Global approaches to teaching global design: stakeholders, programmes and assessments

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ABSTRACT: Engineering is becoming highly globalised in nature and graduating engineering students can expect to work in multicultural teams for multinational organisations in overseas locations and in virtual global teams. Hence, economic and cultural globalisation must be a focal point for training engineers. In this article, the authors address the curricular development issues raised when developing global engineering education programmes. A simple closed-loop model is used to show stakeholder values driving programme design and assessing programme outcomes to meet the needs of the stakeholders. The primary stakeholders of global engineering education include industry, students, faculty, universities, society and accrediting boards. Stakeholder values are addressed in the article, including a discussion of several programmes that has been implemented in order to realise the interests of stakeholders. Examples of programmes that have been implemented include virtual global design teams using information technology, short-term industry tours and global work internships. Less developed are the assessment methods that are needed to close the loop; initial efforts and future directions for these are also presented.

INTRODUCTION

> *Engineering is global, and engineering is done in a holistic business context. The engineer must design under constraints that include global cultural and business contexts – and so must understand them at a deep level. They too are the new* fundamentals.
>
> Dr William Wulf
> President, National Academy of Engineering

INTRODUCTION

The opening quotation by Wulf is typical of exhortations from leaders in engineering education over the last decade. In the USA, the Accrediting Board for Engineering and Technology (ABET) has also included similar prescriptions for engineering education (*cf*. ABET2000 Criterion 3h: …*understand the impact of engineering solutions in a global and societal context* [1]).

In this article, the authors wish to address the curricular development issues raised by these leaders via the use of a simple closed-loop model of stakeholder values driving programme design and assessing programme outcomes to meet the needs of the stakeholders (see Figure 1). The authors posit that the stakeholder values are fairly clear (although there may be some arguments as to which are most important). Programmes have to realise the interests of the stakeholders. Less developed are the assessment methods that are needed to close the loop.

THE GLOBAL CONTEXT FOR ENGINEERING DESIGN

Global Pressures on Engineering Design Education

Engineering is clearly becoming global in nature. Engineers can expect to work in multicultural teams for multinational organisations in overseas locations and in virtual global teams. In both real and virtual collaborations, engineers will be working with, and in, a varied milieu with different technical norms, standards and procedures, and in different cultures and languages [2]. Economic and cultural globalisation now must be a focal point for training engineers and in 20 years, global engineering will be almost all we will do; but the question is, *what should global engineering design education look like today*?

The changing nature and scope of the global economy is characterised by emerging patterns of corporate structure that are both more diverse and more distributed in order to take advantage of global technological diversity and for global market penetration. Global design and production now uses a 24-hour world clock in performing design and manufacturing tasks in all time zones. The regulatory environment is the complex intersection between national and international practices and standards in engineering. However, along with difficulties associated with mixing many languages and cultures come the benefits of diversity in new ideas, new perspectives and new needs.

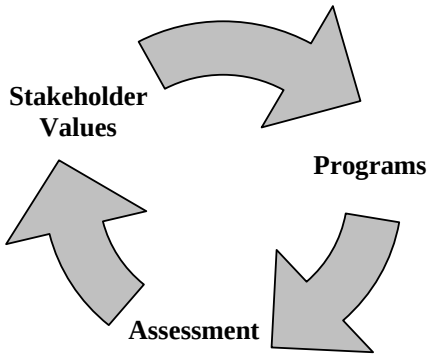

Figure 1: Closing the loop in global design education.

GLOBAL ENGINEERING EDUCATION STAKEHOLDERS

The authors' regard the major stakeholders in global engineering education (GEE) to include industry, students, faculty, universities, society and accrediting boards (such as ABET in the USA). It is constructive to consider what the goals are of these stakeholders and how each derives value from GEE programmes.

Why Industry Values GEE Programmes

Global engineers are necessary for managing a corporation's global enterprise and are necessary for increasing a company's market share in the global economy. Furthermore, global engineering enhances a company's intellectual, social and business capital. Given these needs, any global engineering education that takes place prior to graduation and the first job can reduce *in-company* training for new hires [3].

Why Students Value GEE Programmes

Students see global experiences as *cool*, exciting and intellectually stimulating, but many also want to make a difference in the world. They also see the material benefits of a globally competitive résumé, better starting jobs and salary, and better (lifetime) career potential.

Why Faculty Value GEE Programmes

While faculty, like students, also see global experiences as exciting and see a chance to make a positive difference in the world, they can see, too, that it can be intellectually stimulating and lead to the advancement of knowledge. It can help them remain relevant and competitive in their careers, and maintain and invigorate connections with associates around the world and industry that is globalising ahead of them. Indeed, many faculty now believe that engineering education, research and professional networks will be largely global rather than purely national in the future.

Why Universities Value GEE Programmes

US universities value international student enrolments very differently to the way that they value US students engaging in global education programmes, such as study abroad. The main reasons why universities value international student enrolments are income, talent in technical fields needed by faculty and by employers and diversity. Also, on the material side, universities see GEE as a potential research funding multiplier as collaborative research proposals from multiple universities in multiple countries seem to be especially solicited from funding agencies.

Universities are major stakeholders since international students contribute nearly US$12 billion to the US economy in money spent on tuition, living expenses and related costs [4]. Nearly 75% of all international student funding comes from personal and family sources or other sources outside. The US Department of Commerce data describe US higher education as the country's fifth largest service sector export [4]. Many universities now have active recruitment programmes that are based on an economic rationale, as much as a desire to diversify the campus.

These students help diversify the universities they attend, but that picture has a distinctive character. Asian students comprise over half (51%) of all international enrolments in the USA, followed by students from Europe (13%), Latin America (12%), Africa (7%), the Middle East (6%), and North America and Oceania (5%). Thus, while international students do enrich US universities with talent and diversity, upper income Asian students tend to define that diversity. Taken as a per capita representation globally, these figures are fairly representative by region, if not by social class.

Unfortunately, while university cultures positively influence global education programmes, universities do not have the same material incentives for globalising the education of their own students that they do for attracting incoming international students. Moreover, they are faced with helping their students overcome obstacles of inertia, cost, time to graduation, logistics and foreign language abilities. They tend to do it to help with marketing their universities to prospective students and because of faculty initiatives.

Why Society Values GEE Programmes

Society is a very general concept, but it can be supposed that GEE is widely perceived as promoting individual and social well being. One might also hope that GEE promotes cultural understanding and peace through its integrative effect on professionals across national boundaries. GEE should also develop an understanding of the world, its peoples, its resources and its markets, leading to more informed policy making.

Why Accrediting Boards Value GEE Programmes

Facing pressure from industry, accrediting boards are requiring that engineering graduates understand the context of their engineering education, not just the technical material. One such context is the impact of the global marketplace on engineering solutions. Hence, universities are encouraged to internationalise their curricula to provide that global context.

GLOBAL ENGINEERING EDUCATION PROGRAMMES

The Global Climate

Heightened fears of foreign travel and tightened visa restrictions have led to a pause in the long-term upward trend in international student travel. In several countries, new restrictions have placed additional resource burdens on university programme officers via extensive new requirements, such as Student & Exchange Visitor Information System (SEVIS) in the USA. Despite these negative pressures and a real drop in applications, the number of international students in the USA in 2002-2003 still showed a slight increase (less than 1%) over the prior year, bringing the total to 586,323 [4]. Similar slowdowns have happened seven times in the last 20 years, suggesting that this was not unusual [4]. The sector worst hit was Intensive English Programs (IEP), where intake dropped 35% from summer 2001 to summer 2002; visa delays and denials were blamed for most of it [5].

However, within overall student numbers are major shifts, such as a 14% increase of students from India offsetting a 10% decrease of students from the Middle East [5]. One interesting finding is that, in autumn 2003, almost half of the institutions responding to a survey from the Institute of International Education (IIE) found falling foreign student enrolments, yet 54% reported stable enrolment or increases [5]. This clearly indicates both that university resources and programmes can make a difference and

that the upward trend in international student enrolments will continue if conditions do not change again.

Although reporting data for a year earlier than the above, the IIE reports a robust 4.4% increase in US students abroad in the 2001-2002 academic year, although not as high as the previous year's 7.4% increase [6]. Since 1991-1992, the number of students studying abroad has more than doubled from 71,154 to 160,920. The IIE further reports that campus professionals reported in autumn 2003 that the number of US students studying abroad is still rising strongly, and significant increases in the 2001-2002 data for students travelling to countries like China, Japan, the Czech Republic, South Africa, Brazil and Thailand.

Recent global political crises notwithstanding, the conclusion appears to be that the flow of students internationally continues to grow both into and out of the USA.

The Virtual Alternative

The appeal of virtual education experiences, such as cross-national design teams, or lectures and discussion by overseas engineers and faculty, appears to be rising. As in the corporate and government worlds, information technology (IT) greatly cuts the costs of travel in time and money plus any perceived risks of travel. In education, it allows for scaling up to include far greater numbers of students and even promotes interest in real travel. In any given programme, both real and virtual elements can be present: again, as in the worlds of corporations, non-profit organisations and governments. Virtual work is not as easy as it sounds and the two biggest problems are logistics and collaborative technologies that are negatively and greatly affected by firewalls and other security measures. Nevertheless, virtual collaborations must have a role in the future. Examples of programmes that may be co-located, virtual or mixed are described below [2][7][8].

Constructing Cross-National Design Teams

Some authors have adopted a typology approach with a few key options for constructing cross-national teams [9]. However, the authors believe that a parametric approach is more suitable for dealing with the very high number of options available. Seven logistical parameters that characterise the construction of cross-national team(s) shall first be delineated, as follows:

- Node frequency: bi-nodal; tri-nodal; or more;
- Relationship type: collaborative (continuous, inter-dependent, integrated); competitive: inter-corporate (multinational teams) or international (national teams); cooperative (occasional sharing): show and tell, or parallel;
- Status relations: equal partners; *sub-contracting* mode;
- Languages: mono-lingual or multilingual;
- Curricular structure: in class (multiple teams) or out of class (single teams);
- Duration: expository; short-term; long-term; indefinite;
- World time: compatible (within ±2 hours); manageable (within ±3–6 hrs); difficult (within ±7–8 hrs); impractical (not impossible) for real time (within ±9–12 hrs) [2].

The number of parameters – and the number of values each parameter may hold – implies that there is a very large number of combinatorial possibilities. This leads to the questions: *What are the objectives of the stakeholders for such teams?* and *which modes are most attractive for attaining them?* Answering such questions are necessary for carrying out assessments on such teams and such assessments will, in turn, help to answer those questions in a continuous iterative process.

Using a Consortium Approach

Pennsylvania State University (Penn State), University Park, USA, originally began its GEE programme via a bilateral relationship with the Institut Universitaire de Technologie (IUT), Bethune, France, which dates from 1994, but the cross-national teams and student internship programme only began to grow with funding from Alcoa from 1998 onwards [10-12]. The global internship programme is now a Penn State College of Engineering programme that sends and receives 15-20 students each year [13].

However, there were constraints in working with two universities and two countries; this was expanded to a seven-university and four-country consortium, called Preparing Engineering Students for Work in the Global Economy (Prestige), which is based on advancing global design education while also preparing engineering students for the global economy [14].

In the USA, the Prestige Consortium consists of Penn State (lead), Arizona State University (ASU), and the University of Washington. In Western Europe, the partners are the University of Leeds (lead), École Centrale de Lyon, IUT-Bethune and Tecnun (Universidad de Navarra). The consortium's main objectives are as follows:

- Focus on global product design and development;
- Develop Web-based resources for teaching engineering design;
- Run cross-national design teams;
- Support student travel for study and work in internships in foreign industry and design projects on foreign campuses;
- Support faculty travel for opportunities in teaching and research;
- Develop materials in three languages, namely: English, French and Spanish;
- Share ideas among the faculty and promote specific collaborations in education and research including the development of further funding and publications.

Collaborative Technology: Firewalls and Toolboxes

As noted above, getting and keeping collaborative IT working is difficult. It is easy to find exponents of the way IT is transforming work in inter-institutional and international settings, but in practise, it is hard to find collaborative tools that negotiate firewalls seamlessly – or at all!

A small R&D computer laboratory – a design collaborative *sandbox* – has been established in the least restrictive, and best supported, network environment that was able to be found so that ways to develop and deploy the best collaborative tools could be explored. An dedicated server is being experimented with for TCP-IP audiovisual (AV) conferencing, with peer-to-peer technology (P2P) and with the most used technique: finding a network technician who will *lift* the firewall when the collaborative technology is in use. One graduate and several undergraduate students help run the sandbox. Wireless laptops

that run on the same network have also been added, giving a *nomadic* extension to the sandbox.

The sandbox is so essential to virtual and global programmes – unless one have a dedicated university unit supporting you – that its features are identified here.

A prime sandbox objective is to establish support research in the role and use of IT in the design process and the way that design is taught. Further, the sandbox is to be used for the development and exploration of the technology needed to effectively run distributed design collaborations.

Sandbox technology incorporates the following:

- Three multimedia PCs with USB cameras and one PC server;
- One PC outfitted with PicTel capable of transmitting DVD/VHS video and document camera feed;
- Four laptops with wireless capability;
- All-in-one printer/copy/fax machine;
- Digital sender.

The sandbox utilises the following elements:

- Test software, protocols, methods of interaction, etc, for point-to-point and multipoint collaborations;
- Test software and procedures locally before involving partners;
- Support distributed student design teams, such as FEGI via sandbox technology [15].

Sandbox software includes the following: *MSN Messenger*, *SolidWorks* (CAD), *Alibre Design* (P2P CAD), *Groove* (P2P), *MS Project*, *NetMeeting* (multi-point), *Yahoo Messenger*, plus others

ASSESSMENTS

The universities, faculty, and students who generate, run, and participate in GEE programmes are usually driven by their interests and visions. As such, they are not so much interested in assessing the programmes as they are in realising their dreams. Nevertheless, GEE programmes require funding to grow and funding sources generally require assessments that show the value and impact of the programmes. These assessments should take into account the values placed on GEE programmes by the major stakeholders.

Types of Assessments

Some of the types of assessment methods being employed, or that have been considered, include the following:

- Student reports, presentations and surveys (ie customer satisfaction).
- Scientific investigations employing pre- and post-surveys with universal instruments or experimental methodologies using experimental and control groups.
- Industry feedback, which may be anecdotal or obtained through a systematic survey.
- Student global programme enrolment numbers, which may be an indicator of feedback from past student participants.
- Funding support levels from the universities supporting the programmes and/or from industries that are anxious to globalise engineering education, which may be an important indication of satisfaction by those stakeholders, but it may not be based on existing programme performance and the causes should be investigated.
- Learning portfolios: a very time consuming, if admirable, way to document a programme's effectiveness (see discussion of the Student Tracking System below).
- Anecdotes, while much disparaged, may nevertheless be used to illustrate the more general data with a human face. They are much appreciated by programme funders who use them in presentations. Also, they sometimes produce insights not obtainable in any other way.
- Global professional network wherein students develop a global network of friends and professional contacts.

Three types of assessments are described in more detail below. The types of programme outcomes that can be assessed beyond *it was so cool* are first discussed, even though the pleasure of participating in such programmes is very important. This is followed by a discussion of an online student tracking system developed to provide very good databases for student assessments, anecdotes and reports on their experiences. A comparison of the value for real and virtual global education experiences is also given.

GEE Student Outcomes

A partial list of the types of outcomes from participating in a GEE programme include:

- *That was cool!*
- Increased competitiveness in the job market;
- Cross-cultural fluency;
- Communication skills;
- Realisation of the benefits of diversity;
- Globalised technical knowledge;
- Adaptability to new environments;
- Awareness of relevant factors in the global economy;
- Disposition to work collaboratively in the global economy;
- Ability to place engineering knowledge technology issues within a social and global context.

There is a need to know at what level students possess these outcomes prior to engaging in GEE activities (pre-assessment). Some students may come with many global experiences through having lived abroad, having foreign-born parents, participating in study abroad in high school, etc. Others may have little or no prior experience. However, even those students who are quite experienced may find they learn a lot or experience a different facet of the global economy than before they participated in a GEE programme.

In terms of developing GEE programmes that work and can be disseminated, there is a need to compare the outcomes of different programmes to determine what works, what does not, and what needs tweaking. To do this most effectively requires the use of similar (if not the same) assessment methodologies between different programmes. Unfortunately, existing tools are quite limited and/or dated. In addition, any assessment plan needs to be able to address all of the specified outcomes, which may require a number of tools to be used. In order to increase the reliability and validity of the assessment results, it is important to use different assessment methods, since each might be better at obtaining at a particular facet.

Global Student Tracking System

One of the tools being developed to assess the GEE programmes is a Web-based Global Student Tracking System (GSTS) (see Figure 2). This system is password-accessible via the Web and provides different levels of access for facilitators, students, industry mentors, etc. The system collects information on the following:

- Contact information for students for all locations plus application material and details of placement;
- Assessment log entries at initial application, prior to departure, two weeks after arrival, six weeks after arrival and at departure;
- Final student reports on programme experience;
- Assessment entries that focus on objectives, problems, successes and satisfaction levels (numerical).

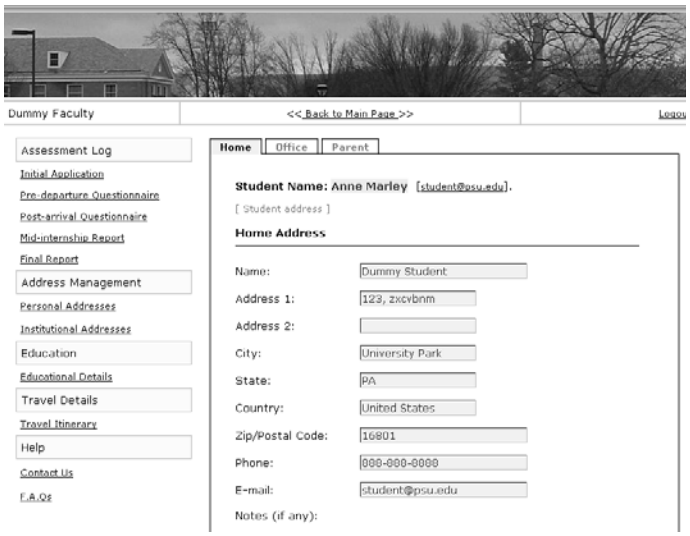

Figure 2: Assessment data collection screen in the Web-based Global Student Tracking System (GSTS).

The GSTS also permits data to be quickly collected using new assessment tools developed and/or obtained. Using the data collected via the system, qualitative research methods are being employed, such as content analysis on student reports, with the coding frame based on the specified set of student outcomes.

Virtual Versus Real in GEE

Virtual teams have been made possible because of IT and made attractive by the comparative advantage offered of deploying the best human resources without the need to assemble them all in one place. The use of virtual teams increasingly characterises the modern engineering workplace and such teams can, and do, cross national boundaries as corporations seek to optimise their global resources and run their design and development operations on a 24-hour clock.

IT need to be utilised as a cost-effective way to globalise the curriculum and to provide students with international experiences without the cost in time and money of overseas study and work experiences. IT-based virtual experiences may be used in a variety of ways to bring the world into the classroom. The most potent ways of doing this is to use real-time experiences in cross-national formats like discussions and teams. In this way, potentially all students could have such virtual experiences in the global economy. Actual travel-based experiences will probably never be possible for even a half of the engineering undergraduate student body at most schools (10% is a more realistic figure). However, virtual experiences are expected to raise the interest levels and participation rates for overseas study and work opportunities.

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World Transactions on Engineering and Technology Education

A Call for Papers

Current events have impacted upon the arena of international conferences and academic travel, impinging on the freedom of intellectual movement to conferences and the like that are so important for the advancement of engineering education internationally and regionally and, indeed, the development of humankind now and into the future. To this end, the UNESCO International Centre for Engineering Education (UICEE) has established the *World Transactions on Engineering and Technology Education* (WTE&TE), which is open to everyone around the world who is interested in the progression of engineering and technology education. The *World Transactions* offers a safer and cost-effective alternative to conference participation.

So far, the first two volumes of the WTE&TE presented a range of papers from across the spectrum of engineering education and from around the world, including over 140 very interesting and insightful representations from many countries worldwide. From this, it can be seen that the WTE&TE contribute strongly to the publication of engineering and technology education papers globally.

Therefore, a call for papers is made for the next issue of the WTE&TE, **Vol.3, No.2**. The very nature of the *World Transactions* is open to every facet of engineering and technology education and is not confined to traditional views about science, engineering and technology. As such, there are no overriding engineering or technology themes, but rather the overarching principle of the globalised expansion of engineering and technology education that is not confined to borders or regions; instead the WTE&TE seeks to benefit all those involved in the engineering and technology through the wider dissemination of knowledge.

The deadline for this issue is **30 September 2004**. Authors should indicate their interest as soon as possible. Additional information can be found at the UICEE's homepage under *World Transactions* at http://www.eng.monash.edu.au/uicee/

Interested persons should submit their original, previously unpublished papers to the UICEE for consideration to be included in the WTE&TE. Authors should be aware of the standard formatting structure, which will essentially be the same as for other UICEE publications. Papers are to be submitted in MS Word format in 10pt font, single-spaced, double column, and a **maximum of 4 pages** in total, including abstract and figures (additional fees will apply for extra pages). Fees are based on cost recovery for editorial and publishing work, and every submitted paper will cost $A450. Also, within the cost structure is the delivery of one copy of the WTE&TE per paper submission by airmail postage to anywhere in the world. Please note that all Australian submissions are subject to 10% GST.

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