A REVIEW OF LITERATURE ON COMMUNICATION SKILLS DEVELOPMENT (CSD) IN THE ENGINEERING CURRICULUM

Rohani Othman and[1] Assoc. Prof. Dr. Zubaidah Awang,
Department of Modern Languages, Faculty of Management and Human Resources
University Teknologi Malaysia
80310 UTM Skudai, Johor, Malaysia

Abstract

Engineering education has expanded recently to include emphasis on the development of some very specific non-technical attributes that match a strong technical base to produce well-rounded engineering graduates who are flexible and adaptable to suit the constantly developing and changing requirements of the workplace. These non technical skills include communication skills, the ability to function in teams, knowledge of societal and contemporary issues, development of global perspective, and ethics awareness. A great importance of these abilities to engineering education has emerged over the last decade even within the international and local scene. Within the Malaysian context, the Engineering Accreditation Council's (EAC) Engineering Program Accreditation Manual(BEM, 2007) , outlines ten learning outcomes that encompasses both the technical and non technical skills which are considered essential for graduating engineers. Similarly, the Accreditation Board of Engineering and Technology (ABET) Criterion 3 (ABET, 2000), outlines eleven criterion which targeted many of these as essential program outcomes in order for engineering programs to be accredited and which are seen as critical for the success in the twenty first century. Communication skills development(CSD) is one of the outcomes required by an undergraduate engineering program in the Engineering Accreditation Council (EAC) for Institutions of Higher Learning (IHL) in Malaysia as well as in the ABET Engineering Criteria 2000 (ABET, 2000). CSD is essential for an engineer who aspires to carry out his/her professional practice in the global arena and especially in the English language. With an increasingly global economy, the Malaysian education system must produce graduates who can communicate effectively in English. Otherwise, it would lose one of its vital selling points for foreign investors to ensure that skilled labor force are sufficient to support internationally competitive commerce and industry and to provide individuals with opportunities to optimize their potentials (Muhammad Rashid bin Rajuddin, 2006; Riemer, 2002).

1.0 Introduction

There may be variations in categorization of the professional skills, but overall the main emphasis is on developing written and verbal *communication skills*, interpersonal skills*,* problem-solving skills, numeracy, information technology and in some models self-management and foreign language ability (Barrie, 2004; Further Education Unit, 1989; Jessup, 1991; Kemp & Seagraves, 1995) . Many engineering programs are now addressing the issue of communication and it is one skill that can be taught and assessed. Nationwide, industry is requiring a greater number of communication and interpersonal skills for entry-level engineers. These facts signals a need to change the

way we teach engineering in order to respond to rapidly escalating technology and its effects on the individual, family, and society, and to be in accord with the increasingly complex nature of life and work in the twenty-first century (Pappas & Lesko, 2001). Yet, there is ample evidence that graduate engineers lack the required standard of communication skills, particularly when compared to the needs of industry internationally (Grünwald, 1999; Jensen, 2000). Communication skills are a regular feature of an engineer's job in industry; some graduates employed in industry have identified that education in communication skills needs to be improved given the demands encountered in industry. Communication is multifaceted and incorporates various elements, such as oral, written, listening, visual, intercultural, interdisciplinary, etc. and these things need to be considered when examining communication in engineering education (Riemer, 2007).

Geppert (1995), contends that the ability of engineers to communicate effectively has always been important to industry and academia but it matters even more today because of the growing complexity of systems and the cross-disciplinary –team approach to engineering. Engineers may be technically competent; however, they often lack good communication skills that are necessary in order to transfer information and reasons. This situation makes excellent technical skills redundant. It is obvious that communication skills are critical tools for success (Dulevičius & Naginevičienė, 2005).

Illing (2001), in his report on *Wanted: skills in communication*, stated that employers now seek graduates with skills beyond the standard paper degree; this includes an excellent level of skills in communication, decision making and teamwork.. Other areas identified in the report included competencies in business acumen, marketing and public relations. Having the most knowledge was not as important as getting the work done in the most effective manner. Employers gave considerable value on graduates acquiring a diverse set of skills in differing work environment.

In reviewing CSD, the literature that follows will provide examples of how CSD is categorized with great importance alongside the other hard core skills. It cannot be implied that CSD is secondary to or more easily developed than the other "hard" technical expertise (Wilk & Anderson, 2002). On the contrary, a great importance of this ability to engineering education has emerged over the last decade (ASEE, 1994), and ABET Engineering Criteria (2000) has targeted many of these as essential program outcomes in order for engineering programs to be accredited. The National Advisory Council (ASEE, 1994), in its report "Engineering Education for a Changing World." refer CSD as a professional skill which is a combination of 'contextual' and 'process' skills, to describe the elements of traditional engineering education, which is seen as critical for the success in the twenty first century.

2.0 CSD in Engineering Education Accreditation Criteria

2.1   Malaysian accreditation standards

CSD is one of the ten learning outcomes identified in the Board of Engineers' (BEM) (BEM, 2007)competency manual. It outlines details for an engineering program to be accredited. The Engineering Accreditation Council (EAC) is a delegated body by BEM as the only recognized accrediting body for engineering degree programs offered in all Institution of Higher Learning (IHL) in Malaysia. Members of EAC comprise of five (5)

stakeholders namely, the Board of Engineers (BEM) [6 representatives], the Institution of Engineers Malaysia (IEM) [6 representatives], Employers [3 representative], National Accreditation Board (LAN) [1 representative] and the Public Service Department (JPA) [1 representative]. EAC has provided leadership and quality assurance in engineering higher education since 2000. EAC accredits programs at 23 IHL (BEM, 2007).

Student achievements are measured by learning outcomes. These learning outcomes distinguish the varying competencies as to what a student will be able to do at the end of a period of study. They are based on ten domains:

i.   ability to acquire and apply knowledge of science and engineering fundamentals;
ii.   acquired in depth technical competence in a specific engineering discipline;
iii.   ability to undertake problem identification, formulation and solution;
iv.   ability to utilize systems approach to design and evaluate operational performance;
v.   understanding of the principles of design for sustainable development;
vi.   understanding of professional and ethical responsibilities and commitment to them;
vii.   ability to communicate effectively, not only with engineers but also with the community at large;
viii.   ability to function effectively as an individual and in a group with the capacity to be a leader or manager ;
ix.   understanding of the social, cultural, global and environmental responsibilities of a professional engineer; and
x.   recognizing the need to undertake life long learning, and possessing/acquiring the capacity to do so.

One of the institutions of higher learning (IHL) in Malaysia, the Malaysia University of Technology or better known locally as *Universiti Teknologi Malaysia* (UTM), has even drawn up its own set of seven graduate attributes in line with it vision and mission statement. UTM is committed to graduating competent, creative and versatile professionals, who are guided by high moral and ethical values in the service of God and mankind. This will require graduates with sound disciplinary and professional knowledge, high self-esteem and *effective skills in communication*; teamwork; critical thinking and problem solving; lifelong learning and information management; ethics and integrity; entrepreneurship skills; and finally leadership skills (UTM, 2008).

2.2   International accreditation standards

One of the most established and recognized signatory accreditation bodies of the Washington Accord representing the United States is the Accreditation Board for Engineering and Technology (ABET). It has developed its new Engineering Criteria (2000, p. 1) which is included in Criterion 3, a set of eleven outcomes that all engineering graduates should have. ABET challenges colleges of engineering to produce graduates with professional as well as technical skills. Specifically, ABET Criterion 3 outlines the desired attributes for graduate engineers One of them is an ability to communicate effectively (3g):

i.   an ability to apply knowledge of mathematics, science, and engineering (3a);
ii.   an ability to design and conduct experiments, as well as to analyze and interpret data (3b);
iii.   an ability to design a system, component, or process to meet desired needs (3c);
iv.   an ability to function on multi-disciplinary teams (3d);
v.   an ability to identify, formulate, and solve engineering problems (3e);
vi.   an understanding of professional and ethical responsibility (3f);
vii.   an ability to communicate effectively (3g),
viii.   the broad education necessary to understand the impact of engineering solutions in a global and societal context (3h);
ix.   a recognition of the need for, and an ability to engage in life-long learning (3i);
x.   a knowledge of contemporary issues (3j);
xi.   an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (3k).

3.0 Defining CSD Program Outcomes

3.1   The Institute for Electrical and Electronics Engineers (IEEE)

Even though ABET and BEM, does not elaborate specifically on the sub components of CSD in its framework, nevertheless, the Institute for Electrical and Electronics Engineers (IEEE), the Institution of Engineers Australia (IEA), and similarly UTM being one of the established IHL in Malaysia have given a very detailed definition of CSD in its expected program outcomes.

The Institute for Electrical and Electronics Engineers (IEEE) (2004) curriculum guideline for undergraduate degree programs in engineering highlighted in Section 5.6, that engineers must be able to communicate effectively with colleagues and clients. Because of the importance of good communication skills in nearly all careers, students must improve on their oral and written skills in a variety of context – both inside and outside of engineering courses. One particular aspect of the activity of an engineer is to pass project requirements to a workshop or to technical support staff, which in an industrial setting may be local or remote. Providing clear and succinct instructions and having a proper regard for the role and purpose of support staff affects the efficiency and the nature of the working environment. This trait is a fundamental communication skill. Considering these issues, students should learn to:

i.   Communicate ideas effectively in written form; this should include technical writing experiences (e.g. of specifications, requirements, safety cases, documentation) as well as report writing and this should address the use of figures, diagrams and appropriate references;
ii.   Make effective oral presentations, both formally and informally;
iii.   Understand and offer constructive critiques of the presentations of others;
iv.   Argue (politely yet effectively) in defense of a position;
v.   Extract requirements from a customer by careful and penetrating questions using a disciplined and structured approach;
vi.   Demonstrate the capabilities of a product.

To enhance or emphasize the requisite communication skills needed by all students, an engineering curriculum at a minimum should require:

i.   Course work that emphasizes the mechanics and process of writing;
ii.   One or more formal written reports;
iii.   Opportunities to critique a written report;
iv.   One or more formal oral presentations to a group;
v.   Opportunities to critique an oral presentation;

3.2   The Institution of Engineers Australia Accreditation Board (IEA)

IEA is another strong international signatory accreditation body of the Washington Accord which could be looked upon as a strong representative of the Asia Pacific Region. IEA uses the term *Stage 1 competency* (IEA, 2005). Stage 1 competency corresponds to the completion of a 4-year Bachelor of Engineering degree accredited by Engineers Australia. It covers three levels of competencies, knowledge (PE1), competencies(PE2) and attributes(PE3). Graduates must demonstrate at least the substance of each element. Assessment will be made in a holistic way.

PE1   Knowledge Base
PE1.1 Knowledge of science and engineering fundamentals;
PE1.2 In-depth technical competence in at least one engineering discipline;
PE1.3 Techniques and resources;
PE1.4 General Knowledge.

PE2   Engineering Ability
PE2.1 Ability to undertake problem identification, formulation, and solution;
PE2.2 Understanding of social, cultural, global, and environmental responsibilities and the need to employ principles of sustainable development;
PE2.3 Ability to utilize a systems approach to complex problems and to design and operational performance;
PE2.4 Proficiency in engineering design;
PE2.5 Ability to conduct an engineering project;
PE2.6 Understanding of the business environment.

PE3   Professional Attributes
PE3.1 Ability to communicate effectively, with the engineering team and with the community at large;
PE3.2 Ability to manage information and documentation;
PE3.3 Capacity for creativity and innovation;
PE3.4 Understanding of professional and ethical responsibilities, and commitment to them;
PE3.5 Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member;
PE3.6 Capacity for lifelong learning and professional development;
PE3.7 Professional attitudes.

IEA went on to further define CSD in its Stage I competency manual in Section 4.3 – PE 3.1: the ability to communicate effectively, with the engineering team and with the community at large (IEA, 2005) as having:
i.   high level of competence in written and spoken English;

iii.   ability to make effective oral and written presentations to technical and non-technical audience;
iv.   capacity to hear and comprehend others' viewpoints as well as convey information;
v.   effectiveness in discussion and negotiation and in presenting arguments clearly and concisely;
vi.   ability to represent engineering issues and the engineering profession to the broader community.

3.3.   University Technology Malaysia (UTM)

The communicative skills development aspiration of a UTM graduate is for the students to be able to incorporate the ability to communicate effectively in Bahasa Melayu and English across a range of contexts and audiences and have the:

i.   ability to present information and express ideas clearly, effectively and confidently through written and oral modes;
ii.   ability to actively listen and respond to the ideas of other people;
iii.   ability to negotiate and reach agreement;
iv.   ability to make clear and confident presentation appropriate to audience; and the
v.   ability to use technology in presentation.

4.0 Mapping of Accreditation Standards of CSD

Since it is not possible to study the full range of professional skills as mentioned in ABET Criterion 3, it has been decided to concentrate only on Communication skills development as

> 'Communication is a very complex process and the focus of this study is primarily on some tools of communication - writing, oral presentations, electronics and graphical communication and the process of group or team working (Kemp & Seagraves, 1995; Wilk & Anderson, 2002).'

The communicative skills development criteria of the three international standards identified earlier in IEEE, IEA as well as the local standards to be achieved by UTM in its graduate attributes are mapped along side each other to achieve congruency in the skills so that they could be used as an assessment indicators for the purpose of future research. Table 1 shows the result of the mapping process and the final outcome of the combined attributes is shown in the right hand column. The final comprehensive list is as follows:

1.   Present information and express ideas clearly, effectively and confidently using technology through oral modes;
2.   Present information and express ideas clearly, effectively and confidently using technology through written modes;
3.   Ability to actively listen and respond to the ideas of other people and offer constructive critiques of the presentations of others;
4.   Ability to negotiate and reach agreement politely and effectively;
5.   Ability to work as a team and discuss multi disciplinary issues collectively.

These attributes will form the basis of the questions used in the closed-form questionnaire for students and faculty members as well as used during the observation and documentation analysis process throughout the investigation on CSD and its implementation in an undergraduate engineering curriculum.

5.0 Final Year Project Design

Capstone design courses or locally known as the Final Year Project design courses are one of the most effective ways for engineering departments to facilitate the outcomes as prescribed above. It is a major design experience, taken in the senior year of an engineering degree program. Duff & Schildgen (2005), compliments the use of capstone design courses as:

> 'The senior project is intended to be a culminating scholastic effort or capstone experience. The objectives are to refine skills in communication, research and information retrieval, critical analysis and criticism, and to demonstrate technical competence in each student's area of study. The senior project is evidence of potential for outstanding performance at the advanced level and is characterized by experimental, theoretical, or developmental work leading to meaningful results presented as a final paper and oral report at the end of the semester.'

Scales et al.(1998) proposed the use of Capstone design courses as it serves to integrate previous course work and it requires students to perform at a professional level, demonstrating technical expertise and communication skills. The capstone design course provides a unique milestone where the combined skills and conceptual attributes of the undergraduate engineering experience can be measured. Numerous facets of the intellectual development of program graduates can be assessed by measuring technical and communication competencies. Here also, an assessment of student confidence in their ability to solve design problems with realistic constraints can be made. Typical quantitative tools for performance assessment include project grades assigned by the course instructor, peer evaluations of team member participation and report quality, and faculty-colleague check sheet evaluations of project reports. Qualitative assessment of capstone design work can be made through reviews of student portfolios and course folders of project work. The structure of capstone design courses can be used to measure student technical performance, and communication and teaming skills which they have developed.

6.0 Conclusion

Engineering curriculum should integrate writing and verbal discussion consistently in substantive ways. Institutions should not view communication skills as separate entities; instead, faculty members should incorporate fully such skills into the engineering curriculum and its requirements. They must prepare students for a significant challenge they will face in adopting these significant learning outcomes into their engineering curriculum. At the speed at which technological advances are changing society and the workplace requires students to possess a greater number of personal skills with which they can effectively cope with the increasing demands placed upon them in the workplace. Pappas & Lesko stressed that changes in the nature of

work, methods of communication, lifestyle, and demands on time and commitment force us to reconsider how we will live in an increasingly technological society. Individuals need to grow in concert with these technological changes in order to adjust to it, and have some influence on this new social order. The society is at the threshold of yet another period of unparalleled growth and change, and the engineering curricula need to prepare students not simply for the technical work they will do in the workplace, but for the engineering lifestyle they will live (2001).

TABLE 1: Mapping of the criteria and standards to develop a combined CSD attributes to access FYP.

IEEE Standards	Institution of Engineering Australia(IEA)	UTM Graduate attributes	SUMMARY OF COMBINED ARRIBUTES
Communicate ideas effectively in written form; this should include technical writing experiences (e.g. of specifications, requirements, safety cases, documentation) as well as report writing and this should address the use of figures, diagrams and appropriate references;	Ability to communicate effectively, with the engineering team and with the community at large; - High level of competence in written and spoken English;	Ability to present information and express ideas clearly, effectively and confidently through written and oral modes	1. Present information and express ideas clearly, effectively and confidently using technology through oral modes
Make effective oral presentations, both formally and informally;	- Ability to make effective oral and written presentations to technical and non-technical audience;	Ability to make clear and confident presentation appropriate to audience Ability to use technology in presentation	2. Present information and express ideas clearly, effectively and confidently using technology through written modes
Understand and offer constructive critiques of the presentations of others;	- Capacity to hear and comprehend others' viewpoints as well as convey information;	Ability to actively listen and respond to the ideas of other people	3. Ability to actively listen and respond to the ideas of other people and offer constructive critiques of the presentations of others

Argue (politely yet effectively) in defense of a position;	- Effectiveness in discussion and negotiation and in presenting arguments clearly and concisely;	Ability to negotiate and reach agreement	*4. Ability to negotiate and reach agreement politely and effectively*
Extract requirements from a customer by careful and penetrating questions using a disciplined and structured approach; Demonstrate the capabilities of a product.	- Ability to represent engineering issues and the engineering profession to the broader community.	Teamwork and Multidisciplinary Skills	*5. Ability to work as a team and discuss multi disciplinary issues collectively*

References

ABET. (2000). ABET Engineering Criteria (Publication no. http://www.ele.uri.edu//daly/criteria.2000.html). Retrieved 21 April 2008, from Accreditation Board for Engineering and Technology, Inc.:

ASEE, Project Board. (1994). Engineering Education for a Changing World. *ASEE Prism*, 20-27.

Barrie, S. C. (2004). A research-based approach to generic graduate attributes policy. *Higher Education Research & Development, 23*(3), 261-275.

BEM, Board of Engineers Malaysia. (2007). *Engineering Programme Accreditation Manual*. Retrieved. from.

Duff, J. M., & Schildgen, T. E. (2005). *Establishing Outcomes for Senior Capstone Projects In Industrial Technology.* Paper presented at the 2005 American Society for Engineering Education Annual Conference & Exposition.

Dulevičius, J., & Naginevičienė, L. (2005). Engineering Communication. *Global Journal of Engineering Education, 9*(1), 19-25.

Further Education Unit, Training Agency (1989). *A Guide to Work-based Learning Terms (London, FEU). .* London: Further Education Unit.

Geppert, L. (1995). Educating the Renaissance Engineer. *IEEE Spectrum*, 39-43.

Grünwald, N. (1999). *Engineers of Tomorrow, Quo vadis German engineering education. .* Paper presented at the 2nd Asia-Pacific Forum on Engineering Technology Education, Sydney, Australia.

IEA, The Institution of Engineering Australia. (2005). *Engineers Australia national Generic Competency Standards - Stage 1 Competency Standards for professional Engineers.*

IEEE, Institute for Electrical and Electronics Engineers (2004). Computer Engineering 2004 (Publication. Retrieved 21 April 2008, from IEEE-CS: http://www.computer.org/portal/cms_docs_ieeecs/ieeecs/education/cc2001/CCCE-FinalReport-2004Dec12-Final.pdf

Illing, D. (2001). Wanted: skills in communication. *The Australian, 24 January*(23).

Jensen, H. P. (2000). Strategic planning for the education process in the next century. . *Global Journal of Engineering Education, 4*(1), 35-42.

Jessup, G. (1991). *Outcomes: The emerging model of education and training.* London: Falmer Press.

Kemp, I. J., & Seagraves, L. (1995). Transferable skills--can higher education deliver? *Studies in Higher Education, 20*(3), 315.

Muhammad Rashid bin Rajuddin, Prof., Dr. . (2006). *Keynote Address.* Paper presented at the Technical and Vocational Education in Malaysia, Hotel Sofitel, Senai, Johor. .

Pappas, E. C., & Lesko, J. (2001). *The communications-centered senior design class at Virginia tech.* Paper presented at the 2001 ASEE Annual Conference and Exposition.

Riemer, M. J. (2002). English and Communication Skills for the Global Engineer. *Global Journal of Engineering Education, 6*(1), 91 - 100.

Riemer, M. J. (2007). Communication Skills for the 21st Century Engineer. *Global Journal of Engineering Education, 11*(1), 1 - 12.

Scales, K., Owen, C., Shiohare, S., & Leonard, M. (1998). Preparing for Program Accreditation Review Under ABET Engineering Criteria 2000: Choosing Outcome Indicators. *Journal of Engineering Education, 87*(3).

UTM. (2008). Seven Attributes of UTM Graduates (Publication no. http://web.utm.my/tncap/index.php?option=content&task=view&id=32&Itemid=57). Retrieved 21 April 2008:

Wilk, R. D., & Anderson, A. M. (2002). *Development of Communication Skills Across the Engineering Curriculum.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition.