The Formation of the Engineer for the 21st Century – A Global Perspective

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***Abstract**: Over the last ten year period there has been an increasing awareness across engineering and technology of the importance of recognising that the practice of engineering increasingly transcends national and cultural boundaries. The current international systems of mutual recognition of engineering education requirements do not on their own guarantee that a graduate possesses the necessary attributes to work effectively within the global/international environment of the future. To take this forward the authors have developed a framework of specific global competencies that takes account of race, ethnicity, culture, and language. It is also concluded that to facilitate this, on-campus and work-based learning environments need to be fully integrated recognising the value of education–industry partnerships based on mutual trust and understanding and that engineering educators need to be trained and developed to teach an understanding of competencies in the context of a global information society.*

Introduction

Over the last ten year period there has been an increasing awareness across engineering and technology of the importance of recognising that the practice of engineering increasingly transcends national and cultural boundaries. Anecdotal evidence now shows that combining global competencies with technical education makes engineering graduates much more acceptable to the job market. In this respect it essentially enhances their employability. Recently the whole issue was considered by the National Academy of Engineering when it outlined the guiding principles shaping future engineering activities in its publication, The Engineer of 2020 (National Academy of Engineering, 2006):

- 'The pace of technological innovation will continue to be rapid.
- The world in which technology will be deployed will be intensely globally interconnected.
- The population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.
- Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation.
- The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever'.

This also suggests that the key attributes for the Engineer of 2020 should be 'to have the ingenuity of Lillian Gilbreth, the problem-solving capabilities of Gordon Moore, the scientific insight of Albert Einstein, the creativity of Pablo Picasso, the determination of the Wright brothers, the leadership abilities of Bill Gates, the conscience of Eleanor Roosevelt, the vision of Martin Luther King, and the curiosity and wonder of our grandchildren'.

Another key driver is the concern that social mission, ethical practices, society and the environment become subservient in the consideration of the formation of the professional engineer of the future. For example, although there are bold statements regarding the creation and development of the

European Higher Education Area (The Bologna Process 2020, 2009) that will promote public good and public responsibility as encapsulated in the Magna Charta Universitatum (1988), there is little evidence at an implementation level that this is been driven through effective curriculum design and educational methods (Tsirigotis, Papadourakis and Karasavoglou, 2009).

Evidence is also reported (Herling, Herling and Peterson, 2001) to show that engineering graduates with cross-cultural global experience are much more tolerant in dealing with cultural differences which they encounter. Thus with the rapid pace of change of technology, society and demographics, engineering educators are now faced with the challenge of examining the package of knowledge, skills and abilities which future generations of engineers will need to survive and succeed in the rapid globalisation of life in the 21st century.

A starting point in establishing what the key competences might be for engineering graduates to practice and contribute effectively in this dynamic global environment are the national professional standards for engineers and engineering graduates including those defining employability. These are explored in the following two sections.

Professional Engineering Competencies

There are a range of national and international agreements and frameworks which specify the required competencies of the professional engineer and in some cases those associated with the graduate from an accredited programme. In the USA for example global competencies form an important component of accredited engineering programmes in accordance with the Accreditation Board of Engineering and Technology (ABET). The educational focus is on achieving outcomes that demonstrate competence in technology, communication skills and multidisciplinary teamwork (Tharakan et al, 2005).

Achievement of these competencies provides the means by which an individual can gain national and/or international recognition of their fitness to practice as a professional engineer, although very few countries enforce this within their regulatory and/or legal framework. However, international agreements such as the Washington Accord (WA) (1988) seek to facilitate the international recognition of individuals who have demonstrated the achievement of nationally defined competencies, such as the UK Standard for Professional Engineering Competence (Engineering Council, UK, 2008). These international agreements are generally confined to the recognition of the signatories to the agreement although this includes most of the worlds ‘developed’ countries. Clearly, one might expect that these agreements should facilitate the mobility of the professional engineer and graduate across national boundaries. However, this implies that there needs to be some convergence or equivalence in the competencies specified and that these include a context which facilitates global and intercultural working. It is therefore useful to examine these nationally and internationally agreed competencies for convergence/equivalence and also the contribution they might make for effective global working.

There are two main international systems for professional engineers’ registration, Engineers Mobility Forum (EMF) (associated with the International Professional Engineer (IntPE)) and the European Federation of National Engineering Associations (FEANI) (associated with the European Engineer (EurEng)). The standard route to IntPE would be a 4-yr accredited Bachelors (US) degree followed by 7 years experience and for EurEng an accredited first cycle qualification as defined by ‘Bologna’ (The Bologna Process 2020, 2009) followed by 4 years experience. The professional competencies specified by the two systems are broadly equivalent (Engineers Mobility Forum (2009), European Federation of National Engineering Associations (FEANI) (2005)). In the context of the contribution the formal education element makes to this formation reference can be made to the respective ‘Graduate Attributes’ specified by the EMF (Engineers Mobility Forum (2009)) and EUR-ACE (EURopean ACcredited Engineer) (2005). These are presented in Table 1.

Clearly, in broad terms the WA/EMF and EUR-ACE attributes are comparable although EMF attributes in the area of Modern Tool Usage and Individual and Team work are enhanced in comparison with EUR-ACE. However, when second-cycle EUR-ACE attributes are considered it is clear that all the attributes are extended and/or taken to a higher level. For example, there is no expectation under the first cycle for the graduate to possess the attribute to work and communicate effectively in national and international contexts. This is made explicit as a second cycle attribute.

Table 1: Engineering Graduate Attributes – EMF v EUR-ACE

WA/EMF Attributes	EUR-ACE Attributes
Knowledge of Engineering Sciences	Knowledge and Understanding
Problem Analysis	Engineering Analysis
Design/development of solutions	Engineering Design
Investigation	Investigations
Modern Tool Usage	Engineering Practice
Individual and Team work Communication The Engineer and Society Ethics Environment and Sustainability Project Management and Finance Life long learning	Transferable Skills

The above comparison leads to the conclusion that both systems should facilitate broadly compatible engineering graduates who therefore should be able to contribute as engineers within an international arena (i.e. on the basis that the competencies and attributes are equivalent). However, these attributes do not place any emphasis on the international/global context within which the attributes are achieved or developed – there is no explicit mention of cultural issues within the first cycle EUR-ACE specification. Although, it is observed that second cycle programmes do appear to acknowledge this through enhancing the transferable skills element. A more robust conclusion is that the current international systems of mutual recognition of engineering education requirements do not guarantee that a graduate possesses the necessary attributes to work effectively within the global/international environment of the future.

Employability

Employability may be conveniently defined as ‘a set of achievements – skills, understandings and personal attributes - that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy.’ (Yorke, 2004, reissued 2006).

A useful national reference document for employability in the UK, the Student Employability Profile, was published by The Higher Education Academy –Engineering Subject Centre (2007). This outlines the qualities and attributes specified by employers and the associated competencies. The published profile also maps the UK Quality Assurance Agency (QAA) Subject Benchmark Indicators to these qualities, attributes and competencies thus linking the key specification benchmarking engineering curriculum in the UK with the expectations of employers. There is also strong convergence between these specifications and the UK Standard for Engineering Competence (Engineering Council, UK, 2008) which represents the basis for international recognition through the WA. In the UK concerns are being expressed that not enough emphasis is being placed on the development of competencies underpinning ethical practice and international/multidisciplinary teamwork (Parry-Jones, R., 2005). These competencies, as do those derived from international/national standards as outlined above, do not however provide the context in which they should be developed to facilitate global working. It is therefore necessary to establish specifically the competencies required for effective working within an international arena and how these might best be developed.

To take this forward the authors have developed a framework of specific global competencies based on those specified above and the need to include a context for global working. These are outlined in the next section.

Global Competencies

So what competencies are required to facilitate and enhance an engineer's personal and professional development and involvement within the context of multicultural and diverse global environments? Engineers will need to (Allan and Chisholm, 2008):

- Take forward and embrace a personal ethic of social responsibility and service within the community based environments which are racially, culturally, ethnically and linguistically different from their own.
- Practice culturally appropriate relationship centred involvement within the global environments in which they work.
- Use communication and information technology that can deliver information to communities of practice who are from diverse racial, ethnic, religious, cultural and linguistic backgrounds.
- Provide leadership that is totally inclusive of ethnic and cultural backgrounds and supports shared decision-making.
- Be able to work on as a team member within inter-and transdisciplinary systems where diverse ways of thinking, being and doing are the basis of practice.
- Show ethical behaviour in all aspects of practice, both personal and professional which involves individuals from diverse global backgrounds.
- Show empathy with all diverse communities and individuals affected by engineering decisions taken in any given situation or environment.
- Consider for planning, developing and generating engineering products and services the value and need to incorporate the determinants of global based views regardless of ethnicity, culture or race.
- Ensure that all interpersonal interactions in the job role and in other lifeplaces are competent and effective within the context of linguistic, racial, ethnic and cultural differences.
- Incorporate fundamental consideration of relevant aspects of cross-cultural diversity into critical thinking, reflective analysis and problem solving in engineering.
- Continuously review and improve cultural competence at the personal and professional levels and within the organisational systems through the engineering job role.
- In decisions and in delivering engineering practice ensure a balance of consideration at individual, professional, system and global societal needs.
- Show entrepreneurial behaviour in all aspects of practice within the context of social responsibility and social justice.
- Embrace philosophy as a pursuit of wisdom in a Global context.

The authors believe that the above should be recognised both in the academic programmes representing the formation of the graduate engineering and in a programme of Continuous Professional Development (CPD) following graduation. Possible approaches to inform engineering programme design inclusive of the above are discussed and presented next.

Engineering Programme Requirements – Global Working

Programmes for engineering education are often now being taken forward with an overcrowded curriculum based on the growth of new subject matter considered to be essential to the formation of engineering graduates. The latest developments have seen employability and related skills and competencies compete for the limited time available on-campus. The key question which needs to be considered is as follows; can all the requirements relating to qualifying at a given level be effectively realised on-campus? The authors believe that many aspects of the curriculum associated with personal, professional and career planning and the associated competencies outlined above can be best achieved using an off-campus approach. Life-place learning as a model could without doubt contribute to the overall process by allowing learners to negotiate how to develop generic competencies using a range of extra-curricula activities (Harris, Chisholm and Allan, 2009). By formalising the unintentional learning, under a life-place approach the learner could demonstrate through reflection, competencies achieved and have these formally assessed. This means the educators must be prepared to emphasise theoretical principles in relation to student centred learning such as contextual learning (Lave and Wenger, 1991; Kolmos, 2002), work based learning (Chisholm, Holifield and Davis, 2005) and indeed blended approaches (Gamble et al, 2008). In this respect engineers will be taught the vital importance of sustaining their profile of competencies by being careful reflective practitioners in relation to operating across a range of global environments. While work-based learning has become well established over the past decade and has increasingly become supportive of 'mode 2' learning (Giddons, 1998), if work-based partnerships are to operate successfully between education and industry they must be based on mutual trust between the educators and those involved in the learning organisation. Such mutual trust is characterised by genuine learning partnerships involving mutual benefit, a sharing of standards and processes and, above all, a mutual belief that a learner centred approach will deliver the required global competencies. In these learning partnerships the academic partner has to accept that, while successful learning environments can be established in the workplace, it remains a real-world environment subject to all the pressures of a commercial organisation. Thus educators have to be prepared to operate in a very different and unstable environment, where they may have to renegotiate and redefine the learning environment continuously, so that the competence outcomes can be achieved.

What key aspects do educators need to develop with students? First and foremost, engineers need the flexibility to respond to and adapt to new and changing global environments. Respect and values that take account of cultural diversity and ethics are also an essential attribute. Jansen (2004) proposes that this could be implemented through two modules, one on 'Cultural Awareness' and one on 'Intercultural Categories', and strongly supports a case study problem solving approach. However, others (Skinner et al, 2007) maintain that this needs to be underpinned by a theoretical model(s) taught conventionally. Emotional intelligence has a key role to play in developing empathy with other races and other cultures. The third input is the key skills required to underpin living in a diverse global society.

Cross-cultural communication, involving verbal and non-verbal communication skills is essential: no matter how good an understanding an engineer has of engineering technology, its implementation and successful development is directly related to competence in multicultural communication. In this context multicultural teamwork is a key development which educators must achieve. In the global information society teamwork, regardless of race, ethnicity or culture, is a key driver in seeking effective engineering solutions. Educators can best develop awareness and appreciation of cultural differences by taking a case study problem solving approach (Kolmos, 2002) and, as a starting point, by asking students to examine their own cultural background and reflect on how it has shaped their attitudes and opinions.

Conclusion

1. Multicultural competency development for engineers is now essential if future generations are to be effective in the global information society.
2. Established national and international standards specifying the required competencies when contextulised for global working provides the basis for establishing a robust and sustainable educational model.
3. A model has been outlined for an approach to global competencies that takes account of race, ethnicity, culture, and language.
4. A model has been proposed based on the integration of the on-campus and work-based learning environments and recognising the value of education–industry partnerships based on mutual trust and understanding.
5. Engineering educators need to be trained and developed to teach an understanding of competencies in the context of a global information society.

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