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A New Engineering Education Model for Malaysia*

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The role of Malaysian engineers in the development of industries, infrastructures and ensuring the general well-being of the country cannot be underestimated. However, since engineers have been left out of top leadership positions, there is a perception that they have a marginal role in the country's progress. Lacking in the non-technical skills, which are necessary for top management or leadership positions, has been singled out as contributing to this dilemma. It is also cited that they have also yet to be active in research and development or to be involved in business on a global scale. A study on the engineering education models worldwide has shown that engineers need to have the interpersonal skills to deal with the public effectively as well as to be technically competent. There is a variation of emphasis and levels of technical competencies aimed in these models; stretching from a broad-based to specialised education. In facing the challenges of the future, it is envisaged that engineers must still possess the necessary technical competencies but should also be trained with a stronger emphasis in engineering science so that they are flexible enough to be involved in several engineering disciplines. To prepare engineers to be leaders in the development of a nation, they must be trained with various industrial skills such as communication, management, law, politics and environment. These engineers must also be trained in humanities, including ethics and professionalism, and be exposed to global scenarios and future trends. The engineering education model developed for Malaysia is expected to be capable of achieving global recognition and accreditation for excellence in engineering practice as well as educating future leaders. This includes strengthening the scientific and professional competency base of the engineering studies, and the inclusion of various humanistic, industrial, practical, global and strategic skills. The model envisages a four-year degree programme, as opposed to the current three years.

INTRODUCTION

UNIVERSITI MALAYA was the first local university to offer engineering degree programmes, and now nearly all public universities offer engineering programmes, with varying entry requirements [1]. The duration of study for engineering programmes at most local universities (those with the STPM entry qualification, an equivalent to the United Kingdom Advanced Level examination) was reduced to three years in 1996. Universiti Teknologi Malaysia which had been offering a five-year engineering degree programme with students entering the programmes after their SPM examinations (equivalent to the United Kingdom Ordinary Level examination), reduced its programme to four years. The duration of study was shorten mainly to meet the manpower needs of the country.

The Institution of Engineers Malaysia and several institutions of higher learning were opposed to the shorter duration. There was no formal study carried out to support the change in the duration of study. At Universiti Putra Malaysia, the course content of a 4-year programme was redistributed over a three-year period, and some of the subjects that are not directly related were sacrificed. Students' performance, nationwide, has reportedly been affected due to the intensive nature of the three-year programmes.

In a study entitled the Formation of Engineers in Malaysia [2], the engineering profession is reportedly not playing a sufficiently important role in the community. The report highlighted that engineering graduates were having a poorer chance of reaching top management positions in both public and private sectors. Young Malaysian graduate engineers have also the perception that engineering is losing its status in the society [3].

These were among several issues to be addressed by the engineering fraternity, which has led to the formation of a study group by the Malaysian Council of Engineering Deans and the Institution of Engineers Malaysia to provide a solution through developing a model for engineering education. The study is expected to provide a framework for the design of engineering curricula. The aim of this paper is to present the engineering education model for Malaysia, developed by the study group.

METHODOLOGY

The status of Malaysian engineering education was reviewed together with the professional requirements. Simultaneously the reviewing of engineering education models of various countries,

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which include countries such as the United Kingdom, the United States, France, Germany, Denmark, New Zealand, Japan, Australia, Canada, Hong Kong, Singapore and Thailand, and the professional systems were carried out. Selection of the countries was based upon the geographical (or regional) position and the status of a country (developed or developing), of which majority are English speaking countries. It should be noted that there are other models such as the Russian and Latin American models that were not studied due to the communication and language barrier.

Detailed information on the review is reported in Sapuan *et al.* [4]. Three countries, namely, the United Kingdom, France and Germany were visited to obtain further insights of the evolution of engineering education over there.

An industrial survey was conducted to gauge the needs and expectations of the Malaysian industries. Several workshops were also held to obtain the feedback from academia and industrialists. A model for Malaysia was finally proposed at the Colloquium on Malaysian Engineering Education—Educating Future Industry Leaders, for further refinement.

MALAYSIAN SCENARIO

The Board of Engineers, Malaysia (BEM) in its accreditation guidelines, considers the following attributes as necessary in preparing for the contemporary engineering practice:

- ability to apply mathematics, science and engineering science in solving engineering tasks;
- ability to understand environmental, economics and community impacts on development;
- ability to communicate effectively and ethically in discharging duties.

The Institution of Engineers Malaysia (IEM) and the Malaysian Council of Engineering Deans (MCED) are in agreement that these attributes are required for engineering graduates, as described in their respective guidelines and reports.

The BEM guidelines stipulate that the minimum number of credits for graduation for those with STPM qualification is 120 credits, of which 80 credits must be allocated to engineering and its related subjects. As for those with the SPM qualification, it was recently imposed that the 120 credits are only considered from the second year of a study. A credit constitutes 15 hours of lectures per 15-teaching week. As for laboratories and workshops, a credit is equivalent to two or three contact hours per week, and for tutorials it is one and a half contact hours per week. Both are for 15-teaching week. No credit is given to practical training, basic sciences and mathematics, computer and basic languages courses [5].

The aforementioned BEM guidelines which were issued in September 1999 is a revised draft version. It was used to assess the three-year engineering programmes, which happen to be the first cohort of the three-year programmes, leading to a situation where programmes were reviewed in retrospective. Nearly all the three-year programmes, including the four-year Universiti Technology Malaysia programme were given conditional approval by the BEM. The BEM guidelines are still being finalised with regards to several details, including the definition of credits. These issues were debated and the complex situation is acknowledged, at the recent Colloquium on Accreditation of Engineering Programmes, organised by the BEM.

The IEM specifies similar requirements to the BEM, in its accreditation handbook for engineering degrees, but recommends 90 credits be allocated for engineering subject lectures [6]. Laboratory works shall cover a minimum of 10 credits or 15% of the total credits. However, as with the BEM guidelines, there was no basis as to the proportion of lectures and laboratory works.

In a recent workshop on Towards Quality Engineering Education (TQEE) it was noted that the definition of credits varied between local public universities, with Universiti Sains Malaysia, Universiti Putra Malaysia and Universiti Kebangsaan Malaysia are having a 14-week teaching semester and the rest a 15-week teaching semester. It was informed that Universiti Malaya has been instructed to reduce its semester to 14 weeks [7].

All public universities, with the exception of International Islamic University, adopted the three-year engineering programme as required by the Ministry of Education, Malaysia [8]. Universiti Teknologi Malaysia reduced their five-year programme to four years, with SPM entry qualification. The three-year programme has resulted in a heavily loaded engineering curriculum, with a minimum of 18 to 19 credits per semester, excluding languages and practical training [1].

The TQEE workshop recommended that an ideal credit loading per semester for engineering programmes is 15 credits. A similar chord was struck at the recent Colloquium on Malaysian Engineering Education Model for the Next Millennium (MEEM), where 15 to 16 credits were agreed as a suitable load to allow students to digest the subjects well.

Academics at the MEEM colloquium unanimously supported the idea of extending engineering programmes to at least 4 years, as reported by Sapuan *et al.* [4]. MCED at their Port Dickson meeting, also agreed upon the implementation of four-year engineering programmes in Malaysia [9].

The TQEE workshop also deliberated on the definition of core, supportive and non-engineering subjects, as there was a confusion with regard to the terminologies used in the BEM and IEM guidelines. Consensus was achieved on definition of non-engineering subjects which were to include management, planning, report writing, mass communications and socioeconomics. Supportive subjects include code of ethics and professionalism, engineering safety and health, apart from basic mathematics and sciences, and computer courses. Those subjects falling outside the scope mentioned are regarded as non-credit subjects. This understanding, however, contradicts the BEM guidelines as to the definition of non-credit subjects.

As a whole, the implementation of the three-year engineering programmes has opened the Pandora box where philosophy, implementation and accreditation of engineering education in Malaysia has to be rationalised. The accreditation guidelines are quite prescriptive, despite no rationale given to the inclusion of several clauses. On the other hand the commotion has brought academics and professional bodies together to finding a solution.

GLOBAL SCENARIO

MCED/IEM Engineering Model Study Group undertook a review of the global engineering education model, after establishing the Malaysian scenario. The detailed information of this work is reported in Sapuan *et al.* [10].

Generally, the number of years of pre-university study ranges from 11 to 13 years. The total number of credits for a student to graduate ranges from 108 to 186 credits for non-European countries. For Germany [11], France [12] and Denmark [13], the credit load ranges from 210 to 243 credits. It should be noted that the credit comparison is not entirely appropriate as the definition differs greatly, even within a country.

The duration of study for all the universities is either four or five years with the exception of Hong Kong [14] and the United Kingdom [15], which still maintain the three-year programmes. However, most of the universities in the United Kingdom are also offering a 4-year MEng programme, i.e. an enhanced bachelor degree, giving greater emphasis to industry related projects [16].

Most of the universities studied have included the final year project, design project and practical training in their engineering programme. Many of the universities give credits to basic sciences and social/humanities courses as part of the overall credits. For example, the percentage of credits for basic and social sciences course is approximately 40% at the University of Nagoya [17] while that at the Indian Institute of Technology is only 15% [18].

The student-staff ratio ranges between 6 : 1 and 31 : 1. It is observed that most of the countries have a low student/staff ratio with the exception of South Korea [19] and South Africa [20]. However, the calculation of student/staff ratio varies between institutions, where some have even included research associates in arriving at the ratio. How relevant is the ratio issue is still debatable, especially with the numerous modes of teaching available.

The model study group classified the global engineering education models into four distinct group, namely, the British, American, European and Hybrid models, as described in [21]. A summary of the classification is given below.

British model

Both specialised and more general engineering programmes are available. These could be a 3-year programme leading to Incorporated Engineering Degree and 4-year or 3-year with matching section programmes leading to Chartered Engineering Degree. Industrial training is desirable but not compulsory. This aspect is taken care of by design and/or industrial projects in most universities. The final year projects, which are usually individually done, are a requirement for both degrees. The transferable skills are embedded within the curriculum [16] in which the Engineering Council recommends at 60% of the total curriculum. Professional status is subject to professional institutions' requirements.

American model

The duration of study for an engineering degree in the United States is 4 years. Industrial training is not compulsory at most universities whereas final year project is compulsory at some universities. Social sciences and humanities courses are generally offered at all universities. Professional status is awarded by the respective states.

European model

In Germany there are three types of tertiary institutions, namely:

- University and Technical University
- Berufsakademie (recently known as University of Cooperative Education)
- Fachhochschule (University of Applied Sciences).

The qualification, Diplom. Ingenieur (Dipl-Ing) is awarded by all institutions, with an additional tag BA and FH for those from Berufsakademie and Fachhochschule respectively. The Dipl-Ing is considered as an equivalent to a Master's degree while the awards from Fachhochschule and Berufsakademie are considered as Bachelor's degrees. The average duration of study at universities is 4.5 years while at Fachhochschule and Berufsakademie are 4 years and 3 years respectively.

In France, the duration of study at universities is 5 years, whereas those going for the Grande Ecoles to study engineering, need to attend the class preparatory for 2 years and followed by 3 years at Grand Ecoles. Rigorous implementation of project-based learning and industrial attachment have enabled the recipients of Dipl-Ing degrees to practice as professional engineers immediately.

There is a strong linkage between the institutions, laboratories and industries in the European model.

Hybrid model

Hybrid comprises models that are a combination of the aforementioned models. The duration of study at most of the universities in this group is four years. Most universities generally offer humanity courses apart from the technical courses. Some universities do not include language courses in the curriculum. There are universities that give credits to co-curriculum. As a whole, the engineering core subjects are between 52 and 63% of the curriculum. Final year project is given credits but industrial training, though compulsory, is not credited.

The Federation of Engineering Institutions of South East Asia and the Pacific (FEISEAP) has proposed an accreditation model that could be adopted by its member countries in order to mutually recognise engineering programmes. Similar accreditation criteria are also required by the Accreditation Board for Engineering and Technology (ABET) which is monitoring the engineering programmes in the United States. ABET defines an engineering programme as a programme that must be able to demonstrate that the graduates shall have the following attributes [22]:

- an ability to design system, component or process and meet desired needs;
- an ability to function in multidisciplinary teams;
- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global/social context;
- a knowledge of contemporary issues;
- an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

From ABET's definition and requirements, any new engineering programme should be able to produce graduates that are technically competent and having sufficient industrial skill. It means that the graduate should possess the knowledge of core engineering subjects, supportive subjects and non-engineering subjects.

Currently, there is also a move towards mutual recognition through a mutually accepted accreditation process. This has been propagated by the Washington Accord [23] and contemplated by FEISEAP [24], which allows free movement of engineers within the member countries.

THE MALAYSIAN MODEL

The vision for Malaysian Engineers [2] is:

> *Engineers shall be technically competent and well-respected professionals spearheading technology and wealth creation in Malaysia.*

In order to realise the vision there is indeed a need for Malaysia to formulate its own engineering education model. Though global engineering philosophies and models studied have shown their dynamic and foresight approaches, verbatim adoption may prove to be detrimental to the development and progress of engineering in Malaysia. Engineering education in Malaysia must ensure that both universities and industries can benefit mutually, for the progress and sustainability of the nation.

The nature of the engineering profession revolves around the practice of engineering science and technology and is firmly rooted in fundamental science. Therefore, engineers must demonstrate good scientific knowledge with the development of general skills, such as those related to self-directed knowledge acquisition, so that engineers will be able to cope with the rapidly expanding amount of new knowledge in the world. Engineering graduates must be equipped with management and related skills to ensure better chances to reach top management post in the industry.

Engineers must be able to adapt with the changing emphasis in scientific fields, for instance in information technology and bioengineering. World without boundaries, globalisation, knowledge-based economies and service industries are emerging terms in the context of the global village [25]. Engineers must be able to practice abroad and therefore, engineers must be equipped with knowledge that can cater for the needs of the global village. Well-respected engineers who are not only technically competent but also maintain a certain level of ethical standard. Engineers must acquire leadership and management skills as well as have the ability to deal with people at all levels.

Completeness in the training of engineers is necessary in preparing engineers who are capable of performing useful functions in the industry, and these include emphasising communication, management and innovative thinking skills [26, 27].

In arriving at the Malaysian engineering education model, two elements were evaluated. These were **input** (entrance qualification) and **output** (type of engineers needed) elements. The output shall define the curriculum requirement, whereas the input shall determine the level of education to be provided. Based upon these two elements the third element i.e., **the formation process** was determined. Input refers to the quality and quantity of students entering the engineering programmes. The formation process refers to the stage at the university where students are trained to become engineers. Those who have completed the formation process and are ready to enter the job market constitute the output.

Output

The following five criteria are considered important in producing graduate engineers after having observed the global engineering models and Malaysia's needs:

- *Scientific strength* provides engineers who are innovative, able to work in research and development activities, and adaptable in different engineering fields.
- *Professional competency* provides engineers who are able to identify, formulate, and solve engineering problems, responsible professionally, and able to use techniques, skills, and modern engineering tools for engineering practice.
- *Multi-skilling* provides engineers who are able to work in different engineering fields and function in multidisciplinary work/teams.
- *Well respected and potential industry leadership skills* provides engineers who are able to understand the impact of engineering solutions in a global/social context, knowledgeable of contemporary issues, able to communicate effectively and be involved in community or social projects.
- *Moral and ethical soundness* provides engineers who understand their ethical and moral responsibilities.

The input and transformation process must be formulated based upon these criteria.

Input

There are three main channels to enter engineering degree programmes in Malaysia, namely, the Matriculation, STPM and Diploma. Both the Matriculation and STPM programmes are completed in one and a half years, whereas Diploma programmes are commonly three years.

The Matriculation programme is carried out in three semesters of 15 teaching weeks. Three fields of specialisation are offered, i.e., biological science, physical science and accountancy. The intake for engineering degree programmes may come from either biological or physical sciences.

All students in these programmes must take and pass three subjects in mathematics and three subjects in physics. Students in the biological science specialisation also take three biology subjects while students in the physical science take three computer science subjects. In addition, all students have to pass the English, Islamic/moral study, Malaysian study, information technology and communication skills subjects.

At the STPM level all students study mathematics, physics and chemistry. One other subject is an option to be taken from the following; advanced mathematics, biology or computing. Thus, students who have completed any of these two programmes will have sufficient knowledge for their engineering studies at Bachelor's level.

Courses for Diploma programmes can be divided into three broad categories, i.e. common courses, basics or foundation courses and technical courses. Common courses include Islamic studies, moral education, entrepreneurship and languages. Basic or foundation courses include mathematics, engineering sciences, engineering drawing, and computer application. Technical courses are core subjects. A typical diploma programme was analysed and it was found that students graduated from this Diploma program have sufficient exposure to technical subjects and also basic sciences and mathematics.

These three main channels shall continue supplying the bulk of the students to do engineering at the universities. Changes in the input element are nearly impossible to make as they are subject to the Ministry of Education agreement. As the preparation for basic mathematics and sciences are adequate, the formation process need not have to provide a similar emphasis.

The formation process

Completeness in the training of engineers, which among others include communication, management and innovative thinking skills, are necessary in preparing engineers who are capable of performing useful functions in the industry, immediately upon graduation [26, 27]. O'Kane [25], in highlighting the future challenges in engineering education, has included globalisation, rapidly expanding knowledge and the changing emphasis in scientific fields as the important aspects to be considered when preparing a suitable engineering programme.

The following skills and competencies are considered necessary in preparing engineering students for their professional training upon graduation and the ensuing years as they develop into professional engineers and managers. This is based upon the level of basic sciences and mathematics in the highschools (the input) and also the professional development requirements and needs (the output).

- *Global and strategic skills* enable students to adapt easily within the borderless world and rapid expanding knowledge.
- *Industrial skills* are those required beyond the scientific and professional competencies, but are necessary in the advanced phase of the graduate's career e.g. management, law, environment, communication, economics, finance.
- *Humanistic skills* provide a balanced engineer with high ethical and moral standards.
- *Practical skills* enable students to be directly involved with hands-on activities or real-life situations, thus providing the basis for integrating the intra- and inter-engineering and non-engineering knowledge.
- *Professional competency* covers the technical competency required to perform specific engineering tasks.
- *Scientific competency* enables students to have a

firm foundation in engineering science, thus enabling them to realign themselves with the changing emphasis in the scientific field and to develop an interest in R&D and innovation.

Table 1 presents typical subjects and minimum credit allocation for the respective skills and competencies as a means of calibrating the model. The model provides a basic guide for curriculum design. The curriculum contents can be varied depending upon the teaching expertise available, the emphasis required (whether scientific, professional or balanced), and incorporating appropriate emphasis on global and strategic, industrial, practical and humanistic skills.

The changing world to a borderless environment, with the WTO and GATTS becoming more influential, calls for graduates that are well prepared to compete globally. It would also allow graduates to be easily assimilated within the domain of the international standards. Since information technology or IT is influencing a greater part of the human society, this subject is indeed important to be considered. The ability to forecast and map technologies and develop strategies would ensure the graduates to be at par or better than any established institutions trained graduates. The borderless world would also demand that the graduates be exposed to the international culture and businesses, and the international language (such as English).

Table 1. Typical subjects and proportions for the respective skills for model calibration

Skills	Subjects	Minimum No. of Credits
Global & Strategic	Language Strategic Planning Information Technology Multimedia International Business Environment	15 Credits
Industrial	Management Finance Economics Engineers in Society Communication Law Occupational Safety Human Resource Management Innovation	15 Credits
Humanistic	Islamic Civilisation Asian Civilisation Nationhood Sociology Psychology	10 Credits
Practical	Final Year Project Industrial Project Design	15 Credits
Professional	Professional Subjects Civil Engineering e.g. Foundation Engineering Water & Waste Engineering Highway Engineering Concrete Structures Public Health Engineering Surveying	30–50 Credits
Scientific	Engineering Sciences e.g. Engineering Mathematics Engineering Materials Fluid Mechanics Engineering Statistics Thermodynamics Engineering Mechanics Programming	50–30 Credits

Most engineers would eventually leave the routine engineering design or supervisory job to become managers and directors of companies. Thus, having a programme that prepares students to this eventuality has become a necessity, where the industrial skills are nurtured from the undergraduate level. These skills would also ensure that engineers would not be 'back room boys' but rather dynamic and well-respected persons that are capable leaders. The transition to becoming managers and directors, and also captain of industries can therefore be enhanced. The management, economics, human resource management, and finance subjects, among others, would provide the basics to sound management and financial control, whereas subjects such as engineers and society and occupational safety would provide the basis for a good practice.

The strong emphasis in practical subjects indicates the importance placed upon the hands-on skills. The practicals must be structured and preferably industry related, thus giving the strong university-industry relationship. The design component is also meant to provide the teamwork experience and solving the real life problem. The issue of industrial skills was also highlighted in the recent National Workshop on the Roles of Industries in Engineering Education among academics and industrialists [28], which emphasised the needs of engineering graduates to have industrial skills. This could be achieved through the establishment of a tripartite university-laboratory-industry link.

The scientific and the professional contents must never be compromised, as these are the core components of any engineering fields. Any slackness in the curriculum could even lead to serious errors by engineers in discharging their duties, and thus denying the respect the profession needs. The model provides flexibility in designing the core curriculum, which can be observed from the range of credit hours allocated (30–50 credits). Nevertheless the study group believes that a greater emphasis should be given to scientific competency, as the knowledge is nearly timeless, whereas technology evolves at such a rapid pace. It is this scientific competency that allows students to have greater mobility in selecting their area of specialisation, in the later years of their undergraduate studies. The strong scientific background would also enable engineers to be more R&D conscious and thus would be contributing to the call for engineers to be more innovative and spearheading the technological advancement of the nation.

The humanistic skills are essentially to produce a balanced engineer. Although ten credits are allocated to this component, the Ministry of

Table 2. Comparison of engineering education models of several countries

Country	Britain	United States	Australia	France	Germany	Proposed Model
Schooling years	11—12	12	13	12	12	12–13
Entry Requirement	A levels	SAT	HSC	Bacc	Abitur	STPM Matriculation Diploma
Year 1				Class Prep		
Year 2				Class Prep		
Year 3	BEng & BSc				Dip-Ing (FH)	
Year 4	MEng	BS	BEng		Dip-Ing (BA)	BEng
Year 5	MSc		MSc	Dip-Ing	Dip-Ing	
Year 6		MS				MS
% Core Courses	>90%	58%	75%	70%	84%	70%
% Other Courses	<10%	42%	25%	30%	16%	30%

Education has already made seven compulsory, which are Islamic Civilisation, Asian Civilisation and Nationhood. The remaining credits should develop further the humanistic aspect of the students and motivate them to be ethically and morally responsible persons whom would contribute effectively to nation building.

The engineering education model allocates about 70% of the total credits to the engineering content and the remaining 30% to the non-engineering content. The study group classifies the scientific, professional and practical components into the engineering content group. Table 2 shows the comparison between the various countries' engineering education models, as to the engineering content and the years of study as well as the degree awarded.

For the purpose of standardisation, a semester is taken as a minimum of 14 teaching weeks and the semester credit is defined as follows:

- One credit of: *lecture* is equivalent to 1 hour per week of lectures.
- One credit of: *laboratory* is equivalent to 2–3 hours per week of laboratory classes.
- One credit of: *tutorial* is equivalent to 1.5 hours per week of tutorial classes.

The study group recommends that tutorials be an essential component to the formation process, to support through the system that has been implemented at the school level. A small class size is recommended to provide greater attention to the students, which is what the tutorial component would be offering. The tutorials would ensure greater understanding of the subject matter, especially when dealing with the scientific component.

RECOMMENDATION

The new Malaysian Engineering Education Model aims to produce graduates with a strong scientific base and are innovative, professionally competent, multiskilled and well respected. Their progression to successful industry leaders would become a natural consequence. The engineering degree programme must be enhanced to a 4-year programme and begin with a strong emphasis in scientific competency (engineering sciences) and on this strong scientific foundation shall be built the global and strategic, industrial, humanistic, practical and professional skills and competencies.

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