

History, Philosophy and Trends in Engineering Education (EE): The Malaysian Context

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Abstract: Malaysia is in the process of becoming an industrialised nation. The transformation from being a predominantly agriculture-based to industry-based economy in a rapidly changing world requires a large pool of competent engineers. This has sparked great interest amongst local educators and various stakeholders in the role of EE. A review and revamp of EE has been called for. The purpose of this paper is to help interested parties understand the EE system, the role, challenges and future of EE in Malaysia. This paper reviews the history and philosophy of EE in Malaysia, and thus provides a basic understanding of the tertiary EE system. It also compares and contrasts the past, present and future trends between Malaysian and the global EE.

1.0 Introduction

Engineers play a very important role in transforming a traditionally agriculture-based country, such as Malaysia into a fully-industrialised country. As the world undergoes changes in all major aspects of life, the challenges engineers of the future will face also change. The attributes of engineers that will be needed are quite different from what they used to be. To produce engineers with the required attributes, it is vital to look into EE.

This paper presents the history and present scenario of EE in Malaysia. It describes pre-tertiary, pre-university and tertiary EE and the philosophy of EE, which determines the purpose, process, nature, and ideals of EE in Malaysia. The role of EE, current trends, and future challenges of EE are also presented.

2.0 History and Present Scenario of EE in Malaysia

Education in Malaysia is under the responsibility of the Federal Government of Malaysia. The national education policy in the country has been designed to support the country's aspiration to be an industrialised nation by 2020. Thus, one of the goals of the education system is to ensure the development of a highly educated, highly skilled and strongly motivated workforce to fulfill the needs of the nation.

The education system in Malaysia comprises pre-school, primary school, secondary school, pre-university education and tertiary education. The primary school and the secondary school form the pre-tertiary education. The pre-university education consists of Form Six (one and half year programme) and matriculation (one or two year programme). Both the pre-tertiary and the pre-university educations are under the responsibility of the Ministry of Education (MOE) whereas the tertiary education is under the responsibility of the Ministry of Higher Education (MOHE) [1]. Educational policies and priorities in Malaysia are systematically linked to the national development plans. Thus, MOE and MOHE are committed to provide education and training services that are in line with the major thrusts in the Five Year Development Plans (also known as Malaysia Plan). Now Malaysia is in the 9th Malaysia Plan for the period of 2006 to 2010.

Pre-tertiary education

Pre-tertiary education is a centralized system with standardized curricula and examination systems throughout the country. Numerous educational programmes have been established by MOE to cater for

students' needs. Much effort is directed at strengthening pre-tertiary education by equipping schools with better technology, facilities, and providing appropriate curriculum.

The government, through MOE provides eleven years of pre-tertiary education to all children in the country: the primary school (from age seven to twelve years old) and the secondary school (from age thirteen to seventeen). The primary school is a compulsory six-year educational programme. At the end of primary school, students take a public examination set by the MOE [2].

The secondary school is a five-year educational programme that consists of a three-year lower secondary level and a two-year upper secondary level. After the lower secondary level, students can opt for four different programmes in the upper secondary, namely science stream, arts stream, technical and vocational programmes [2]. The needs of academically inclined students are secured through the provision of a curriculum that develops students' interests in the fields of science, technology and arts, whereas for the less- academically inclined, the vocational programme is an alternative pathway to learning. At the end of secondary school, all students take a public examination set by the MOE, named Sijil Pelajaran Malaysia (SPM) for the science stream, arts stream and technical students while students under vocational programme take Sijil Pelajaran Vokasional Malaysia (SPVM).

Several curriculum reforms at the pre-tertiary level have taken place since its inception. These include the introduction of new subjects such as life skills and information communication technology (ICT) at the primary school and the life skills, invention curriculum, ICT and vocational subjects in the secondary school. Life skills subject is one of the main subjects in primary school and lower secondary level. The aim of this subject is to prepare students with basic knowledge and skills, to promote interest in EE, and to develop positive work culture in technology and entrepreneurship. The MOE ICT policy stresses on ICT literacy for all students, the role and function of ICT as a curriculum and teaching-learning tool, and the use of ICT to increase productivity, efficiency, and effectiveness of the management system [2].

In preparing students for EE, the invention-based curriculum that emphasizes creativity, technology, skills and values is introduced at the upper secondary level. Subjects include technical drawing, engineering drawing, engineering technology, computer-aided design (CAD), manufacturing technology and marketing [2].

Pre-university education

Students graduating from secondary schools (SPM holders) can continue their studies either in pre-university education or tertiary education. The pre-university education consists of Form Six (one and half year programme) or matriculation (one or two year programme) which is under the MOE responsibility [3]. In Form Six, students may opt for science or arts stream. The curriculum is set by the MOE with the aim of preparing students to further their studies at Bachelor's degree. The students who opt for the science stream will normally continue their studies in engineering field.

The matriculation programme follows the standardized curricula designed by the MOE. There are two options for students in the matriculation programme: Biological Science or Physical Science. Those who opt for Biological Science may continue their studies in medicine, dentistry or other related fields at the university level while those who opt for Physical Science may continue their studies in engineering field.

Tertiary education

Tertiary education which is under jurisdiction of MOHE, comprises government-funded institutions of higher learning (HEIs) and private-funded institutions of higher learning (PHEIs). The HEIs include polytechnics, colleges, community colleges, industrial training colleges, teacher training institutes, and public universities while the PHEIs include private universities, private colleges and foreign university branch campuses. Higher Education in Malaysian context covers certificate, diploma, undergraduate levels and postgraduate studies. Undergraduate studies consist of Bachelor's degree level while the postgraduate studies consist of Master's degree and PhD levels [1].

The first institution of higher learning in Malaysia was established in 1906, known as the Technical School. The school was further expanded, and in 1946 it was renamed as the Technical College, Kuala Lumpur. The college offered diploma courses in engineering, architecture, town and country planning and

land and quantity surveying. In 1960, the college offered the first engineering courses at degree level. The college was further upgraded with the establishment of Institut Teknologi Kebangsaan in 1972 and in 1975 the college became Universiti Teknologi Malaysia (UTM) [4].

In early 1970, there were only five government-funded universities in Malaysia: Universiti Malaya (1962), Universiti Sains Malaysia (1969), Universiti Kebangsaan Malaysia (1970), Universiti Putra Malaysia (1971) and Universiti Teknologi Malaysia (1975) [1]. All of these universities offer engineering degree programmes but only UTM offer engineering diploma programmes. For the period of 1990 to 2000, the government established four more universities in the country that offer degree programme in various engineering fields to cater for the growing demands from the SPM, STPM and matriculation students.

The government also established polytechnics throughout the country to produce technicians, technical assistants and act as a feeder to engineering degree programmes. Polytechnics provide courses for three-year diploma programmes and two-year certificate programmes. The first polytechnic in the country is Politeknik Ungku Omar, established in 1969 [5]. At the moment, there are twenty polytechnics throughout the country which offer diploma and certificate programmes in engineering fields.

The government is very committed in providing quality education to all the citizens. The strategies for growth and development of the education sector under the Seventh Malaysian Plan (1996-2000) represented a significant departure from previous plans because it gave more attention to technical training and vocational education as well as to science and technology [6]. During this period, the government established four university-colleges to cater for the various educational needs of the country. In 2005 onwards, all of these university-colleges were upgraded to a university level.

Besides establishes more government-supported HEIs, the government also encourages the private sector to participate in education. Currently, there are twenty universities, twenty polytechnics and thirty four community colleges supported by the government and eleven private universities, sixteen private university-colleges, four branch campuses of international universities and four hundred eighty five private colleges in the country [1]. Most of these HEIs and PHEIs offer engineering programmes at degree, diploma or certificate levels.

The establishment of MOHE in 2004 is another milestone in the higher education system in Malaysia. MOHE is the governing authority, overseeing both the government and the private higher educational institutions in the country. Based on the reports produced by MOHE in 2005 and January 2007, the National Higher Education Action Plan (2007 – 2010) was launched in August 2007. The action plan aims for holistic human capital development, that is to produce Malaysians who are intellectually active, creative and innovative, ethically and morally upright, adaptable and capable of critical thinking. The human capital model is a well-rounded individual with an appreciation for humanistic pursuits such as the arts, culture, sports and volunteerism [7].

Being owned and funded by the government, HEIs must ensure that their strategic objectives are in line with those of the MOHE. The HEIs should become more dynamic, competitive, and able to face the challenges of a changing world and must also produce graduates who can acquire and apply their knowledge in the context of contemporary society.

The government strategies in promoting the establishment of public and private institutions of higher learning to fulfill Malaysia's desire to become a centre of educational excellence has resulted in an increase in educational opportunities at the tertiary level. By building a world-class system that is flexible and innovative, the government hopes to be a regional education hub of educational excellence.

3.0 Philosophy of EE System in Malaysia

EE encompasses teaching, learning and assessment activities of engineering and technology at school, college and university levels to develop the knowledge, skills, and attitudes of students. The philosophy of EE is of fundamental importance because it determines the purpose, process, nature and ideals of EE. It is the basis of the outcome-based Malaysian EE Model (MEEM) developed in 2000 which provides a framework to review and redesign the curriculum. The paper by Megat Johari, M. M. N. *et al* [8] described the model in detail.

The purpose of EE in Malaysia is influenced by the requirements of major stakeholders comprising the MOHE, the Engineering Accreditation Council (EAC) under the purview of the Board of Engineers,

Malaysia (BEM), the Institution of Engineers Malaysia (IEM), the Malaysian Council of Engineering Deans (MCED), and potential employers. The purpose is recast into the criteria used to identify the programme objectives. According to the MCED/IEM Report (2000), five criteria of engineers identified in the MEEM are:

- Scientific strength, which enables engineers to conduct innovative research and development in traditional and new areas such as biotechnology, nanotechnology, and information technology.
- Professional competencies, which enable engineers to be technically proficient in performing specific engineering tasks in a world driven by rapid technological advancement.
- Multi-skilled, which enables engineers to perform a variety of engineering tasks and adapt to different engineering disciplines, and committed to life-long learning.
- Well-respected and leadership quality, which prepares engineers to lead in business and public service, able to communicate effectively, understand other cultures, and contribute to the wider world.
- Morally and ethically sound, which prepares engineers to be responsible and ethical citizens.

The programme objectives which state the desired attributes of engineers are translated into programme learning outcomes which specify the skills and competencies that students should obtain in the educational process. The MEEM recommended six skills and competencies to satisfy the five criteria aforementioned. These are global and strategic, industrial, humanistic, practical, professional and scientific skills [9]. These skills are necessary to prepare graduates in facing future challenges in EE. Some of the major challenges as described by O’Kane [10] are globalization, rapidly changing technological advancement and new emergent scientific fields.

Global and strategic skills enable students to acquire new knowledge and compete globally. Industrial skills equip the students with knowledge beyond the scientific and professional disciplines necessary for their career development. This includes knowledge concerning the environment, economics, management, finance, law, human resource management, occupational safety, human relations and communication. Humanistic skills help instill moral and ethical values in an engineer. Practical skills provide hands-on experience in integrating engineering and non-engineering knowledge. Professional skills encompass technical competency in specific engineering areas. Scientific skills provide a strong foundation in engineering science and mathematics to enable students to adapt and respond to changes in science and technology, conduct research and produce innovative design.

These skills are then mapped to a group of related courses with course learning outcomes that support the programme outcomes. The MEEM recommends that a greater emphasis (70% of the total credits) should be given to scientific competency compared to the other five skills because it prepares students for further study and research in specialized areas, and contributes to the technological advancement of the nation.

Having identified the kind of engineers to produce, the next step is to design a systematic methodology or process to achieve that goal. The EE process to transform input (students) into output (engineers) identifies the methods for:

- acquisition of new information through a variety of teaching and learning approaches.
- transformation and manipulation of knowledge through learning activities such as lab work, field work, practical training, assignment and project.
- application of engineering theory, knowledge and skills to benefit the society.
- evaluation of the teaching and learning process and student’s learning outcomes through various formative and summative assessment.

Felder *et al* [11] suggested a variety of effective teaching techniques in the context of EE which include active and cooperative learning. In Malaysia, several instructors have adopted active and problem-based learning in EE and reported encouraging results [12][13][14][15][16][17][18].

The nature of EE in Malaysia is future-oriented, encourages creative activities to stimulate innovative thinking, fosters independent and active learning. It is multi-disciplinary to solve real-life problems in a multi-ethnic, multi-cultural and multi-religious community. Similar to the traits of engineers described by Jeffs and Smith [19], Malaysian EE aims to produce engineers with high moral and ethical values such as

respect, equality, responsibility, integrity and trustworthiness. Formal education needs settings with conducive infrastructure, facilities and environment for teaching and learning.

The ideal engineer sought after by the society depends much on the character of the society. The ideal Malaysian engineer is one who does not only possess the scientific knowledge and technical expertise but also the non-engineering skills, while upholding high ethical and moral values. To inculcate ethical and moral values, the MOHE has made several subjects compulsory. These are Islamic Civilisation, Asian Civilisation, and Nationhood. On the macro level, it is hoped that Malaysian EE could produce engineers who can compete globally, support racial integration and harmony, fair distribution of wealth, and a more prosperous economic and social life for the nation.

4.0 Role of EE

The rate of increase in global technological development has provided the impetus for change in engineering training and education. To meet the challenges in the rapidly evolving technical, social and global environment, the EE system has a responsibility to provide engineering graduates with a broad balance of generic competencies and insights as a foundation on which to build a wide range of careers [20]. 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.

The EE system in Malaysia must be capable of achieving global recognition and accreditation for excellence in engineering practice as well as educating future leaders. Engineering education plays an important role in determining the kind of engineering graduates that the engineering education system is to produce. In order to eliminate the current mismatch between the supply of engineering graduates by higher education institutions and the demand by industry, it is crucial to look at the global trends and challenges.

In keeping abreast with national aspirations and global importance, MOHE has set guidelines for the learning goals of education [7]. The general goal of university undergraduate education is to produce graduates through the:

- i. Provision of knowledge and practical skills based on scientific principles.
- ii. Inculcation of attitudes, ethics, sense of professionalism and leadership skills for societal advancement within the framework of the national vision.
- iii. Nurturing of the ability to analyse and solve problems as well as evaluate and make decisions critically and creatively based on evidence and experience.
- iv. Development of the quest for knowledge and life long learning skills for continuous upgrading of knowledge and skills that parallel the rapid advancement in global knowledge.
- v. Consideration of other general and specific issues those are relevant to the policies of the institution, country, region or the world.

In order to prepare engineers for the ‘industrialised Malaysia’ by 2020 the education system must aim to produce graduates who are holistic, with a strong technological and scientific base with design ability. Graduates who are innovative, professionally competent, multi-skilled, equipped with soft skills and globally recognized would become successful industry leaders. They must be able to adapt with the changing emphasis in scientific fields and global concerns, for instance in information technology and bioengineering, and sustainable development with regards to environmental concerns, economic, social and employment competitiveness [21].

A good engineering programme should produce multi-skilled engineers with strong moral and ethical values who are able to understand the impact of engineering solutions in a global, social and cultural context, knowledgeable of current issues. Engineers who are able to communicate effectively and participate in community or social projects will be marketable globally.

5.0 Current Trends of EE in Malaysia

Economies in most developed countries have evolved from being agriculture-based to industry-based and now to services [22]. Globally today, there is an increasing amount of engineering effort that goes into software and other intangible products, although, manufacturing physical products will still be what most engineers would be associated to do [23]. For the post-industrial world, continuous manufacturing and productivity improvements, demand inelasticity when compared with income growth and international outsourcing have caused a continued movement of manufacturing plant investment abroad and the loss of engineer positions [22]. The trend of a sharp decline in manufacturing activities is obvious in the US, South Korea and Japan which is due to the shift of investment to countries such as China, Malaysia and Thailand, where the manufacturing costs are lower [22][23]. As a development strategy, Malaysia has decided that it can no longer rely on foreign direct investments (FDI) in low-cost labour-intensive industries for its future economic growth [7].

In our local scenario, mammoth infrastructure projects such as the Kuala Lumpur International Airport, Petronas Twin Towers and Smart Tunnel were built with core technical know-how which was not fully indigenous to Malaysia [24]. Professional, talented and skilled labours were imported to overcome the shortage of local resources. Although some technical transfers might have taken place, developing Malaysia own human capital would constitute a long-term solution to the human resource problem.

World-class human capital is one of Malaysia's main agendas in achieving its Vision 2020. In the 9th Malaysia Plan, Malaysia targets to generate high value-added capabilities to raise its position in the global value chain in order to attract higher value-added knowledge-intensive investments.

The importance of higher education in this process must not be underestimated—it is today considered by both developed and developing nations to be a critical agenda in the formulation of national policies. The success of these endeavours is immediately obvious. Highly-skilled IT and software engineering graduates, for example, have become the cornerstone of new industries like offshoring and business process outsourcing that bring in billions in revenues per year. Wealth will continue to be created in countries that can develop and attract human capital that is able to generate new knowledge and commercialise it to meet the world's needs. Malaysia seeks to achieve similar success in selected emerging fields like biotechnology, life sciences, nanotechnology and space sciences. In due time, Malaysian researchers are expected to be at the forefront of new technologies and contribute towards the country's socioeconomic progress [7].

Globalization of the economy, the decline of the welfare state, and the commoditization of knowledge have significant effects on higher education [25]. Due to the globalization effect which calls for the restructuring of higher education, Malaysian public universities were corporatized in 1998. Universities are expected to operate like business organizations, putting emphasis on the production of knowledge as a marketable good and a saleable commodity instead of producing and transmitting knowledge as a social good. The number of private colleges and universities thus, mushroomed to around 600 after the enactment of the Private Higher Educational Institutions Act in 1996 [24], to take advantage of the situation. The changing role of higher education, especially in developed countries, in the era of globalization is closely linked with the emergence of a post-industrial economy, in which productivity relies predominantly on science, technology, knowledge and management [25].

According to Lee [25] student enrolment has greatly increased over the past four decades as more countries strive to expand their higher education systems. In 2003, the number of student enrolment in Malaysia, in the public institutions of higher learning alone was 300000, of which only 30 percent of total enrolments pursued technical and engineering courses [24]. Therefore, the government made numerous initiatives to promote engineering education, continuous learning and training to address the issue. Several new universities have been established to provide more places for the increasing number of school leavers for their tertiary education. Focus to increase the enrolment of students in engineering and science is not without facing the competitions from other major courses such as medicine and law, or from more artistic

and humanistic courses such as arts and design, graphics and entertainment related, management, commerce and IT [22][25].

In line with the current national development in achieving the industrialised nation status in its Vision 2020, there are demands for engineers to fulfill the vacancies in the electronics, automotive and aerospace manufacturing, Research & Development (R&D), and the construction sectors. Engineering programmes mainly offered by higher education institutions in Malaysia are from the following main engineering fields: Electrical & Electronics, Mechanical and Civil engineering. However, with the current global developments, engineering courses offered by the universities have also varied to include biomedical, biotechnology, biological, information, communication and computer, manufacturing and materials, mechatronics, and environmental engineering programmes.

Global development also generates more demand for technologist, especially in the oil and gas industry, heavy machinery, manufacturing industries and maintenance work. The number of engineering technology universities and colleges has increased within the past fifteen years. Programmes offered include marine, chemical, electrical, and electronics & telecommunication engineering technology; aircraft maintenance, industrial maintenance, and design & manufacturing technology.

The reality of multinational corporations, global supply chains, advances in information and communication technology, and international markets requires a revamp in the engineering education [23][25]. Referring to the National Higher Education, Action Plan 2007-2010, the MOHE introduces a holistic programme that cuts across all disciplines and focuses on communication and entrepreneurial skills. The programme, which is intended to build a balanced perspective in all students, will expose them to subjects beyond their area of specialisation. For example, students reading for degrees in the sciences such as medicine, engineering and chemistry will be exposed to courses covering literature and philosophy. Based on the MOHE emphasis, curriculum changes are made in order to produce engineers who are holistic and fit future requirements [21].

6.0 Challenges for the Future

The challenges that EE will face in the coming decades will be wide-ranging [26]. The pace of technological advancement is accelerating and new technologies are being developed, and subsequently being made obsolete, at an increasing rate. Globalization, technology, governance, changing missions and expectations, the emergence of competitors, the utility of maintaining tenure, and securing new revenues, increase product and reducing costs are a few of the recurring challenges facing by higher education at the millennium [27]. A university plays a vital role in changing the society. To produce engineers who can keep pace with global technological development, there must be:

- i. Corresponding innovation in how engineers are educated. Faculty and students must be prepared to learn and to acquire new knowledge and technology.
- ii. Awareness that the technology has become increasingly integrated with all aspects of our lives. The skills that an engineer will need to acquire may differ from what he already knows.

The ultimate challenges mentioned by Wankat *et al* [28] is that the growing number of engineering schools that need to regard teaching in a meaningful way. Multidisciplinary collaboration between engineers and non-engineers is essential to attain suitable level of professionalism.

Among global challenges mentioned by Fortenberry [29] are maintaining technical currency, life-long learning, managing globalization and socio-technological challenges. Integrated and dynamic curriculum must be introduced at all education levels. Partnership between universities and industries is a must to ensure seamless amalgamation of scientific and engineering knowledge in teaching and learning, and maintaining multidisciplinary workforce pipeline.

Globalization makes the nations inter-dependent and inter-connected to work. World-wide education systems are borderless. Graduates should be prepared in competitive global environment. Graduate are expected to adapt to the philosophical paradigm shift of the changing role of an engineer. The emergence of new engineering disciplines and technologies is not a barrier for teaching and learning, but requires more stress on fundamentals of science and mathematics. Socio-technological factors such as physical, racial and

political are other challenges. Government must tackle these issues carefully. In Malaysia, there are many challenges faced by educators. These are some of them:

- i. Partnership between industries and universities to ensure technical currency and life long learning.
- ii. Professional bodies such as IEM, and BEM play limited advisory roles of the national associations in Malaysia.
- iii. Unattractive remuneration makes it difficult for universities to recruit quality and experienced faculty members.
- iv. Many research findings are not commercialized.
- v. Infrastructures and facilities inefficiencies that impair a university's ability to adapt and change.
- vi. The mismatch between students' electronic and visually-based learning style and the traditional university pedagogy. Many professors do not keep abreast of the development of student-centered instructional methods and continue to insist on exclusively lecturing.
- vii. Various cultural, ethnic and concerns that must be entertained.
- viii. Changing governmental attitudes and patterns, which also implies to changing of education system.

Fortenberry [26] and Merton *et al* [30] suggested the following solutions to face the challenges in teaching, learning and assessment.

- i. Persuading educators to adopt new teaching techniques. Educators and learners are human participants in the learning process systems.
- ii. Gaining departmental and college support and approval of the curricula. Courses, laboratories, curricula and instructional technologies are the tools of the learning process.
- iii. Creating department and college level structures to coordinate manage and sustain the new programmes over time. The goals and objectives of faculty, departments, professional societies, employers, accreditors and other stakeholders must be clear.
- iv. Sustaining and increasing collaborative relationships across disciplinary and university boundaries. External social, political and economic are constraints to the engineering practice and education.

Besides the suggestions given by Fortenberry [26] and Merton *et al* [30], the authors recommend that the Malaysian government should offer more attractive remunerations to attract quality educators for HEIs. HEIs, with the support of government should introduce programmes to help commercialize research findings.

7.0 Conclusion

In order to move forward it is important to understand the history and to reflect upon it. To prepare ourselves for the future, it is necessary to look at the global changes, and trends. The education system must be able to overcome the challenges that arise from the era of globalization. EE plays an important role in planning, strategizing and charting the path for future engineering programmes in Malaysia. The government puts its commitment through the MOHE in supporting and in funding HEIs, and to encourage the investment in PHEIs.

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