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Global Engineering Criteria for the development of the global engineering profession

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ABSTRACT: Engineering professionals and students need to be prepared for the increasing use of advanced technology and appropriate skills and attributes in their future workplaces; this is primarily due to the process of globalisation of engineering education and the increasing mobility of engineering professionals around the world. As a result, there is an urgent need to revitalise existing engineering professional criteria implemented for engineering programmes worldwide. In addition to the essential engineering (*hard*) and professional (*soft*) skills, engineering criteria must include *global* skills that will help engineering professional to work globally. The current criteria implemented for the assessment of engineering professional skills in different countries are reviewed in this article. The author endeavours to propose a 3-dimensional *Global Engineering Criteria* model that can be implemented worldwide for the assessment and accreditation process of engineering programmes. The necessity and advantages of this model are also described in this article.

INTRODUCTION

The workplace situation of engineering professionals has changed over the last two decades. Engineering education crosses borders and engineering professionals work globally facing different cultural workplace backgrounds. Current engineering criteria, which have been implemented and assessed for the accreditation of engineering programmes, have to be changed to a 3-dimensional perspective of engineering professional skills. As a result, there is a need to revitalise current engineering professional criteria for engineering programmes that have been implemented around the world. It is strongly suggested that, in addition to the essential *hard* and *soft* skills, new engineering criteria must include essential global skills that can help engineering professionals to work globally.

ACCREDITATION PROCESS

The Accreditation Board for Engineering and Technology (ABET) in the USA voluntarily started the process of accreditation and quality assurance in engineering and technology programmes. Various organisations at the national level have also been developing and carrying out the process of accreditation in other countries; however, the strategies and processes of the ABET have been replicated in many national accreditation programmes worldwide. The various national accreditation developments include: the Canadian Engineering Accreditation Board; the Hong Kong Institute of Engineers; the Engineering Council of the UK; the National Board of Accreditation, India; the Institute of Engineers, Ireland; Engineers Australia (formerly the Institute of Engineers, Australia, (IEAust)), Russian Association for Engineering Education (RAEE), etc.

In engineering and technology education, the two important systems or consortia of accreditation and quality assurance are the Washington Accord and the Bologna Process. The objectives of the Washington Accord are to recognise the substantial equivalence of accreditation systems of various organisations and engineering education programmes in the signatory countries. The six signatory nations are the USA, Australia, Canada, the UK, Ireland and New Zealand, with Hong Kong, South Africa, Japan, Malaysia, Singapore and Germany joining later [1].

In the Bologna Process, the 29 ministers of European higher education ministries decided to strengthen and promote the European higher education system by 2010 [2]. The most important decisions in the meeting was the adoption of a binary system of higher education in Europe, ie a system based on two cycles, such as undergraduate and graduate. This will foster the process of the internationalisation of higher education, plus promote student mobility within Europe and globally.

EXISTING ENGINEERING CRITERIA

ABET is a milestone in developing engineering criteria for the accreditation of engineering programmes in the USA and several other nations. As such, it is relevant to review existing engineering criteria.

The ABET established accreditation criteria for six countries under a mutual agreement in the late 1980s; these agreements have since been extended to many countries worldwide. The ABET's Criteria for Accrediting Engineering Programmes (effective for evaluations during the 2005-2006 Accreditation Cycle) have been introduced recently [3]. The general criterion applied to basic level programmes is divided into eight different parts such as, students, programme educational objectives, such as professional component, faculty, programme criteria, etc. Criterion 3 relates to the knowledge, skills and behaviours that students acquire in their degree programme. Important criterion elements are as follows:

- *To meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*;
- *An ability to function on multi-disciplinary teams*;
- *An understanding of professional and ethical responsibility*;
- *An ability to communicate effectively*;
- *The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*;
- *A recognition of the need for, and an ability to, engage in life-long learning*;
- *A knowledge of contemporary issues* [3].

The recent guidelines produced by Engineers Australia in the competence standards for professional engineers also contain important engineering ability and professional attributes for the accreditation of education programmes. The following points are extracted from these guidelines:

- *Understanding of social, cultural, global and environmental responsibilities and employability of sustainable development*;
- *High level communication skills*;
- *Understanding of, and commitment to, professional and ethical responsibilities*;
- *Ability to function effectively in multidisciplinary and multicultural teams* [4].

Several other national accreditation agencies have designed (or are designing) accreditation criteria consisting of the above few elements in order to accredit engineering programmes within their countries. However, there is no uniform accreditation model of necessary professional attributes that can cover all the required global skills. In order to avoid complexity and variations in accreditation criteria for engineering programmes worldwide, there must be a system of *Global Engineering Criteria* that can be implemented in all nations.

KEY ISSUES IN GLOBAL PROFESSIONAL PRACTICE

Increasing numbers of engineering students, rapid changes in technology and the internationalisation of engineering education have forced increased attention on engineering professional skills. As a result, there is a strong need to revise the *soft* skills of engineering profession and to include *global* skills in the engineering criteria. This will also foster the process of globalisation of engineering education, as well as the transition of engineering graduates from the local to the international workplace. Global mobility, multicultural workplace environments, the internationalisation of engineering education, higher numbers of engineering graduates and student enrolments, etc, are few of the important and key issues that have created an increasing need for the designing of global engineering professional criteria for engineering programmes.

A recent statistical analysis gathered through surveys indicated that engineers are expected to be *technically proficient in a given field*, as well as *know how to behave and operate within an organisation* [5]. Indeed, Nguyen further states that an *ideal engineer is expected to possess a diversity of skills and attributes, with technical competency balanced by non-technical competency* [5].

Globalisation of Engineering Education

Literature research has shown that the process of globalisation of engineering education is directly affected by the increased liberalisation of trade and professional services. Also, the mobility of engineering professionals has increased globally over the past two decades. As suggested by Jones, engineering education needs to have several dimensions that have not generally been incorporated for *past generations of engineering students, including foreign language proficiency, cultural background development, international business concepts and international technical issues* [6]. As a result, the application of a proper accreditation model, which will have internationally recognised global criteria for the assessment of engineering programmes, is required to facilitate the global mobility of engineering professionals around the world.

Mutual Recognition of Engineering Professions

Literature search shows that, across the world, there are several difficulties in the recognition of engineering programmes taught or awarded in other countries. For example, engineering programmes taught in Asia are not easily recognised in developed countries. The first and most far-reaching mutual recognition agreement was initiated in 1989, when representatives of engineering accreditation agencies from six countries signed the Washington Accord [7]. The literature search also shows evidence of several other developments in the mutual recognition of professional courses within Europe [8]. However, these developments are very small in number compared to the growth of engineering education worldwide. Also, these developments are based on particular collaborations and are limited to specific programmes only. As a result, there is an urgent need for the mutual recognition of engineering courses worldwide.

Engineering Graduates at the Workplace

A relevant literature survey on students' learning outcomes shows that graduates from university courses lack important skills, such as communication, decision-making, problem solving, leadership, emotional intelligence, social ethics, etc; further, these students lack the required ability to work with people from different backgrounds [9]. There is increasing evidence of a mismatch between graduate students' skills being developed during their studies and those needed in the workplace. Moreover, there needs to be a clear understanding of essential generic and professional attributes of graduates to ensure quality in higher education [10]. Various assessment models devised in engineering education have not revealed the qualitative assessment of the necessary attributes associated with graduate students.

It is essential that engineering graduates need to be prepared for the increasing use of advanced and appropriate technology in their future workplaces. In addition, there is a strong need to include assessment criteria of so-called *global skills* along with *soft skills* in the accreditation framework of engineering programmes, especially since engineering graduates need to work within multicultural and international workplace environments.

Multicultural Workplace Environments

In addition to essential core skills, such as engineering design, problem solving, analysis, etc, the engineering graduate must be aware of, and hold competences in, multicultural workplace environments and situations. Recent literature on engineering professional skills shows that engineering graduates lack cultural awareness and diversity, which are required for effective engineering practice and improvements in the engineering profession [11].

GLOBAL ACCREDITATION CRITERIA: 3-D MODEL

A 3-dimensional model of *Global Engineering Criteria* for engineering professional skills, as outlined in Figure 1, can be implemented for the accreditation of engineering and technology programmes. The proposed *Global Engineering Criteria* have three different units and elements of competence as shown in Figure 1. This elaborated on below.

Hard Skills (X-Axis)

Important engineering and technology elements contain the following necessary skills, as shown along the X-axis. These skills can also be called *hard* or *core* skills and cover:

- Fundamental knowledge of science, mathematics and engineering;
- Expertise in an engineering subject (any one discipline);
- Engineering competence;
- Engineering design and problem solving skills;
- Research and development skills.

Soft Skills (Y-Axis)

The Y-axis shows the essential elements related to *soft* skills or professional skills and include:

- General knowledge;
- Strong communication skills;
- Competence in managerial and organisational skills;
- Understanding fundamental negotiation and interpersonal skills;
- Awareness of engineering ethics and empathy skills;
- Understanding of safety and sustainability issues.

Global Skills (Z-Axis)

In addition to these two elements, it is proposed to include a third axis for additional *global* elements. These elements contain essential *global* skills, such as the following:

- Awareness of global political and societal issues;
- Understanding of cross-cultural and multicultural issues;
- Understanding of the globalisation of engineering education;
- Knowledge of the international labour market and workplace imperatives;
- Understanding of international business, economics and the world market;
- Foreign language proficiency;
- Competence in applying engineering solutions and applications within a global context.

ADVANTAGES OF THE 3-D GLOBAL ENGINEERING CRITERIA

Advantages in implementing a 3-dimensional *Global Engineering Criteria* model are stated as follows:

- Accreditation of engineering programmes consisting of the 3-D global engineering criteria should facilitate the process of the global mobility of engineering professionals around the globe.
- The introduction of 3-D global engineering criteria should promote the concept of the mutual recognition of engineering courses within different countries.

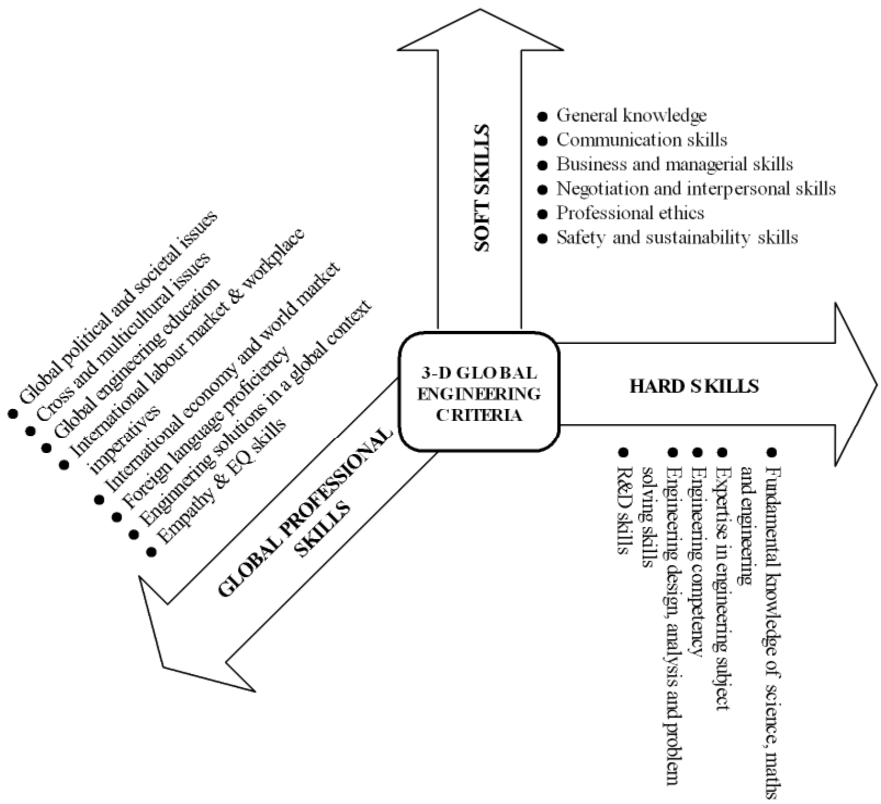

Figure 1: The proposed 3-D global engineering criteria for the development of the global engineering profession.

- Essential global skills and multicultural awareness helps engineering professionals to work in multicultural and global environments.
- Global engineering criteria should foster the process of international collaboration in engineering education to develop combined degree programmes, joint curricula and research activities. This should also help in developing international exchange programmes between various universities, and promote online and distance education.
- There is very little evidence of the assessment of R&D activities and facilities available in an engineering institution. Therefore, it is essential to include R&D skills in the engineering criteria. This, in turn, may facilitate the development of joint research and development activities in engineering and technology. This may also enable access to modern facilities and infrastructure in R&D activities at engineering institutions between developed, and developing and underdeveloped nations.

ASSESSMENT OF GLOBAL PROFESSIONAL SKILLS

Most assessment methods developed and implemented in higher education systems, including engineering education, lack the clear-cut theoretical and conceptual base of the term *generic attributes* for graduates [10]. The fundamental process of incorporating generic attributes or global attributes into the course curricula is one factor, whereas the proper assessment of these attributes is the second important issue. There may be several debates and discussions about how to teach these attributes to engineering graduates, and at what stage? The two important issues are as follows:

- Can these attributes be taught (or learned) during the course curricula?
- Can such attributes be learned (or trained) at the workplace?

Although gaining mastery in professional attributes for any profession is a life-long and continuous process, there is a possibility to teach several important components of generic or professional attributes to graduates during the course. It is also suggested to train graduates for few attributes at the workplace during their initial training. Several components of *global* skills can be taught during academic exchange programmes with overseas universities or institutions. A successful implementation of one such exchange programme is academic practice abroad for the internship of students between Hochschule Wismar - University of Technology, Business and Design, Wismar, Germany, and Higher Education Professional School (HEPS), Tarnów, Poland [12]. The case study shows that the bilateral collaboration between two academic institutions in Wismar and Tarnów facilitated several collaborative activities for engineering diploma students, teachers and academic staff. This includes study visits, educational exchanges, cultural exchanges, teacher training and international mobility.

The question arises about the assessment of these *soft* skills. Technical or *hard* skills can be monitored and assessed by the coursework curricula and the student's outcomes or results. However, all the *soft* skills cannot be monitored or taught in the coursework, but are mostly acquired outside the classroom and at workplaces. Recent literature on the assessment of engineering programmes illustrates several examples of the developments of assessing professional skills, such as students' ability to evaluate and resolve ethical dilemmas, the assessment of team skill developments and project effectiveness, etc [13]. It is necessary to design common global assessment tools to assess most of the *soft* skills related to the engineering professions.

CONCLUSIONS

The workplace situation of engineering professionals has been changing over the last two decades due to several factors, such as globalisation, global mobility, free trade agreements, etc. The engineering professional environment has evolved into multicultural workplaces. The current engineering criteria, which are being implemented and assessed for the accreditation of engineering programmes, have to be modified to incorporate 3-dimensional *Global Engineering Criteria* of engineering professional skills. A proposed model of these criteria and its important advantages are described in this article.

REFERENCES

1. Washington Accord (2004), http://www.washingtonaccord.org
2. Bologna Declaration (2004), http://www.bologna-bergen2005.no
3. Engineering Accreditation Commission, 2005-06 Engineering Criteria: Criteria for accrediting engineering programmes (effective for evaluation during the 2005-2006 accreditation cycle). Baltimore: ABET Engineering Accreditation Commission (2004), http://www.abet.org/criteria.html
4. Engineers Australia Accreditation Board, Accreditation management system: education programs at the level of professional engineer. Document PO5, Canberra: Engineers Australia (2005), http://www.ieaust.org.au/
5. Nguyen, D.Q., The essential skills and attributes of an engineer: a comparative study of academics, industry personnel and engineering students. *Global J. of Engng. Educ.*, 2, **1**, 65-75 (1998).
6. Jones, R.C., Formation of engineers for international practice. *Australasian J. of Engng. Educ.*, 6, **1**, 7-17 (1995).
7. Prados, J.W., Peterson, G.D. and Lattuca, L.R., Quality assurance of engineering education through accreditation: the impact of Engineering Criteria 2000 and its global influence. *J. of Engng. Educ.,* 94, **1**, 165-184 (2005).
8. Enemark, S. and Plimmer, F., Mutual Recognition of Professional Qualifications. FIG Taskforce on Mutual Recognition of Professional Qualifications, February (2002), http://www.fig.net/pub/figpub/pub27/figpub27.pdf
9. Wellington, P., Thomas, I., Powell, I. and Clarke, B., Authentic assessment applied to engineering and business undergraduate consulting teams. *Inter. J. of Engng. Educ.*, 18, **2**, 168-179 (2002).
10. Barrie, S., Academics' understanding of generic graduate attributes: a framework for assuring quality. *Proc.3rd Australian Universities Quality Forum (AUQF)*, Adelaide, Australia (2004).
11. Rojter, J., Professional engineering as social practice: humanities and social sciences in engineering curricula, *Proc. 9th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland (in print) (2005).
12. Lisowska-Lis, A., Wojciechowska, E., Mitkowski, S.A., Pudlowski, Z.J. and Grünwald, N., Academic practice abroad: a case study of Hochschule Wismar and the HEPS in Tarnów. *Global J. of Engng. Educ.*, 9, **1**, 69-76 (2005).
13. Shuman, L., Besterfied-Scare, M. and McGourty, J., The ABET *Professional Skills* – can they be taught? Can they be assessed? *J. of Engng. Educ.*, 94, **1**, 41-55 (2005).