requires education training, and practical work in engineering education (Kurz, 2008).

In alternative course structures, joint degree programs are provided. They provide students with multicultural experiences, new learning environments and better professional perspectives. New professional opportunities enable academics to obtain knowledge of other teaching and learning environments. Institutions can exchange their experience in policy and practices and develop innovative activities in an international framework. Joint and multiple degrees become more common in European engineering education. Many institutions adopt the path of internationalization of engineering education. However, a whole range of curriculum issues including quality assurance, accreditation, student mobility, and mutual recognition have to be re-structured and re-validated for every program (Dominguez, 2008).

With improvement in information and communication technology (ICT), new approach to engineering education emerges. In the last few years there has been a pan-European interest in building up virtual universities. The Open University in the UK and the Virtual University of Northern European countries are some of these examples (Peltola, 2008).

On the issue of continuing engineering education (CEE), some megatrends that affect CEE are observed in the studies of HUT Dipoli (Markkula, 2004). Engineering companies operate more and more in global markets. As work becomes multidimensional and network-based, labor markets become globalized.

USA

Engineering education curriculum in America has undergone various phases of changes, reflecting the changing needs in the changing world. In 1930s, it was based on practical application. As an applied science, engineering education in the 1930s advanced from focusing on scientific and mathematical applications to technical competence in engineering design and practical application. For quality assurance, the Engineers Council for Professional Development (ECPD) first began accrediting programs (Gibbons, 2008).

In the 1950s, it was based on theoretical understanding. In order to “keep pace with the rapid developments in science and technology”, scientific research and engineering science predominated the focus at U.S. engineering colleges. Consequently, engineering curricula also became more theoretical and technical and less oriented toward the practical applications of the past (Gibbons, 2008). In the 1990s, it was based on outcome-based education. By the 1980’s many employers reported that engineering graduates lacked the integral skills necessary for the late 20th century economy. They possessed strong science, technology, engineering and mathematics (STEM) skills, but their professional abilities were noticeably deficient compared with graduates in other fields.

By the 1990s, as in other fields in higher education, outcome-based engineering education emerged, demanding engineering graduates to be all-rounded professionals with an orientation to become global engineers. To attain these, new standards were set. In the case of America, the Accreditation Board for Engineering and Technology (ABET) produced a new set of accreditation standards in 1996 called *Engineering Criteria 2000: Criteria for Accrediting Programs in Engineering in the United States.* The new standards continued to stress mathematical, scientific and technical knowledge, while adding a new focus on professional skills such as teamwork, effective communication and an understanding of the larger social, environmental and economic impact of engineering products and design (Gibbons, 2008). To meet the changing needs of the nations as well as humanities, curriculum in engineering education has been changed. Subsequent to the changes in the goals of engineering education, the subject contents have been revised, appropriate pedagogy devised, and relevant assessment and evaluation methods designed accordingly.

On the features of new engineering curriculum, the new approach focuses on graduates' skills rather than on their required coursework. The learning outcomes, rather than the credit hours of study, become the criteria for graduation. Secondly, the programs become more open. New paradigms such as open-source and open-content, as manifested in initiatives such as Open CourseWare, the Open Knowledge Initiative, the Sakai Project, and the Google Book project, hold out the potential of providing universal access to both knowledge and higher education (Duderstadt, 2006). Thirdly, the new curriculum guideline focuses on learning outcomes rather than the courses taught.

The traditional graduate attributes include problem-solving abilities, analytical skills, communication skills (oral, written, and graphic), ability to relate to practical aspects of engineering, inter-personal skill, management skills, and decision-making skills. Additional attributes of 21st Century engineer graduates include learnability (learning to learn, on one's own), strong desire for life-long learning-continuous education, ability to work in a team, exposure to commercial disciplines, creativity and innovation, integrative skills, international outlook, ability to deploy IT, ability to work at interfaces between traditional discipline, and commitment to sustainable development.

In curriculum content, business and humanities have added in the engineering courses. Extracurricular activities have been strengthened. Internship in industry has become compulsory. To develop students' international outlook, student exchange programs have become popular.

Concerning teaching methods, new and innovative teaching methods are being developed at various U.S. universities in response to EC2000. As a whole, these are student-centred, focusing on students' learning rather than teachers' teaching. The teaching and learning become interactive and IT-assisted. For instance, the Learning Factory was a cooperative effort developed at the Pennsylvania State University with other universities. The mechanical, industrial, electrical, chemical engineering and business programs in these universities worked with industry partners to provide real-world problems for their students culminating in a capstone design course (Gibbons, 2008).

Concerning assessment methods, the "bean counting" evaluation methods are being replaced. The cornerstone of this new approach is that engineering departments create a continuous improvement process that evaluates the achievement of program outcomes and objectives. ABET evaluators no longer audit programs based on minimum standards. Instead they determine whether programs are meeting their goals based on the skills demonstrated by their graduates (Gibbons, 2008).

The consensus of all engineering stakeholders is that EC2000 has improved student learning and students are better prepared for the challenges of the 21st century economy. They have better problem-solving and communication skills and clearer appreciation of ethical and societal issues. Despite these gains, the 2004 graduates perceived no decrease in their mathematical, scientific or engineering science aptitudes (Gibbons, 2008).

In the USA, the Engineering Accreditation Commission (ABET), in its criteria for 2004-2005, advocates the integration and implementation of a broad education to understand the impact of engineering solutions in a global, economic, environmental and societal context. Discipline specific criteria, such as in chemical engineering, further specify that engineers must have ``ethics, safety and the environment" included in the curriculum. Several international professional engineering accreditation bodies from New Zealand, Australia, South Africa, Ireland and Canada have similar wording to that in the USA accreditation requirements. The United Kingdom requires that chartered and incorporated engineers must "undertake engineering activities in a way that contributes to sustainable development" (Gibbons, 2008).

Japan

Engineering education is dominated by national universities in Japan. As in India, China and Korea and unlike America, the high costs of programs in engineering and science have favored the development of the leading programs in these disciplines at national universities rather than at private universities, which have limited resources. The most prestigious of the national universities are seven institutions established during the late nineteenth and early twentieth century by the Emperor of Japan (Akiyama & Hagler, 1996).

As in Korea and China, admission to national universities is highly competitive and based mainly on the results of the entrance examinations organized by the College Examination Center. Japanese refer to the examination time as shiken jigoku, examination hell. Social and creative development of some students can be stifled.

Under the pressure of economic recession, students in Japan have to learn harder in university. The economic slow-down led to decreased hiring by business and graduates. Even graduates from prestigious schools, where job placement of graduates were once automatic, have difficulty in finding positions. Consequently, employers are less eager to invest in years of training before the recent graduates can become productive. Employers are demanding more accomplishment during the university years by the graduates that they hire. Students are thus increasingly compelled to work harder during their university years (Akiyama & Hagler, 1996).

Under the influence of internationalization, the college entrance examination in Japan includes a section on spoken English. This test reflects universities' desire that entering students exhibit improved competence in speaking and understanding English, as well as competence in reading and writing it. In the past, English classes in Japanese high schools have concentrated almost exclusively on grammar and vocabulary (Akiyama & Hagler, 1996). Besides, the Global Engineering program aggressively recruits students from overseas to ensure there are always three or four foreign students on campus (Akiyama & Hagler, 1996).

Until recently, engineering students at national universities enrolled in engineering courses only after they completed two years of general education courses. A present trend, however, is for students to enroll in engineering courses immediately upon entering the university and to meet their general education requirements by taking appropriate courses throughout their undergraduate degree programs. This trend was triggered by the 1991 decision to permit individual universities, instead of the Ministry of Education, to determine the requirements for completion of degrees. (Akiyama & Hagler, 1996).

In university research (UR), traditionally, Japanese universities have emphasized instruction more than research. Over the past decade or so, however, research expenditures and research personnel at universities have increased, although growth has slowed during the recent economic slow-down. The quality of undergraduate education is expected, nevertheless, to improve by incorporating recent research achievements. On the other hand, contract research has emerged. Recently, prestigious universities have realized 20% of their operating budgets from external sources, such as contract research (Akiyama & Hagler, 1996).

One of the main features of Japanese engineering education is that much of what, in the United States, would be considered general education is completed before entrance to the university. This allows more room in the curriculum for engineering courses. The general engineering prep courses such as calculus, physics, and chemistry are completed either in high school or through private tutoring before taking the entrance exams. Students are able to start their major course of study in their freshman year. Combining this with the year round school, effectively, it gives the Japanese student an advantage that can be numbered in years (McGuire, 2008).

The concept of groups is important to under the Japanese society. It means everyone needs an identity with, and fellowship of, a group. We can easily notice such characteristic in the Japanese universities. Within each engineering discipline, students in cohort attend the same set of courses together, and thus spend much of each day together. Friendships among classmates are formed quickly. The fraternity among engineering students is formed soon after they start their studies. In America, such opportunity to forge fraternities in learning activities and scholastic work is not readily available. In Japan, engineering classmates become life-long friends. After graduation, they are capable of networking with each other within their industry (McGuire, 2008).

Mentorship is another feature of Japanese engineering education. It is a structured system in which upperclassmen and professors are given the responsibility for mentoring the junior students. Each professor leads a research team which is built upon a hierarchy consisting of an assistant professor, five or so graduate students, and ten or more undergraduate students. The senior professor has responsibility for mentoring the junior assistant professor, helping him or her to become a full professor. While the professor and the assistant professor watch over the graduate students, the assistant professors and the graduate students watch over the undergraduate students. The undergraduate students are watched over and mentored to assure their progress. Because of the group structure, it is rare for a student to fall behind and become a failure (McGuire, 2008).

Summary: Major Changes and Trends Internationalization of Engineering Education

Under the influence of globalization, international and regional cooperation among different countries, engineering education is moving towards great mobility under various initiatives such as the Washington Accord, APEC, and the Bologna Agreement. For the sake of mutual recognition of engineering qualifications, engineering curricula are being homogenized accordingly.

New Demands on Engineering Graduates

In the past, graduates of engineering traditionally worked in local engineering companies. They expected to work for lives in their home countries, not overseas. There was no need to have good entrepreneurial skills. This no longer meets the future needs. Graduates in engineering now are required to possess generic competencies such as teamwork, interpersonal skills, and ability to work in an international team with students of different disciplines and/or nationalities. Secondly, they should have broad scope of disciplines. An engineer today must be able to cope with a broad scope of disciplines including economics, management, communication, languages and solid training in interdisciplinary and international teams. Thirdly, engineering graduates need to develop a sense of social responsibility and ethical concern, particularly in the sustainability of global engineering development. They also need to have at least a second language, and sensitivity towards cultural differences. Fourthly, they should have cross competence including innovation, management, quality, networking, customer, and safety. Fifthly, new attitudes and abilities have to be cultivated. The graduates should develop critical thinking and creativity. They should have flexibility, assertiveness, pro-activeness, team playing, networking skills, leadership, presentation skills, professional skills, tolerance, ability to predict, reliable, risk taking attitude, openness to new technologies, and competitive spirit.

Undergraduate research (UR) is a fairly new concept in engineering education; so is the continuing engineering education (CEE) which demands life-long learning to update and upgrade engineering practice.

In recent decade, credit system and transferability of credits have been developed fast in many countries. With the introduction of outcome-based education, on-campus problem-based learning has been shifted to off-campus work-based learning. Internship requirement and exchange student programs become popular.

Recommendations

1. As engineering education is being internationalized, the government can keep in step with the international community by joining regional and international cooperation initiatives in engineering education, such as the Washington Accord. Universities can modify engineering education content and structure to meet the criteria for international accreditation. Professional bodies can cooperate with and / or set up comparable agencies to ABET and others. Stakeholders can begin dialogue about the nature of higher education appropriate to prepare citizens for the 21st century world. Students should be encouraged to participate in international research exchange programs whereby they can gain experience and skills for accreditation purposes.
2. Due to a paradigm shift in teaching and learning in science and engineering programs, the government can set up accountability measures to ensure quality and funding for new modes of learning that include active learning strategies and distance learning. Institutions of higher learning must design new program structures, identify desired learning outcomes, determine ways to align and attain their outcomes through revising course content, provide pedagogical training for faculties, adopt a variety of teaching and learning methods, and devise appropriate assessment criteria and methods. Among them are outcomes-based assessment, authentic assessment, portfolio, capstone project, etc. On the other hand, universities can introduce interdisciplinary learning in the undergraduate curriculum and explore the use of case studies of engineering successes and failures as a learning tool. Besides, universities can provide opportunities for students to participate in a variety of extra-curricular activities through which they can develop their professional and generic skills, and reward those who do (e.g. academic credit, student record of achievement). They can also provide and promote continuing engineering education (CEE). Industry can provide authentic cases for problem-based learning and internship placements. Finally, government, universities and industry can work together to find ways to fund internships and research projects.

Notes

1. Washington Accord (1989) is one of the six international agreements governing mutual recognition of engineering qualifications and professional competence. Bologna Accords (1999) signed among 29 European countries to make academic degree standards and quality assurance standards more comparable and compatible throughout Europe.

References

Akiyama, H., & Hagler, M. (1996). A status report on engineering education in Japan. *FIE '96 Proceedings of the 26th Annual Frontiers in Education, 01.* Retrieved from http://fie.engrng.pitt.edu/fie96/papers/177.pdf

Bologna Process. (2010, June). *About the Bologna Process.* Retrieved from http://www.ond.vlaanderen.be/hogeronderwijs/bologna/about/index.htm

Clandinin, D. J., & Connelly, F.M. (1996), Teacher as curriculum maker. In P.W. Jackson (Ed.), *Handbook of research on curriculum,* (pp. 363-401). New York: MacMillan.

Dominguez, U. (2008). *Special interest group C5 - status of double degrees in EE in Europe. Retrieved 18 Jan 2011 from* http://www3.unifi.it/tree/index.php?l=c&s=5

Duderstadt, J. (2006). *Working draft of the quality subcommittee of the Secretary of Education's Commission on the future of higher education.* University of Michigan.

Gibbons, M. (2008). *Section 1: Recent trends in degree production at U.S.engineering colleges* (Internal Survey)

Höffer, R. (2008). *Special interest group C1 - promoting higher Engineering Education in Europe, retrieved Jan.18,2011 from* http://www3.unifi.it/tree/index.php?l=c&s=1

International Engineering Alliance. (n.d.). *Agreements covering tertiary qualifications* in engineering [Introduction]. Retrieved from http://www.washingtonaccord.org/

Kurz, G. (2008). *Special interest group C4 - promotion of pedagogical abilities of engineering teachers, retrieved Jan.18,2011 from* http://www3.unifi.it/tree/index.php?l=c&s=4

Ljubljana. (2005). Access to higher education and undergraduate research, BEST Symposium on Education, 2005.

Markkula, M. (2004). *Managing continuing engineering education (CEE) effectively, Helsinki.*

McGuire, J. (2008). Engineering education in Japan: My experience, *retrieved Jan.18,2011 from* http://fie.engrng.pitt.edu/fie96/papers/454.pdf

Peltola, H. (2008). *Special interest group D4 - virtual university collaboration,* retrieved January18, 2011, from http://www3.unifi.it/tree/index.php?l=d&s=4

Schwab, J. (1978). The practical: Translation into curriculum. In I. Westbury, N. J. Wolkof & J.J.

Spady, W.G. (2000). Thinking out of the box. *American School Board Journal,* vol. 187, no. 1, 52-53.

Teaching and Research in Engineering in Europe. (n.d.). TREE thematic network. Retrieved from http://www.unifi.it/tree/

Vygotsky, L.S. (1978). *Mind and society: The development of higher psychological processes.* Cambridge: Harvard University Press.

Wojewoda, N. (2006) *Special interest group B6 - stimulating undergraduate research,* retrieved January 18, 2011, from http://www3.unifi.it/tree/index.php?l=b&s=6

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