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Research paper

Competencies of Engineering Graduates: What are the Employer's Expectations?

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Abstract

Recently, universities keep receiving complaints from the industries regarding the capability of engineering graduates when starting their new job. The complaints were always about the inability of the engineering graduates to adapt in the industry. This is due to minimum exposure of industrial training period given by university to them. As a result, most of fresh engineering graduates do not have enough industry experience that is demanded by industry. Worse case, there is mismatching skill during industrial training which not relevance to what they are studied before. This problem contributes to unemployment issue among engineering fresh graduates. The purpose of this paper is to review and analyse about the engineering competencies from all over the world. The paper is written on extensive secondary data analysis. It is revealed that the criteria needed by employers from most developed countries are almost similar. Based on summary, technical and non-technical skills are both important to become a competent engineer. There are some recommendations to develop and improve both technical and non-technical skills that can be emphasized by authorities of higher education especially in Malaysia.

Keywords: *Competencies; Engineering; Employer's Expectations; Skills; Higher Institution; Review*

1. Introduction

In this century, rapid technological change parallel with extensive economic restructuring leads some to associate technology with unemployment issues and social distress. Technological change drives long-term economic growth, productivity and improvement in living standards. Historically, this process has led to net job creation, as new technology in an old industry is replaced with new and modern ones and workers need to adapt to it (1). Globalization era needs human capital resources with competency, competitive and multi-skilled to lead a country to be a developed country. Malaysia is one of developing country in the world that is facing the unemployment issue among engineering graduates because they are depending on academic qualifications to get jobs (2). Even though the unemployment rate in Malaysia is considered low as compared to countries like the United States and other countries in Europe, this issue should not be ignored(2). This is because graduates are human workforce that is vital and become the core for innovative and productive high-income economy(3). This is also proven in others developing country like Uganda, which is the educated human resources are also lack of employability skills that are needed in the labour market(4). This issue arise when there is insufficient or inappropriate education and training which does not focus on soft skills such as innovation and creativity, communication skills and entrepreneurship to increase the competency and competitiveness of the workers(4). A low quality of human capital resource may lead to a slow movement of economy in a country. This is a huge problem in the most of developing country in the world including Malaysia. The unemployment issue in Malaysia is always reflected to the system of higher education in order to produce graduates that meet the industries expectations. Although there is improvement done in the education system, there are still complaints received from the employers(5). It is also clarified that there is an issue with education systems that fail to produce future workers with the kinds of skills required by today's industries(6).

Furthermore, universities keep receiving complaints from the industries regarding the capability of engineering graduates when starting their new job. The complaints were always about the inability of the engineering graduates to adapt in the industry field (7). There is even a consensus in the engineering community about what those competencies should be: communication skills, business skills, teamwork skills, creativity, lifelong learning skills, and problem solving skills (8). This is due to minimum industrial exposure period given by university to them. As a result, most of fresh graduates do not have enough experience that is demanded by industry. Worse case, there is mismatching skill during industrial training which not relevance to what they are studied before. This becomes university responsibility in providing students with significant and valuable industrial training (7). Engineering graduates may need additional training to acquire missing competencies, which comes at cost to their employers (8). The uncertainty about what engineering really involves and feelings of being less-prepared may convince some graduates to abandon engineering altogether. This can partially reflects a nationwide loss of interest in engineering, a belief that engineering careers are no longer secure, and the realization that other professions pay higher wages (8).

The development of higher education and careers in the 21st century is discussed based on knowledge, skills and ability of graduates to meet industries expectations. Higher education is based on preparing a standard curriculum for students in certain period of time in order for students to be equipped by emphasizing the

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knowledge and specific skills (9). Meanwhile, the industries expectations and job market are influenced by economy, social and competition. Recently, it has been recognized that fresh graduates have less knowledge and skills required by the industries (5, 10). The unemployment issue among graduates is the vital challenge to the university and industry to collaborate to find the solution(11). The role of universities in preparing graduates who are competent, innovative and meet the expectation of industries is very important to ensure that graduates have the skills and knowledge industries. Student development is not only measured in academic performance but also includes the soft skills and qualities required by the industries (5). Some of the skills required by the industry are language skills, communication skills, thinking skills, planning and administration, and information and communication technology (ICT) skills (12) Furthermore, (11) explains graduates with high labour market are those who think critically, the ability to argue, knowledgeable and eager to learn. Meanwhile, European Union (EU) estimates that 35% of new jobs will require high skills qualifications (13). So, the challenge nowadays university should be parallel with the current demands of industries and able to provide skilled and competent graduates according to requirements of the industries(14). In order to enhance the career preparedness of students, the university need to play an important role by providing guidance and counselling services such as counselling and career guidance, career fairs, career workshops, and programs of other interventions.

2. Engineering Competencies

Competencies of engineers can be shaped especially while they are still studying. An enough competency of engineering is needed before they jump to the industries to start their career. There might be a lot of difficulties they may face in early career engineers. For example, there are lots of new challenges with unstructured, real world applications of their technical knowledge that they may have not learned at university (15). Furthermore, new engineers need to navigate unfamiliar systems that is used by the industries(16). As a new engineering graduate, a fresh new engineer may be still figuring out their identities and goals for their careers. Thus, in order to help new engineers prepare for a successful transition to the workplace, engineering practice is vitally important to understand what elements shape early career engineers' decisions(15).

The study done by as can be found in (17) shows that there is an urgent need for engineering programmes to improve in all areas, especially in non-technical aspects of engineering education. In addition, continuously updating and improving the technical engineering skills and knowledge are very important for changes in the technologies growth(18). The Employability Skills Framework listed thirteen most important generic skills acquired by the engineering graduates. The skills are based on criteria emphasized for professional skills from Criteria for Accrediting Engineering Programs as approved by Accreditation Board for Engineering and Technology (ABET). The finding on engineering employability skills is summarised in Table 1 according to the importance of employability skills expected by employers.

The skills and attributes that required for Malaysian engineering graduates is referring to criteria that defined in United State of America (USA), United Kingdom(UK), Australia (AUS) and Japan in their framework of engineering and employability skills as identified by industry and employers(19). Table 1 and 2 show the elements that included in the frameworks from those countries and elements that fixed by Ministry of Higher Education (MOHE) of Malaysia. Malaysian engineering education mainly guided by accrediting body, Engineering Accreditation Councils (EAC) of Malaysia and the Malaysian Quality Assurance (MQA) Department of the Ministry of Higher Education Malaysia. EAC is the body appointed by Board of Engineers Malaysia (BEM) for accreditation of engineering programme in Malaysia. Accreditation policy required engineering graduates to have the necessary attributes, skills and competencies reflected in the graduate outcomes in EAC Manual (19)

Table 1: International Engineering Skills of Ministry of Higher Education (Malaysia), EAC of ABET (USA) and TAC of ABET (USA).

Skills	Ministry of Higher Education (Malaysia)	EAC of ABET (USA)	TAC of ABET (USA)
Communication effectively	The ability to present ideas with confident and effective through aural, oral and written modes, not only with engineers but also with the community at large.	An ability to communicate effectively	An ability to communicate effectively
Competent in application and practice	The ability to use the techniques, skills, and modern engineering tools.	An ability to use the techniques, skills and modern engineering tools necessary for engineering	An appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines
Interpersonal or team working skills	The ability to function effectively as an individual and in a group with the capacity to be a leader or manager as well as an effective team member.	An ability to function in multidisciplinary team.	An ability to function effectively on teams. A commitment to quality, timeliness, and continuous.
Engineering problem solving and decision making skills	The ability to undertake problem identification, apply problem solving, formulation and solutions.	An ability to identify, formulate and solve engineering problems;	An ability to identify, analyse and solve technical problems
Apply knowledge of science and engineering principles	The ability to acquire and apply knowledge of engineering fundamentals.	An ability to apply knowledge of math, science, and engineering;	An ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology
Competent in specific engineering discipline	The ability to acquire in-depth technical competence in a specific engineering discipline.		
Understand professional , social and ethical responsibilities	The ability to understand the social , cultural, global and environmental responsibilities of a professional engineer, and commitment to professional and ethical responsibilities	An understanding the impact of engineering solutions in a global and societal context. An understanding professional and ethical responsibilities.	A respect for diversity and a knowledge of contemporary professional, societal and global issues. An ability to understand professional, ethical and social responsibilities
Lifelong learning	The ability to recognize the need to undertake lifelong learning, and possessing / acquiring the capacity to do so.	A recognition of need and ability to engage in life-long learning	A recognition of the need for, and an ability to engage in lifelong learning
Engineering system approach	The ability to utilize a systems approach to design and evaluate operational performance.		

Design and conduct experiments Description	The ability to design and conduct experiments, as well as to analyse and interpret data.	An ability to design and conduct experiments, as well as analyze and interpret data; An ability to design a system, component or process to meet desired needs;	An ability to conduct, analyze and interpret experiments and apply experimental results to improve processes An ability to apply creativity in the design of systems, components or processes appropriate to program objectives
Knowledge of contemporary issues	The ability to continue learning independently in the acquisition of new knowledge, skills and technologies. Nowadays, the use of information, communication and computing technologies are very essential in the knowledge- based era.	A knowledge of contemporary issues	
Competency in theoretical and research	Having the competency in theoretical and research engineering.		
Entrepreneurial skills	Having basic entrepreneurial skills.		
Products			
Quality and Safety			

Table 2: International Engineering Skills of UK-SPECS, IES (Singapore), the Engineers Australia Accreditation Board and JABEE (Japan).

Skills	UK-SPECS	IES SINGAPORE	THE ENGINEERS AUSTRALIA ACCREDIATION BOARD	JABEE (JAPAN)
Communication effectively		Communicate effectively	Ability to communicate effectively; not only with engineers but also with the community at large	Japanese-language communications skills including methodical writing, verbal presentation and debate abilities, as well as basic skills for international communications
Competent in application and practice		Use the techniques, skills, and modern engineering tools necessary for engineering practice	Ability to utilize a systems approach to design and operational performance.	The ability to implement and organize works systematically under given constraints
Interpersonal or team working skills	Demonstrate effective interpersonal skills	Function effectively within multi-disciplinary teams and understand the fundamental precepts of effective project management	Ability to function effectively as an individual and in multi-disciplinary and multicultural teams, with the capacity to be a leader or manager as well as an effective team member	
Engineering problem solving and decision making skills		Identify, formulate, research through relevant literature review, and solve engineering problems reaching substantiated conclusions;	ability to undertake problem identification, formulation and solution	
Apply knowledge of science and engineering principles			Ability to apply knowledge of basic science and engineering fundamentals	Knowledge of mathematics, natural sciences and information technology, and the ability to apply such knowledge. The ability and intellectual foundation for considering issues from a global and multi- lateral viewpoint
Competent in specific engineering discipline			In depth technical competence in at least one engineering discipline	Specialized engineering knowledge in each applicable field, and the ability to apply such knowledge to provide solutions to actual problems
Understand professional , social and ethical responsibilities	Demonstrate a personal commitment to professional standards, recognizing obligations to society, the profession and the environment	Understand the impact of engineering solutions in a societal context and to be able to respond effectively to the needs for sustainable development; Understand professional, ethical and moral responsibility	Understanding of social, cultural, global and environmental responsibilities of the professional engineers and the need of sustainable development; Understanding of professional and ethical responsibilities and commitment to them	Understanding of the effects and impact of technology on society and nature, and of engineers' social responsibilities (engineering ethics);
Lifelong learning		Recognize the need for, and have the ability to engage in life-long learning	Expectation of the need to undertake lifelong learning, and capacity to do so	The ability to carry on learning on an independent and sustainable basis
Engineering system approach	Use a combination of general and specialist engineering knowledge and understanding to apply existing			

	and emerging technology			
Design and conduct experiments Description		Design and conduct experiments, analyse, interpret data and synthesize valid conclusions. Design a system, component, or process, and synthesize solutions to achieve desired needs;	Understanding of the principles of sustainable design and development;	Design abilities to organize comprehensive solutions to societal needs by exploiting various disciplines of science, engineering and information
Knowledge of contemporary issues				
Competency in theoretical and research	Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate and maintain engineering products, processes, systems, and services. Plan and manage engineering projects.			
Entrepreneurial skills	Provide technical and commercial management			
Products	Develop, produce, install and maintain own product			
Quality and Safety	Improve the quality and safety of engineering products and processes	Considerations for public health and safety, cultural, societal, and environmental constraints;		

3. Discussions and Recommendations

Competency of an engineer is ability of non-technical and occupational skills that are just as important as technical skills(20). Many researches in Malaysia revealed that fresh engineers in Malaysia are fine in technical skills but lack in non-technical skills (20, 21). But, based on Tables 1 and 2, they summarize that most countries accentuate technical and non-technical skills. This combinations are very important and supported by Engineering Competency Model by Clearinghouse(22). There are four tiers that should be mastered by an engineer based on this model. Tier 1 is Personal Effectiveness Competencies is the most important competency includes seven criteria which are Interpersonal skills, Integrity, Professionalism, Initiative, Adaptability and Flexibility, Dependability and Reliability and Lifelong Learning. In Tier 2, Academic Competencies which are Reading, Writing, Mathematics, Science and Technology, Communication, Critical and Analytical and Computer Skills are primarily learned in a school setting which include cognitive functions and thinking styles. Academic competencies are likely to apply to all industries and occupations. Tier 3 which is Workplace Competencies represent motives and traits, as well as interpersonal and self-management styles. They are generally applicable to a large number of occupations and industries. The criteria are Teamwork, Client/Stakeholder focus, Planning and Organizing, Creative Thinking, Problem Solving, Prevention and Decision Making, Business, Legal and Public Policy, Sustainability, Societal and Environmental Impact, Engineering Economics, Quality Control and Quality Assurance and Safety, Health, Security and Environment. In this model, Industry-Wide Skills Technical Competency includes Foundation of Engineering, Design, Manufacturing and Construction, Operational and Maintenance, Professional Ethics, Business, Legal and Public Policy, Sustainability, Societal and Environmental Impact, Engineering Economics, Quality Control and Quality Assurance, and Safety, Health and Security Assurance. As can be compared between criteria in this model and criteria that are fixed in Table 3, they are quite similar.

Based on research done by(17), Graduates were seen did not meet the market demand and expectation where they were seen as lacking of creativity, not innovative and creative, not competitive, dependent and poor in communication skills. They also said that 23% of employers were dissatisfied with technical skills of engineering graduate employees. In addition, based on previous studies in Malaysia and United States, most employers did not satisfy with the graduates interpersonal skills (23). Most Malaysian graduates are unemployed are because of too depending on academic qualifications but lack on non-technical skills that are very essential to the employers(11).

Therefore, it was suggested to the authorities of higher education to develop more of technical and non-technical skills through their curriculum and co-curriculum (23). Based on research done by(24), Project Based Learning (PjBL) is said can be used to develop more non-technical skills among engineering graduates. It is found in that the engineering students claimed that they were able to train and practice their non-technical skills through PjBL because of the appropriateness of PjBL as a platform or medium to improve their technical skills, as well as non-technical skills. Besides, Problem Oriented Project Based Learning (POPBL) should be employed by engineering students because it was said can promote more creativity, innovative, critical thinking and analytical thinking in their approach(25). Based on these discussions, the university graduates need knowledge and skills appropriate to the job market in the 21st century. (14) describes the skills related to careers in the 21st century is the cognitive efficiency, including in-depth knowledge in their areas of expertise, problem-solving skills and making decisions and the ability to maintain the personal traits associated with a career . This issue becomes a challenge to universities to provide standard curriculum in order to produce graduates who are multi-skilled and implicates to the curriculum and the factors supporting the career development of students.

In order to achieve both benefits to universities and industries, a collaboration between them should be reorganized(26-28). An interrelated relation between academic researcher, university and industry has to be built. Currently, Malaysia begins on focusing research product commercialization in university for development of nations as they believe that university will produce a research that can give additional profit to the nation. Thus, university plays huge role of sharing research and collaborating with industry and government for research product commercialization(29). In order to differentiate teaching and learning programs, support the funding and application of research, and reinforce the role of universities as drivers of innovation and growth(1).

Figure 1 shows Engineering Competency Model by (22).

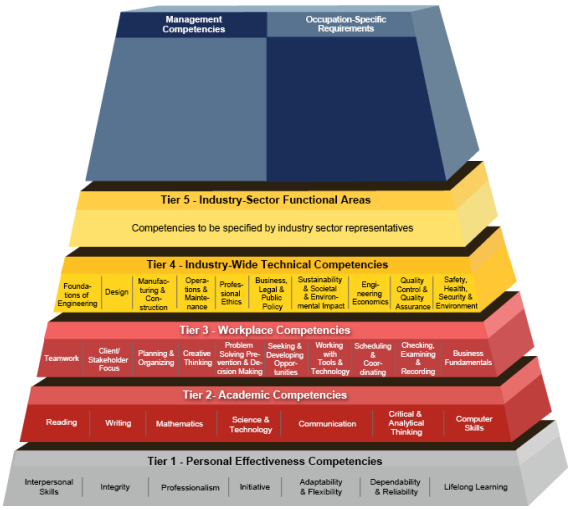


Fig. 1: Engineering Competency Model

4. Conclusions

This paper reviews the unemployment issue among engineering graduates and the competencies of engineers from various developed countries that are fixed by their own board. The competency of an engineering graduate is reflected to higher institution authorities in providing proper curriculum in order to develop technical and non-technical skills among graduates. This will be a very huge challenge to public universities in Malaysia to produce graduates with specialized skills to undergo employment in the industries. As suggestion, a very specific career preparation framework will be built in order to create a flow that can be referred by many parties to increase the employability skills among fresh graduates, yet the unemployment issue can be slowly vanished. This framework will be a platform for students in understanding their potential, the working field experiences and able to increase their specific skills.

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