Quality Assurance in Engineering Education: Accreditation and Its Global Influence

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Abstract

Historically the quality of engineering education has been controlled by the institution itself and monitored by the national level government organizations. As engineering has become a more global profession, issues of *quality* assurance and competitiveness of *engineering education were being* intensifying continually. With the effect of globalization 3.0 (2000-present), the concern of quality assurance and competitiveness of engineering education has been amplified further. In general, as education has been impacted by globalization, schools and education systems now are competing on a global arena rather than just local or national competition. Accreditation Board for Engineering and Technology (ABET), founded in 1932 as an engineering professional body, dedicated to the education, accreditation, regulation and professional development of engineering professionals and students in the United States. However, the less developed countries were facing difficulties to maintain quality of engineering education as required in the global market. As a consequence, developed countries do not find a smooth supply of competent engineers. With this realization, the International Engineering Alliance (IEA), a global not-for-profit organisation, seeks to improve engineering education and competence globally. It fulfils this mission through its constituents: education agreements that are concerned with standards, best practice accreditation processes and mutual recognition of accredited engineering programmes and agreements for defining and recognising professional competence. An explicit outcome of IEA is the Washington Accord originally signed in 1989. This accord is an international accreditation agreement for tertiary-level engineering qualifications between the bodies responsible for accreditation in its signatory countries and regions. With this, the accreditation had become increasingly prescriptive and a powerful tool for quality assurance. It is a "Quality Stamp" which ensures that an accredited programme has undergone a rigorous process of external peer evaluation based on predefined standards and complies with the minimum requirements. This paper focuses on the outcomes of accreditation to enhance excellence in engineering education. Previous studies in various national contexts are reviewed and the question of whether accreditation can really uphold a sustainable engineering education is answered.

Keywords:
Accreditation, Higher Education, Quality Assurance, Continual Quality Improvement (CQI).

1. Introduction

Globalization means the speedup of movements and exchanges of human beings, goods, and services, capital, technologies or cultural practices all over the planet. Globalization promotes interactions between different regions and populations around the globe. It is a dynamic process carried out through various channels such as free trade, liberalized capital flows and movements of people. Historically, there are four phases of globalization which are (i) humanising the globe (300000-10000 BCE), (ii) localising the global economy (10000 BCE–1820 CE), (iii) globalising local economies (1820–1990) and (iv) the new globalisation (1990-now). Here, we will be discussing the last two globalisations, its effect on engineering education as well as quality assurance (Kumar et al. 2020).

The globalization and mobility have been created based on technological development and which further created flow of knowledge, people, and skills. As such, engineering education has become an integral part of this globalised economy and its sustainable development. The developed countries, as the leader of globalisation, needs more engineers with "compatible" engineering qualification to support this massive trend of globalisation in world economy. This international mobility of engineering graduates has compelled educational institutions to enhance the quality and standard by introducing various quality assurance and professional accreditation processes to become compatible with each other countries in the global market (Li and Lie 2015).

As a result, most of the engineering educational institute, employers, and professional organizations are keen in the quality of education received by engineering graduates who aspire to be a part of global engineering practices at home country or abroad under the effect of globalisation. This gives birth the quality assurance and professional accreditation which are important for countries that rely on human resources export and import (Alam et al. 2007, Chowdhury and Alam 2012, Becker 2006, Chowdhury et al. 2013). However, although quality assurance is a big concern for every institution, the ultimate quality of engineering graduate varies significantly from country to country. This variation hinders the engineers to work in a team in the global market.

In realising this mismatch, International Engineering Alliance, a global non-profit organisation, comes forward to resolve the issue. In 1989, six organisations from Australia, Canada, Ireland, New Zealand, the United Kingdom and United States observed that their engineering programmes were substantially equivalent in terms of curriculum, delivery and practices. Then they sign an agreement to accept graduates from these countries without any differences. This agreement is known as "Washington Accord". Since then more members are joining every year and as of 2020, there are 21 full and 7 provisional members. The members are called signatories. Provisional signatories are recognized as having appropriate engineering educational systems but not fully implemented. Full Washington Accord signatory countries are considered to have the best developed and well-respected systems for engineering education (Chowdhury et al 2013). In the following sections, the procedure of accreditation under Washington Accord is discussed in detail.

As the authors have long teaching and accreditation experience in Malaysia, a full signatory under Washington Accord, most of the information are extracted from various document of Board of Engineers Malaysia (BEM). As these are standard, information is presented here without significant modification from BEM sources (BEM 2020, IEA 2020, EAC 2012).

2. Accreditation of Engineering Programme

Engineering is the application or practical uses of fundamental science and mathematics to solve problems. Scientists often get the credit for innovations, but it is the engineers who are making those innovations available to people under real-life environment [10]. However, in this globalized era, most of the engineering employment has shifted to global market with the focus on time-to-market, cost, quality, customer orientation, health and safety, zero waste, life-cycle costs, social and political concerns, etc. it is a major shift of the traditional engineering education. Engineers nowadays require strong technical capability, communication and persuasion skill, ability to lead and work effectively as a member of a team, understanding of the non-technical forces that profoundly influence engineering decisions, higher level of achievement through continual quality improvement (CQI).

As such educational quality is to be controlled from global perspective from where the accreditation concept aroused and guided by Washington Accord. It reflects a professional judgment that certain standards of educational quality are met. It also tells prospective students and the public that graduates have achieved a certain minimum level of competence in their fields of study. Washington Accord focuses in details on specific engineering programs that educate students for professions.

3. Qualifying Requirement and Accreditation Criteria

Under Washington Accord, an engineering programme shall be assessed to enable graduates to work in any country of signatory of Washington accord. The followings are the assessment criteria (BEM 2020).

3.1 Programme Educational Objective

Programme Educational Objective (PEO) is a specific statement in relation to university mission and vision which describe the expected achievements of graduates in their career in 3-5 years after graduation. The PEO must be cascaded down to curriculum with proper link to Programme Outcome (PO). As an example, the PEO for Mechanical, Materials and Manufacturing Engineering, University of Nottingham Malaysia are as follows (Nottingham 2021):

1. Graduates will demonstrate technical competency and leadership to become professional engineers leading to a successful career.
2. Graduates will demonstrate commitment towards sustainable development for the betterment of society.
3. Graduates will pursue lifelong learning in generating innovative engineering solutions using research and complex problem-solving skills.

3.2 Programme Outcomes

Programme Outcomes describe what students are able to perform by the time of graduation. These relate to the skills, knowledge, and behaviour that students acquire through the programme. As an example, Manufacturing Engineering Programme in International Islamic University Malaysia have long and painstaking but successful experience in accreditation under Washington Accord where the students of an engineering programme are expected to attain the following as shown in Figure 1 PO (MME 2021):

3.3 Course Outcome

In a programme of four year engineering education on the average has about 30-40 courses. Under the process of accreditation each of curses must have, but not limited to, course synopsis/syllabus, course learning outcomes, a matrix linking course outcomes to programme outcomes, a list of reference or textbook. These are to be recorded and endorsed by the curriculum committee. Examination papers, answer scheme and selected graded examination papers, projects, quizzes, tutorial questions, assignments, class projects are to be preserved systematically for reference and inspection. Course Outcomes of MANU 3312 Design of Machine Components, a third-year level manufacturing engineering course, are as follows that upon completion of this course, students should be able to:

1. Analysis of failures due to static and variable loading, estimation of endurance limit, and application of safety factor.
2. Design and analysis of permanent and non-permanent joining.
3. Design and selection of antifriction bearings, and journal bearing.
4. Design and analysis of spur, helical, and worm gears for power transfer.
5. Design and analysis of flexible mechanical elements and mechanical springs.

These course outcomes are to be meaningfully linked with programme outcome as shown in Table 1. It is worth of saying that if any course fails to have significant link with programme outcomes, that course is said to be irrelevant.

Table 1: Linkage between course outcome (CO) and programme outcome (PO) for a third year level Manufacturing Engineering course MANU3312 Design of Engineering Components at International Islamic University Malaysia'

Course Outcome of MANU 3312	Manufacturing Engineering Programme Outcomes											
	01	02	03	04	05	06	07	08	09	10	11	12
1. Analysis of failures due to static and variable loading, estimation of endurance limit, and application of safety factor	√	√	√				√					
2. Design machine elements such as shafts, keys, springs, power screw, and analysis of permanent and non-permanent joining.		√	√									
3. Design and selection of antifriction bearings, and journal bearing.			√									
4. Design and analysis of spur, helical, and worm gears for power transfer.			√									
5. Design and analysis of flexible mechanical elements and mechanical springs		√										

#	Programme Outcome	Description
1	Engineering Knowledge	Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation to the solution of complex manufacturing engineering problems.
2	Problem Analysis	Identify, formulate, conduct research literature and analyse complex manufacturing engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
3	Design/ Development of Solutions	Design solutions for complex manufacturing engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
4	Investigation	Conduct investigation of complex manufacturing engineering problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
5	Modern Tool Usage	Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex manufacturing engineering problems, with an understanding of the limitations.
6	The Engineer and Society	Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex manufacturing engineering problems.
7	Environment and Sustainability	Understand and evaluate the sustainability and impact of professional engineering work in the solutions of complex manufacturing engineering problems in societal and environmental contexts.
8	Ethics	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9	Individual and Teamwork	Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
10	Communication	Communicate effectively on complex manufacturing engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11	Project Management and Finance	Demonstrate knowledge and understanding of engineering management principles and economic decision- making and apply these to one's own work, as a member and leader in a team, to manage projects in multidisciplinary environments.
12	Lifelong Learning	Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Figure 1: Programme outcome as established for Manufacturing Engineering Programme at International Islamic University Malaysia (MME 2021).

3.4 Academic Curriculum

The teaching-learning and assessment approach shall be appropriately supporting the achievement of programme outcome through course outcome delivered on outcome based education (OBE). Overall, the academic curriculum must be balanced with all technical and non-technical as well as human science attributes listed in the PO. The curriculum of about 130-140 credit hour shall integrate theory and practice through adequate exposure to laboratory work and engineering practices. The curriculum must be well balanced with engineering core and general education component such as mathematics, computing, languages, general studies, co-curriculum, management, law, accountancy, economics, social sciences, etc. In addition to classroom teaching, curriculum also must include seminar, industry visit, integrated design project, industrial training, final year project, etc. The curriculum shall encompass the complex problem solving, complex engineering activities and knowledge profile. The curriculum development and assessment of student performance sequence are shown in Figure 2.

Figure 2: Basis for curriculum development and assessment of students' performance.

3.5 Industrial Training
Industrial training is a compulsory element for all engineering programme usually done after completing 3rd year of studies or its equivalent. This is to have real life professional exposure. It is desirable for students to achieve capability of carrying out complex engineering activities in real life setup. It is considered that there is no real substitute for first-hand experience in an engineering-practice environment, other than exposure to the industrial environment outside the university. The duration of industrial training is to be 2-6 months.

3.6 Integrated Design Projects and Final Year Project
Integrated design project is a one year long project at third year level that involves solving complex engineering problems through design, analysis and processes. As such it is a culminating and intellectual core course to meet consideration of health and safety, cultural, societal, project management, economy, environmental complexity, and sustainability. This is a group project and serves as a basis for individual and team activities. The programme should seize the opportunity to deliver and assess many relevant POs through the integrated project.

On the other hand, a final-year project is also a one year investigative research-oriented project to engineering studies at fourth year. The student is expected to develop techniques in literature review and information processing, analysis, judgement and assessment under the supervision of an academic staff. It is recommended that final-year projects should also provide opportunities to utilise appropriate modern technology, computer, simulation, etc.

3.7 Academic and Support Staff and Facilities
It is required for any engineering programme to have enough qualified academic staff to teach engineering students. The academic staff is preferably to have higher academic qualification such as Masters and PhD degree with professional and industrial experience. This is to provide effective teaching, supervision, advise, research project, professional development and interaction with industries. The academic staff to student ratio 1:20 is a guideline. There shall also be sufficient, qualified and experienced technical and administrative staff to support to the academics and co-curricular activities. On the other hand, teaching and learning facilities such as classrooms, learning-support, study space, library, computing facilities, laboratories and workshops, etc. are also must for effective teaching and learning. Supporting facilities such as residential hostels, sport and centres, health centres, student centres, and transport must be adequate to facilitate students' life on campus.

3.8 Quality Management Systems
The programme must ensure that there exists a quality management system to monitor the student activities. It stars with admission and finally through the achievement of CO→PO→PEO based on OBE. Students intending to pursue engineering programmes shall have a good achievement in mathematics, physics, and chemistry and other natural sciences. The normal entry qualification should be A 'level equivalent. It must have adequate arrangements for planning, development, delivery and review of engineering programmes together with the staff academic and professional development. The process of CQI shall be in place with full accountability. The looping of CQI is shown in Figure 3 (UTM 2021). The programme should demonstrate the necessary steps for students to get feedback and suggestions on improving the programme such as committee, forum, feedback services, and so on.

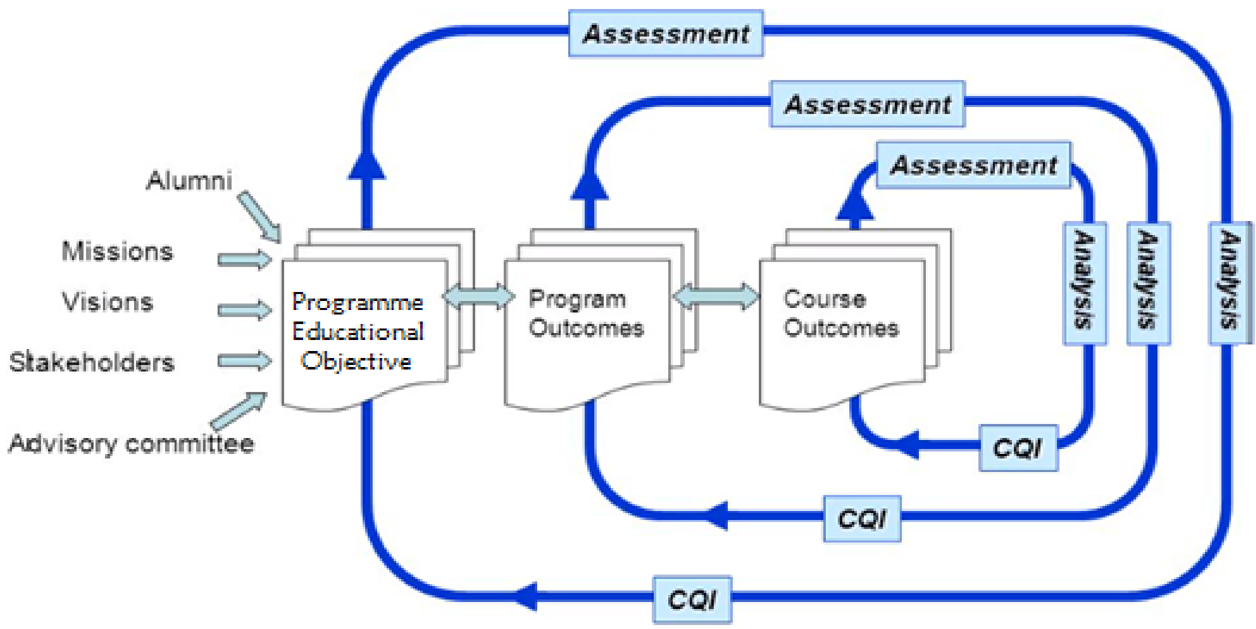

Figure 3: Practice of continual quality improvement (CQI) (UTM 2021).

4. Conclusions

In this paper the quality assurance systems and accreditation of engineering programme have been discussed. The central view of this paper is how the engineers can successfully work in global environment beyond the national boundary. It also briefly discussed the basic requirement of engineering accreditation under Washington Accord and its benefits. This paper showed the followings.

1. Great opportunity for import/export of human resources with engineering background. Engineers can communicate and performs engineering activities in a team beyond the national boundaries.
2. Great opportunity for third world country to provide engineering education at least with minimum fulfilment of Washington Accord requirement.
3. Washington Accord is an outcome based education with specific outcomes that are basically common with other signatories.
4. In general, Washington Accord has open the door of globalization in the field of engineering and mentoring the signatories.
5. It has specified everything for accreditation which is consider a very good guideline but too much specification also leads to poor uniqueness.

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Biography

Mohammad Yeakub Ali is a Professor in Mechanical Engineering Programme Area at Universiti Teknologi Brunei. He earned B.S. in Mechanical Engineering from Bangladesh University of Engineering and Technology, Dhaka, Masters in Manufacturing Systems Engineering from Asian Institute of Technology, Thailand, and PhD. in Mechanical Engineering from Nanyang Technological University, Singapore. He has published more than 200 articles in journal and conference proceedings. His research interests include manufacturing systems, optimization, scheduling, machining, micromachining as well as engineering accreditation. He is a Chartered Engineer with the Engineering Council UK, a Chartered Professional Engineer with Engineers Australia and a Professional Engineer with the Board of Engineers Malaysia as well as the member of many professional societies including ASME, IEOM, and IEM.

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