Generic Skill Mismatch and Engineering Graduate Attributes: The Impact on Engineering Programs Accreditation

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ABSTRACT

Is engineering education providing relevant skills for the engineering graduates? This paper highlights the skills mismatch stipulated for accredited engineering programs by the accreditation bodies, namely; the Accreditation Board for Engineering and Technology, Inc. (ABET), the International Engineering Alliance (IEA) and EURopean ACcredited Engineer Label (EUR-ACE) and the educational frameworks on engineering programs developed by various regional/international organisations, such as; the TUNING and the CDIO. The paper also discusses how the engineering graduate attributes should reduce the skill disparity of future engineers and evaluates the generic learning attributes for the purpose of engineering program accreditation. An inductive analytical approach is applied to design the analysis framework for this study. The common generic skills criteria of the accreditation bodies and related educational framework are also analysed. The paper also calls for a review on the generic attributes of engineering graduates for the purpose of the accreditation of engineering programs in order to prepare future engineers to work in the complex environment globally.

***Keywords**: generic attributes, engineering education, accreditation, TUNING approach*

COMPETENCIES OF ENGINEERS

Engineering competencies are labeled in numerous terms though they actually signify similar concept. Researchers and educators refer to the skills other than technical and engineering-related competence as generic skills (Benjamin et. al, 2012; Badcock, Pattison and Harris, 2010), soft skills (Yaacoub, Husseni and Choueiki, 2011), employability skills (Md Yusoff, et. al., 2012), transferable skills (Malmqvist, 2009), professional skills (Shuman, Besterfield-Sacre and McGourty, 2005), soft and global competencies (Patil and Codner, 2007), professional competencies (International Engineering Alliance, 2009) and generic competences (Palma, de los Rios and Minan, 2011; Male, 2010). This paper however, will refer to these skills as generic competencies throughout the discussion. This is due to the understanding that such skills are common in all branches of learning, regardless of the field or discipline.

The generic skills performance of engineering graduates is a major concern by engineering-related employers. Olsson (2005: pp 14) acknowledged the increased importance of generic skills in the "work-life" of engineers and attributed such change to the shift from industrial to knowledge-oriented economy. According to Robertson (2008: pp 3), "engineers do not design bridges to stand up, they design them not to fall down." He revealed that engineering lessons have been educating students on how to hinder "failure of engineered solutions," not only visualizing "successful engineering design." Hence, engineering education should be well-planned in order to provide future engineers with relevant generic attributes expected of the engineering profession. Not only that the education should consist engineering fundamentals, it should also focus on the social skills such as communication, team work and etc.

Male, Bush and Chapman (2011) identified 64 potential generic competency items and explored the generic engineering competencies required by engineers graduating in Australia. The extensive list comprises technical and non-technical components following their definition of generic engineering competencies which stated as "competencies that engineers across all disciplines require for their work" (Male, Bush and Chapman, 2011: pp 147). A factor analysis was performed for correlated items and an eleven-factor model was derived. The 11-factor model of competencies included communication, teamwork, self-management, professionalism, ingenuity, management and leadership, engineering business, practical engineering, entrepreneurship, professional abilities and application of technical theory.

Similarly, Lattuca, Terenzini and Volkwein (2006) emphasized that employers placed high importance on engineering graduates' ability to communicate effectively, work in teams, design and apply modern engineering tools. The authors also reported employers' perception that these skills have gradually declined over the years and employers are not only concern on the graduates' learning outcomes but more importantly on the preparation of the new engineers, regardless of their engineering field. In a similar study, Patil, Nair and Codner (2008) added the list of deficiency in engineering university graduates to include

problem solving, leadership and social ethics skills. The researchers (form Monash University, Australia) engaged a survey on one hundreds Australian employers from various engineering related professions which have recruited at least one Monash University graduate.

Earlier, Nguyen (1998) listed seven attributes of generic skills expected of modern professional engineers in her study namely attitudes, business practices, proficiency in languages and international and national history or culture to name a few. The author defined the final component to include national history and development, common history, multiculturalism, religion, gender, social life and custom, economics and political issue and cultural differences as importance sub-components. Similarly, Chubin, May and Babco (2005) stressed on the problem of cultural competence faced in the engineering profession. The authors verified that cultural competence is much needed both for the engineering faculty and the engineering workplace. It is also anticipated that such type of competence can reduce the gap between practitioners and their clientele. The authors raised a rather intriguing issue that only a small portion of the engineering classroom is culturally represented with diverse race, gender and ethnicity which actually reflects the future of the engineering profession. They recommended several strategies;

1) systematic improvement on the educational environment for engineering students across all levels of K-16 education and beyond
2) diversifying the faculty by replacing the aging faculty with more culturally competent age group
3) promoting more women and minorities to hold upper-level administrative positions and
4) planning programs which facilitates the employment, retention and advancement of underrepresented groups.

Evidence from literature has presented significant generic attributes for engineering graduates. Taking into account these attributes, this paper highlights the generic skills mismatch specifically focusing on the generic skills promoted by the respective authorities involved in engineering programs. It also discusses how the engineering graduate attributes should reduce the skill disparity of future engineers for the purpose of engineering program accreditation.

METHODOLOGY

An inductive analytical approach as proposed by Thomas (2006) was initially applied to design the analysis framework for this study. An analysis was carried out to investigate the generic skill requirements of the accreditation bodies namely the Accreditation Board for Engineering and Technology, Inc. (ABET), the International Engineering Alliance (IEA) and the **EUR**opean **AC**credited **E**ngineer Label (EUR-ACE) and two engineering educational frameworks, namely; TUNING and CDIO. Firstly, a list of common generic attributes promoted by these respective bodies was generated. Secondly, an analysis was performed to identify the extent to which these organizations placed importance

on these generic attributes. A discussion on the analysis is presented in the later section of this paper.

WHAT ARE GENERIC ATTRIBUTES IN ENGINEERING?

The generic skills or attributes of the engineering graduates are referred by the accreditation bodies and educational frameworks as professional skills (ABET), transferable skills (EUR-ACE), generic skills (TUNING), professional profiles (IEA) and personal, professional and interpersonal skills and attributes (CDIO) as listed in Table 1 in the Appendix. It is also important to highlight the three types of generic competences highlighted by TUNING (Gonzalez and Wagenaar, 2008: pp 17). These are:

1) Instrumental competences which includes cognitive, methodological, technological and linguistic abilities
2) Interpersonal competences comprising of individual abilities such as social skills
3) Systemic competences namely skills and abilities which concern the whole system (a combination of understanding, sensibility and knowledge where prior acquisition of instrumental and interpersonal competences are required)

The common generic elements of graduating engineers echoed by the five organizations (Table 1) are individual and team work, communication abilities and engagement in lifelong learning. In regards to individual and team work, ABET, CDIO and TUNING elaborated on the importance of multidisciplinary team. CDIO discussed the element further by adding the leadership factor. TUNING, on the contrary, regards the leadership component as stand-alone skill which must be demonstrated by engineering graduates.

The element on effective communication was emphasized by all the organizations but the CDIO detailed the aspects of effective communications including the strategy, structure and types of communication. It also highlights the importance of communication in foreign languages including English and other languages. TUNING, in contrast, highlights the ability to speak and write in the native language as another communicative facet which engineering graduates should possess. The European languages differ quite substantially and this perhaps instigated TUNING to explore such element. Interestingly, the ability to communicate with non-experts in the field is also emphasized in TUNING. This is perhaps to differentiate the formal and informal communicative situations encountered by engineering graduates whereby the latter necessitates them to be more tactful and observant when communicating with the non-experts. Knowledge of a second language however, is a separate skill focus in TUNING. Stakeholders had to choose from 26 languages which were listed in the questionnaire in order to identify their views regarding the ability in languages other than the native language (Ward, 2009).

All the organizations were in accordance that graduate engineers should recognize the need and possess the ability to engage in lifelong learning. The EUR-ACE, TUNING and IEA highlighted the independent aspect of lifelong learning whereas CDIO supplemented lifelong learning with curiosity, perhaps highlighting one's inquisitiveness which drives continuous learning. IEA, in addition, associates the lifelong learning element with the context of technological change.

The CDIO syllabus gave a very comprehensive weight to the elements of generic attributes of the engineering graduates. However, in certain cases, the elements were placed in a different term. For example, awareness on engineering practice and impact of engineering solutions, awareness of project management, universal knowledge and the ability of meeting legal and regulatory requirements are not grouped under Personal, Professional and Interpersonal skills and attributes but classified under several sub-topics in CDIO in the Enterprise and Societal Context. The CDIO is also proposing a unique criterion when it highlighted system thinking as one of its generic abilities expected of graduate engineers. This generic component involves among other things; holistic thinking of a system and the emergence and interactions in systems, including the system's behavior and its elements (CDIO, 2013).

It is also interesting to discover the unique emphasis of the IEA on generic abilities, which is not underlined by other organizations. It gave due emphasis on the ability to comprehend local knowledge, especially on the widely applied principles specific to the authority in practice. In engaging with the engineering activities, engineers must also possess the ability to protect the society as this component is the highest priority standard (IEA, 2013).

TUNING has a very long listing of generic skills which concerns the engineering discipline. It has itemized its 32 generic competences into five distinct groups for ease of understanding as shown in Table 2 (TUNING, 2013).

The list is by no means a measurement on what TUNING has developed comparative to others. Neither does the list function to inform on the generic skill attributes that engineering organizations have failed to focus. It merely indicates the different emphasis on generic skills which are highlighted by TUNING and communicated to the stakeholders on what the students are expected to know, comprehend and be able to perform prior to graduation.

The next section differentiates the TUNING approach and other engineering organizations in more detail.

DISCUSSION AND CONCLUSION

It is important to highlight the problems faced when comparing the existing accreditation standards on generic skills (i.e. ABET, EUR-ACE and IEA) and that of CDIO and TUNING during this research undertaking. Firstly, there is no single document that the researchers could refer to when analysing the generic skills attributes focused in TUNING as opposed to ABET's Criteria for Accrediting Engineering Programs, EUR-ACE's Framework Standards for the Accreditation

of Engineering Programs, IEA's Graduate Attributes and Professional Competencies and CDIO Syllabus.

Table 2: TUNING's Five Groups of Generic Competences

Group	Generic Skill
1. Internationalization	a) Understanding of cultures and customs of other countries b) Appreciation of ethical issues c) Appreciation of diversity and multiculturality d) International relations and collaborations e) Ability to work in the international context
2. Entrepreneurship	a) Patents and IPR b) Creativity c) Initiative and entrepreneurial spirit
3. Professional skills	a) Grounding in basic knowledge of the profession b) Basic general technical knowledge c) Capacity for analysis and synthesis d) Research skills e) Capacity to learn
4. Interpersonal skills	a) Leadership b) Interpersonal skills c) Ability to communicate with non-experts d) Oral and written communications in native language e) Critical and self-critical capability f) Teamworking
5. Personal skills	a) Ability to work autonomously b) Problem solving c) Capacity to adapt to new situations d) Knowledge of a second language e) Concern for quality f) Will to succeed g) Elementary computing skills h) Capacity for applying knowledge in practice i) Decision making j) Information management skills

Source: Ward (2009)

Initially the researchers referred to OECD's A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering (2011) as the main reference. This document is insufficient as a focal reference as it has to be read together with a project report that analysed the Tuning methodology in the Electrical and Information Engineering disciplines (Ward, 2009). Secondly, TUNING provides more explicit outcomes expectations than the existing accreditation standards. For example, TUNING considers the competencies in greater detail by defining learning outcomes at different education levels (i.e. Bachelors, Masters and PhD), not simply program outcomes at the degree level. Finally, the generic skills listed in TUNING should not be compared with other accreditation standards because its function is not to supersede these accreditation standards on generic attributes but more of a supplementary effort through its provision of expanded criteria.

Based on relevant research and analysis, authors would like to highlight the following important issues on the generic skills components.

a) There is a mismatch between the generic skills emphasized by various engineering accreditation bodies and engineering educational framework on the generic competencies expected of engineers
b) This raises the question on the consistency on the accreditation criteria imposed on the generic skills of graduating engineers if the respective accreditation bodies and educational framework does not resonate on the list of generic skill attributes
c) The CDIO and TUNING provides very detailed explanations on the generic skill attributes. However, they do not affect the accreditation exercise. ABET, the IEA and EUR-ACE involved accreditation but were not as detailed in their generic abilities expected of graduating and practicing engineers.
d) The generic skills listed in TUNING are very explicit and should serve as a complimentary benchmark to the accreditation standards. The accreditation bodies will find the expanded criteria useful in assessing whether the engineering programs have been successful in preparing the generic competences of the engineering graduates.

Competencies raised by CDIO and TUNING on the ability to converse in foreign languages including English should not be taken lightly. In the world of globalisation where engineers are faced with diverse roles, language is a common ability which is often overlooked. Interestingly, engineers who are competent in foreign languages or second language including English would be more advantaged when employed by international companies. Not only that, cultural competency as highlighted by Chubin, May and Babco (2005) and the internationalization criteria of engineering graduates emphasized by TUNING is another crucial generic competence. Engineers may need to operate in unfamiliar setting; hence cultural competency and appreciation of other cultures are highly crucial for them to function in such unknown settings.

Engagement in entrepreneurship is also another generic ability that warrants further attention. Although the CDIO and TUNING approaches highlighted on

this component, the focus vary accordingly. CDIO emphasizes technical entrepreneurship whereas TUNING concentrates more on patents, intellectual property rights and the initiative and entrepreneurial spirit of the graduates. Despite the common link to "innovation" and its commercializing opportunities, Male, Bush and Chapman (2011) categorized this component under the generic competency as it is not explicitly specified by Engineers Australia as a competency for engineering graduates for the purpose of accreditation.

In conclusion, this paper calls for a review on the generic skills/attributes of engineering students as stipulated for accredited engineering educational programs and key reasons instigate the need for such a reevaluation are:

1. the mismatch on generic attributes stipulated by accreditation bodies and educational frameworks developed by regional/international approaches (CDIO, TUNING).
2. other attributes deemed important taking into account current developments in the engineering profession specifically cultural competency and second language ability of engineers coming from non-English speaking background.

ACKNOWLEDGEMENT

The researchers would like to acknowledge Universiti Teknologi Malaysia for supporting this research project and the Ministry of Higher Education Malaysia for funding this project under the Exploratory Research Grant Scheme (ERGS). Vot no.4L035.

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Table 1: Generic Skills/Attributes Emphasized by Various Engineering Accreditation Bodies and Organizations

	ABET	EUR-ACE	IEA	CDIO	TUNING
Generic Skill Attributes / Specific Term	**Professional skills**	**Transferable skills**	**Professional competency profiles**	**Personal, Professional and Interpersonal skills and attributes**	**Generic skills**
1) Individual and Team work	√	√	√	√	√
2) Communication	√	√	√	√	√
3) Awareness on engineering practice and impact of engineering solutions	√	√	√	√	√
4) Awareness of project management		√	√	√	√
5) Professional and ethical responsibility	√		√	√	√
6) Engage in life-long learning	√	√	√	√	√
7) Universal knowledge			√	√	
8) Local knowledge			√		
9) Problem analysis			√	√	√
10) Evaluation of outcomes and impacts of complex activities			√	√	

11) Protection of society			√		
12) Meet legal and regulatory requirements			√	√	
13) Engineering reasoning and problem solving				√	√
14) Experimentation and knowledge discovery				√	
15) System thinking				√	
16) Risk taking, Flexibility, Creative and critical thinking				√	√
17) Managing engineering activities			√		
18) Judgment			√	√	
19) Responsibility for decision			√		
20) Concern for quality					√
21) Capacity to learn					√
22) Capacity for applying knowledge in practice					√
23) Elementary computing skills					√
24) Capacity to adapt to new situations					√
25) Basic general technical knowledge of the profession of students' work area					√
26) Information management skills					√
27) Ability to work autonomously					√

28) Will to succeed					√
29) Interpersonal skills					√
30) Grounding in basic knowledge of the profession in students' work area					√
31) Initiative and entrepreneurial spirit					√
32) Ability to communicate with non-experts					√
33) Critical and self-critical abilities				√	√
34) Ability to work in an international context					√
35) Knowledge of a second language					√
36) Research skills					√
37) Appreciation of diversity and multiculturalism					√
38) Leadership				√	√
39) International relations and collaborations					√
40) Patents and intellectual property rights					√
41) Understanding of cultures and customs of other countries					√

ABET – Accreditation Board for Engineering and Technology, Inc is the worldwide leader in the accreditation of engineering programs. It currently has 32 member societies which work together to review and accredit degree programs in the United States and the international arena. (http://www.abet.org)

*EUR-ACE – **EUR**opean **AC**credited **E**ngineer Label or EUR-ACE is* a certificate awarded to engineering degree programs by the authorised *accreditation agencies which promotes a set of standards for high quality engineering degree programmes in Europe. (http://www.enaee.eu)*

IEA – The International Engineering Alliance is the organization which coordinates six international agreements; the Washington, Sydney and Dublin Accords on agreements covering tertiary qualifications in engineering, and the APEC Engineer, International Professional Engineers and International Engineering Technologists on agreements covering the competence standards for practising engineers and technologists. (http://www.ieagreements.org/)

CDIO – An initiative focusing on the educational framework to produce the next generation of engineers. It promotes the educational experience which emphasizes the engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products. (http://www.cdio.org/)

TUNING – TUNING Educational Structures in Europe began as a project in 2000 to link the objectives of the Bologna Process and the Lisbon Strategy to the higher educational sector. TUNING has developed into a process, an approach to (re-)designing, develop, implement, evaluate and enhance the quality of the academic programmes in European universities. (http://www.unideusto.org/tuningeu/). The discussions in this paper has made substantial reference to the EIE Surveyor Project (2009) as it was the Final Report for Task on: The alignment of generic, specific and language skills within the Electrical and Information Engineering discipline using the TUNING approach.