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Preparing Engineers for a Global Workforce through Curricular Reform*

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The advancement and accessibility of Information Technology (IT) resources, as well as the express delivery of commodities and goods, have accelerated the process of globalisation. These events have created a challenging environment for developed countries to be globally competitive and coexist in an economic environment with equally competent developing countries. The strategies being adopted by several countries are for sharing a workforce that is mobile and could be relocated without any productivity and efficiency issues. Needless to say, this dictates a serious discussion in the development of academic programmes to address global engineering. The burden of reform is usually placed on developed nations. However, this cannot be achieved unidirectionally. The future holds equitable promise and advantage for both developed and developing countries. In this article, the authors encourage all countries across the world to globalise their engineering curricula. A concept for an innovative, densely-packed, four-year undergraduate global engineering programme was developed by modifying the existing industrial engineering programme at Northern Illinois University, DeKalb, USA, by introducing a Global Engineering Emphasis (GEE) package. The GEE package includes a number of modules dealing with language expectations, communication skills, multiculturism, sensitivity issues and engineering related global issues in societal/engineering/business fields. This approach depends heavily on multinational corporations in providing summer internships, relevant case studies and projects. The GEE concept can be readily expanded to other engineering disciplines.

INTRODUCTION

A common definition of global engineering hardly exists and thus impedes the development of related academic programmes. Many people view globalisation from different perspectives. While some view it as an economic issue, others look at it as an opportunity for developing countries to compete with developed countries. It is also apparent that the term *internationalisation*, in most cases, refers to regional cooperation and that *global* means worldwide. There are also some other definitions, such as *Europeanisation*, which reflects some trends in Europe, or the *globalisation of the English language*, which defines its spread.

Nevertheless, the need for globalisation to be adopted by the engineering community is pretty obvious. Many specialists have predicted *innovation* will be the main paradigm shifter in the quest to keep the world competitive. The creators of innovations (mainly engineers) must tune up their training in order to meet the global needs and challenges. Looking at the fact that engineering education leads to one of the most portable professions, its globalisation is both practical and necessary.

Perhaps in the most desirable terms, global engineers should be able to function professionally in any country, speak the language of that country and be

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totally familiar with the dominant cultural, ethical, technical management, business practices and expectations. In addition, such a person should be able to readjust rapidly to other international assignments.

Such a definition obviously requires at least a five-year undergraduate programme in engineering with a significant number of add-ons. However, these days, any programme exceeding the *four-year* format is hardly acceptable to a majority of students in the USA. New, efficient and quality-emphasising approaches must be provided to those students interested in global engineering.

Taking into account the globalisation needs, it would be highly desirable to develop a universal degree programme in global engineering for each of the major engineering disciplines. An attempt to accomplish that goal points out great difficulties due to a world-wide differences of opinions, as well as substantial variations in the educational, accreditation and licensing systems [1].

Presently, there are several international engineering programmes in the USA that require five years. In most cases, they are combinations of the BS in engineering and BA liberal arts degree programmes, and include study-abroad requirements in engineering and languages. Recently, a study by an ASME panel on manufacturing engineering suggested the need for several modules for efficient globalisation of manufacturing engineering curriculum [2]. These were identified as follows:

- Liberal Arts (social sciences, humanities, languages);
- Business (global markets);
- Standards (international);
- Personal Management (changes and adaptability);
- Holistic Engineering Practice (systems and critical thinking).

The ASME study concluded that teaching these requirements within the confines of a four-year curriculum will be very problematic. Further, it was noted that the skills in foreign language and culture should be relegated to a fifth year and/or professional life-long learning.

After reviewing several international engineering programmes in the USA and Europe, as well as the ASME panel's suggestions, the College of Engineering and Engineering Technology at Northern Illinois University, DeKalb, USA, instituted plans to develop an innovative global engineering programme to fit within the four-year track.

Growing complexities in global engineering require experiences way beyond international experiences in design. Current global engineering tasks increasingly demand project and product management skills [2][3]. The authors of this article concluded that an undergraduate industrial engineering programme covering various aspects of logistics, forecasting, supply chains, competitive manufacturing, integration of processes, human dynamics, psychology in the workplace, human factors, etc, would provide an excellent starting background for the globalisation of engineering curricula. Some of these topics were utilised in the development of Global Engineering Emphasis (GEE) package. The introduction of the GEE package into a classical industrial engineering programme creates a new track that deals with globalisation matters. This track would require some minor modifications of the existing industrial engineering programme at Northern Illinois University, but will maintain the original number of credits. Students in the GEE track will have to accept some extracurricular responsibilities in addition to two summer internships.

The GEE track is not mandatory – it will run parallel to the classical *Industrial Engineering* track. This track can easily include other engineering disciplines by introducing one or two industrial engineering courses into the already developed GEE package and selecting appropriate summer internships and a global capstone project.

THE GEE CONCEPT

The key characteristic of the GEE concept is that it is not tied to any specific country, economic region or language. Globalisation is just too dynamic and requires flexibility in academic approaches. The GEE concept will strengthen the current Accreditation Board for Engineering and Technology (ABET) expectations regarding international issues, such as knowledge of contemporary issues and understanding the impact of engineering solutions in a global/societal context.

The GEE concept was developed within the framework of the Washington Accord (WA) and the Bologna Process (BP)/European Higher Education Area systems. These two major international accreditation consortia are respectively exemplified by the ABET and EUR-ACE standards [4-7].

The GEE package has six modules, as follows:

1. Foreign Languages (Conversational Skills);
2. Multiculturism;
3. Case Studies in Multicultural Settings;
4. Electives related to Global Engineering;
5. Summer Internships;
6. Global Capstone Project.

The degree of globalisation will depend upon the number of modules taken and completed, as well as meeting foreign language expectations. Each of the GEE modules are discussed individually below.

FOREIGN LANGUAGES

This stage is perhaps the most contentious issue in all academic programmes dealing with globalisation aspects. For visualising the range of the language requirements, we would like to mention two programmes, namely:

- The *International Engineering* programme at the University of Rhode Island, Kingston, USA [8];
- The *Export Engineering* programme (mainly electromechanical engineering) at Kaunas University of Technology, Kaunas, Lithuania [9].

The University of Rhode Island programme offers a combined five-year BS/BA programme with the BS in a selected engineering area and the BA degree in selected language (German, French, Spanish and soon Chinese). The combined BS/BA programme has also study-abroad semesters in engineering and languages. The Kaunas programme is an eight-semester programme with four separate language tracks. Each track is taught in its entirety either in German, French, English or Russian. The language preparations come primarily from high school programmes, which require one or two foreign languages. The students enrolled in this programme supplement their conversational skills with a short course dealing with the *engineering side* of the instructional language. They are also expected to acquire conversational skills in non-instructional language outside their track – English is preferred in most cases. Depending on the knowledge of languages, some waivers are possible.

By now, the English language has become the primary means of international communications in engineering education, multinational corporations and trade circles [10][11]. Along the same lines in the Netherlands and Scandinavia, there is an increasing number of engineering and business programmes taught in English. In international student exchange programmes, many overseas universities offer engineering instruction in English in addition to their home languages [12]. In many countries, including those in Eastern Europe, the English language is rapidly becoming their second language. A similar observation was made by a multinational corporation that operates 100 divisions in several continents [13]. Currently, about 40% of the world's population outside the technical communications domain have varying degrees of command of the English language. Reflecting these ongoing trends, sources cited in ref. [10] have coined a very interesting term – *the globalisation of English*. Considering these trends during the development of the GEE concept, it was decided to supplement the widely accepted international communications in English with a conversational knowledge of some key foreign languages. It also acknowledges that languages will require a lifelong process of being updated.

The conversational knowledge of at least one of the widely used key languages could be acquired at home (ethnic backgrounds), high school language programmes and extracurricular courses, then later honed during summer internships and interactions with international student groups. High school students will be informed early on about the requirement of conversational skills. In these matters, the University's multilingual engineering faculty could evaluate, advise and assist the GEE track students.

MULTICULTURISM

At Northern Illinois University, all students are required to take at least six courses in humanities and the arts, social sciences and interdisciplinary studies. From that group of courses, the GEE students will have to select at least three courses dealing with the multiculturism, contemporary social institutions, contemporary moral issues, cultural sensitivities, etc. Case studies (see below) and seminars offered by the multicultural faculty and collaborating multinational corporations further emphasise the importance of the same topics. In addition, all the GEE students will be encouraged to join the international students' groups, and interact with its members and advisors.

Multicultural aspects constitute a very critical part of global engineering. With English being the primary language in communications, the ability to function in multicultural settings and different value systems may often be much more important than a complete knowledge of a regional language.

CASE STUDIES IN MULTICULTURAL SETTINGS

The case studies will be selected to represent the current technological, managerial and multicultural interfaces or issues within the context of global engineering.

Many of the multinational companies involved in the programme have representatives on the University's college and departmental advisory boards. Their human resources and corporate engineering staff will

be engaged in these activities. It is anticipated that the case studies will touch on a very successful Danish multinational model used in integration the acquired companies and suppliers, where the corporate management sets the common goals to divisions located throughout the world [13]. At the same time, all divisions have to devise methods appropriate to their own practices to reach the common corporate goals. Some divisions, being in very different cultural settings, will also have to develop new interdivisional methods or a *third culture* in order to work and communicate among each other.

Caspersen notes that cultural challenges for engineers moving in a global setting are largely not met [13]. He also points out that only a very few engineers had opportunities to have multicultural experiences during engineering studies. These authors are convinced that the GEE concept will correct this much needed shortfall.

ELECTIVES RELATED TO GLOBAL ENGINEERING

In the undergraduate industrial engineering programme with the GEE, three of the original technical electives will be replaced with same number of new electives. This exchange of courses will not affect the ABET accreditation requirements – it should be viewed as the courses expanding the vision of engineering in a global setting. These elective courses will be designed to reflect various important aspects of globalisation and taught, as applicable, by the Colleges of Business, Engineering, Health and Human Sciences and Law.

The three new elective courses could be selected from the following:

- Global Entrepreneurship;
- International Standards and Quality Control;
- From Idea-to-Product and Patent Law-International Implications;
- International Safety and Labour Laws;
- E-Commerce and MIS for an International Enterprise;
- Global Health Care Systems-Engineering Support.

All non-industrial engineering students who are enrolled in the GEE track will be required to take at least one-to-two courses in industrial engineering dealing with logistics or design for manufacturing – in addition to the above-mentioned three electives. Some online courses offered by professional organisations could replace or supplement some of these electives. One such organisation is the International Engineering Consortium, which covers the areas of IT, computer engineering and electronics [14].

SUMMER INTERNSHIPS

The GEE students will be required to participate in two summer internships (at the end of the second and third academic years) with multinational companies within the USA or abroad. By this time, all the GEE students must have acquired conversational skills in one of the key foreign languages. During their summer internships, one joint international design or manufacturing project would be initiated, continued and completed. This project, if necessary, could be initiated and completed by employing various telecommunication means. Each party will write all progress reports and the final report in the language of participating partners, as well as in English. In addition, the GEE students will be involved in the academic capstone project.

The Office of Cooperative Education/Internships will work with the University's partnering multinational corporations in providing meaningful international experiences during summer internships. In the past, the College's engineering cooperative education students have been placed in many countries. With an increase of Spanish speaking students in the College, internships in Latin America have been expanded.

GLOBAL CAPSTONE PROJECT

In line with the ABET's requirements, all GEE-track students will have to participate and complete their capstone project. The capstone project, if approved, could be based on extended variations of the summer internship projects. New projects could also be provided by multinational companies. In most cases, the global capstone design projects will be team projects with partners abroad. In some of the projects, students from regular engineering (non-GEE) engineering programmes could also participate. In these team projects, the GEE students would take the leadership or facilitate the group work.

In general, the global capstone projects will be selected to relate to engineering design for manufacturing in a multinational environment with a focus on automation, economy and mass production, logistics and telecommunications.

IMPLEMENTATIONAL CHALLENGES AND ISSUES IN AN INDUSTRIAL MULTINATIONAL ENVIRONMENT

The GEE model proposed in this article strongly depends upon the participation of multinational industrial partners because of their capability to bring real life global projects into the classroom. Their participation is also

important because of their understanding of cross-cultural and intercontinental issues as they relate to engineering and business practices. This collaboration will be of mutual interest to corporations as they will be able to evaluate a new kind of global engineers.

Figure 1 depicts a hypothetical model of a multinational corporation. It also outlines various relationships and connections that could exist within a multinational corporation. In general, the further the philosophical distance from the Headquarters' Corporate Culture (HCC), the higher the barriers and obstacles will loom in implementing global issues and developing satisfactory interactions with the units.

A unit in Figure 1 is defined as a corporate division or supplier. A multitude of units could operate at the same Unit Operational Culture (UOC) level. Unit interactions at various UOC levels depend upon on similarities or differences in language communication skills, cultures, customs, value systems, and the acceptance of globalisation and overall corporate goals. These elements will obviously influence all operations.

For example, units operating within, or at, the UOC1 level will have similar language skills, cultures, customs and value systems to HCC. In theses situations, there will be easily-developed natural interactions with the headquarters. The UOC2 level units may have moderate differences from the same operations-influencing aspects found at the UOC1 level. Here, the UOC2 level units have to work harder in order to establish satisfactory operational interactions with the UOC1 level units and headquarters.

Various degrees of challenging operational situations could occur at the UOC3 level. At this level, there could be significant differences from the operations-influencing aspects found at the HCC, UOC1 and UOC2 levels. Here, assistance and encouragement has to be provided in order to move the UOC3 units to better performance levels. It can be easily visualised that engineers with GEE education and an understanding of the influencing issues will be invaluable catalysts.

The model depicted in Figure 1 and the Danish experiences were considered in developing the GEE concept [13]. In this concept, a significant number of multicultural courses, global engineering related courses and case studies with multicultural issues were introduced. It is important to note that the GEE summer internships can take place at any UOC level

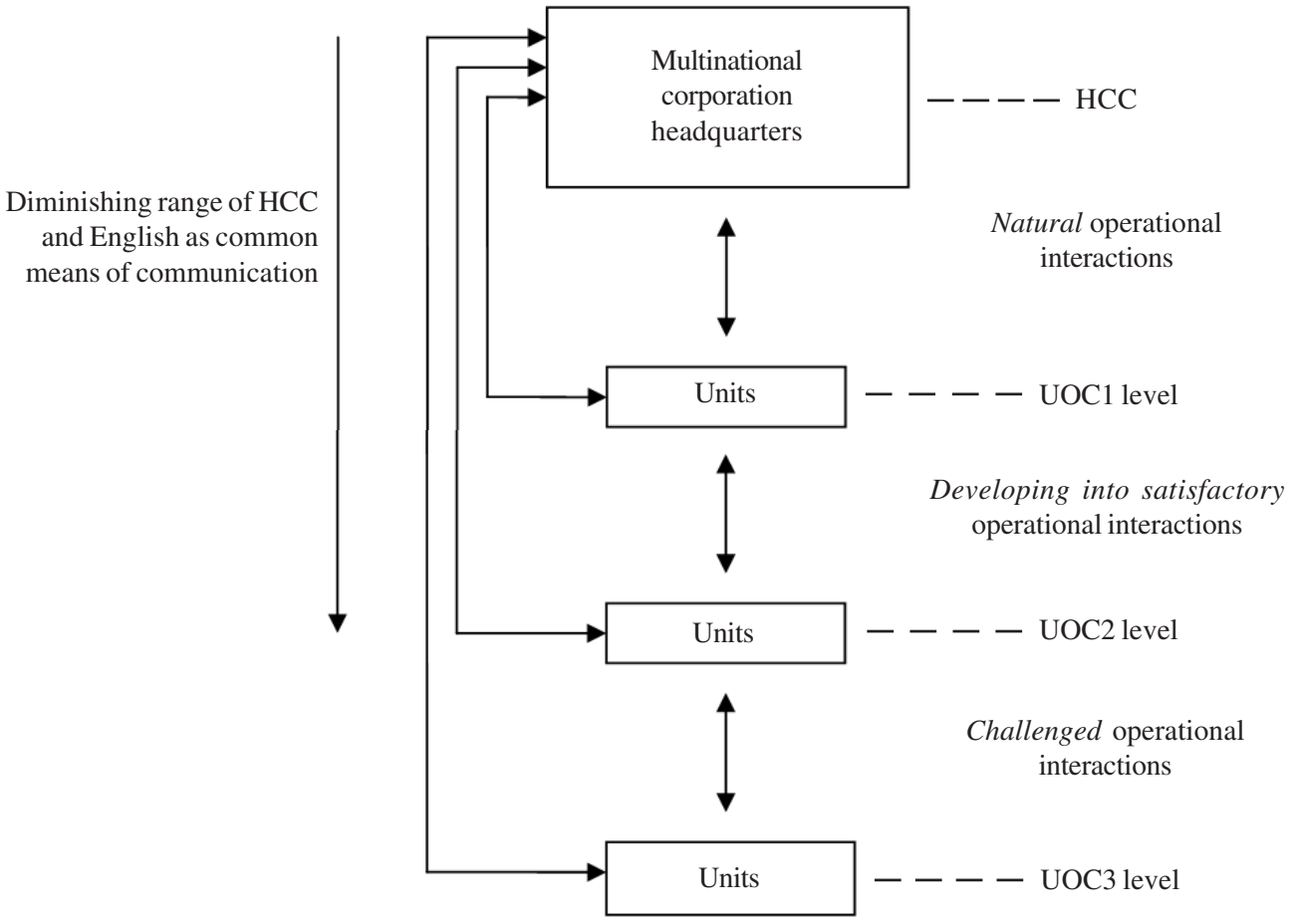

Figure 1: A hypothetical operational model of a multinational corporation.

or a combination thereof. The global capstone projects could also be selected from a variety of units. The GEE-track students and graduates should have sufficient training to work at various operational levels within a multinational corporation.

RESPONSIBILITY OF DEVELOPING COUNTRIES

Even though globalisation will benefit all countries in the long run, it is apparent that, in the short term, developing nations can benefit from other countries due to outsourcing, technology transfer and economic stimulation. It will not be out of place to make a sincere request to developing countries to seek parity by reengineering their own curricula to include concepts of globalisation and develop partnerships with students, faculty and universities in technically advanced countries. Equally important is placing students or graduates with multinational corporations. The IT community has witnessed international and worldwide placement of personnel in the beginning of this millennium, but the engineering community still has to experience a surge in other areas. There are several cases of joint partnerships and offshore research/production set-ups, but a true exchange of engineering professionals in the global environment is yet far from being abundant.

SUMMARY

In general, the global engineering must be viewed as a team-based, application-oriented and IT-supported undertaking.

A densely packed innovative concept within the undergraduate programme in industrial engineering is defined to address those issues associated with global engineering. However, this concept can be also easily applied to other engineering disciplines with minor modifications.

Most of the GEE modules described here are sufficiently general to be applicable to other engineering disciplines. A proper selection of summer internships, global capstone projects and technical electives should address the majority of globalisation issues in specific disciplines.

Students planning to enter the GEE track should commit in their minds to complete all of the GEE stages. Conversational foreign language skills should be acquired in high schools. This is an added responsibility to those students intending to enter the GEE programme. This expectation should be emphasised by high school counsellors.

The degree of each student's globalisation in any engineering discipline will depend on the number of the GEE modules completed. In general, highly motivated students will do well in their studies and internships. Taking into account the proper scheduling of courses and summer assignments, the densely packed GEE structure should fit within the four-year framework of the basic industrial engineering programme. Students, especially if they hold part-time jobs, could select a slower pace. It is estimated that the GEE concept will introduce about one year of solid global experience into engineering programmes.

It is anticipated that graduates having completed all GEE track requirements will have an excellent start with multinational companies. GEE graduates should function equally well in the conventional MS and PhD programmes in engineering. In addition, with their backgrounds, GEE graduates could decide to enrol into international graduate programmes in management and business, and then continue in those tracks.

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BIOGRAPHIES

Dr Promod Vohra, who migrated to the USA from India in 1986, holds two degrees in electrical engineering and a doctoral degree in instructional design and development. In the majority of his academic career, has been dedicated to addressing the cultural and social needs of international students migrating to the USA for pursuing opportunities in higher education. As the Dean of the College of Engineering and Engineering Technology at Northern Illinois University, he feels that the need for a globally competent engineering workforce is stronger than ever and systemic interventions need to be made in existing programmes in order to accomplish this goal. As an active member of the UNESCO International Centre for Engineering Education (UICEE), he feels that the forum provided by UICEE is ideal to initiate this dialogue and establish intercontinental partnerships.

Romualdas Kasuba, PhD, Dr Hon, PE is dean emeritus and professor emeritus in the College of Engineering and Engineering Technology at Northern Illinois University. He served the College as the founding dean since its inception in 1986 to 2003 when he retired. He is also an international member of the Lithuanian Academy of Sciences. Now, with colleagues in the College and in Europe, he is involved in international engineering education projects.

Divya Vohra is currently working as an industrial engineering supervisor for United Parcel Service. She received her bachelor's degree from Northern Illinois University in industrial engineering and graduated Alpha Phi Mu in spring 2005. She is currently a graduate student pursuing a Master's degree in industrial engineering at Northern Illinois University. She strongly believes that the industrial engineering programme is the best suited programme for the global needs of an engineering skilled global workforce. Widely travelled, she has studied different systems and is optimistic about engineering programmes in the USA and other parts of the world that address the technical workforce needs of the world through curricular reform.