EDUCATING FUTURE ENGINEERS: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

In this paper, various trends and challenges facing the world are discussed. These include urbanization and inequality in wealth distribution, clean air and clean water, food distribution, energy, global warming and climate change, old and new diseases and aging population, as well as physical-space and cyber-space security. The new Digital Revolution or commonly known as 4th Industrial Revolution causes anxiety in the industry, academia and society as we are uncertain of the future of our jobs and what new disruptive technologies are coming. The author also gives USA and Malaysian examples of challenges and limitation in STEM education. To tackle the challenges, we require new ideas and inventions which will only be possible with excellent knowledge workers. A brand new set of technology breakthrough will require different skill sets, particularly on STEM skill sets, in the engineering workforce. Good engineering workforce (engineer, engineering technologist and engineering technician) is considered as the driver for the success of any nation in this globalized world. The paper also touches on the challenges faced by future engineers vis-à-vis globalization and mobility of engineers; and what skills young engineering graduates should acquire to face the challenges. In the opinion of the author, what is important now is for the educators to train future graduates who can embrace life-long learning and professional skills with strong basic fundamentals of natural sciences and engineering, and who are ready-to-evolve rather than graduates who are just ready-to-market as many of the graduates will be entering a whole new and unknown sea of employment. Values and ethics should also not be forgotten in educating future graduates. In particular, three IC's are advocated for our future graduates: Integrity & Competence, Integration & Communication, and Internationalization & Cooperation.

Keywords: Engineering education, skill set for engineering workforce, STEM education, mobility of engineers.

1.0 INTRODUCTION

Ir. Professor Tan Sri Dato Dr Chin Fung Kee is one of the most respected and outstanding civil engineers in Malaysia, both in engineering practice and also in engineering research and education.[1] He is a renowned leader in geotechnical and structural engineering. He played a key role in the development of engineering education, research and practice in the country. Professor Chin completed his secondary education at the Bukit Mertajam High School and was awarded a Straits Settlements Scholarship at Raffles College, Singapore where he obtained a First Class Diploma in Arts. Then he was awarded a Queen's Scholarship in 1949 to study Civil Engineering at the Queen's University in Belfast. At Belfast he won the Foundation Scholarship in Civil Engineering and the Belfast Association of Engineers Prize. In 1952, Prof. Chin graduated with First Class Honors in Engineering and proceeded to complete his Master's at the same University while working as an assistant lecturer. In 1954 Professor Chin returned to Malaya and served as an engineer with the Drainage and Irrigation Department before joining the University of Malaya in 1955 as Lecturer, Senior Lecturer and finally a full Professor.

Prof. Chin (who was a senior lecturer then) played a major role in the formation and development of the Faculty of Engineering, University of Malaya, Kuala Lumpur. The Government of Malaya then decided to offer an endowment to any department/faculty which was prepared to move to Kuala Lumpur "lock stock and barrel" from Singapore. Prof. Gray (who was professor of civil engineering then) together with Prof. Chin agreed to take up the offer and was asked to see the Prime Minister of Malaya, YTM Tunku Abdul Rahman Putra. With the approval of the Tunku, an allocation of RM1.5 mil endowment was given to the Faculty for its development. Under the stewardship of Prof. Chin, the project went on full swing to build the Faculty of Engineering in early 1958; assembling the then existing government designs of buildings already constructed for the new Faculty of Engineering buildings at Lembah Pantai. The buildings were completed in a record time of four months, in time for the engineering courses to commence in October 1958 without any break in the moving of the Faculty to Kuala Lumpur "lock, stock and barrel". Professor Chin's great achievement in UM Faculty of Engineering, attained through the collective effort of both staff and students, was to build up in a short period of a few years, a degree which attained international recognition. A pass in engineering degree from the University of Malaya was readily accepted by British, Australian and American Universities for postgraduate studies which normally required a good honors degree. There was reluctance and decline by senior engineers to be posted as the State Engineer in Penang in the early 60's. One non-UM trained engineer agreed to accept the post on condition that he could have three UM engineering graduates as his assistants. This speaks volumes of the confidence on the quality of UM engineering graduates those days.

Prof. Chin was acting Vice Chancellor of University of Malaya for seven years and for a period he was concurrently the Professor and Dean of Engineering, Deputy and Acting Vice Chancellor. He retired as Emeritus Professor in 1973 and joined Jurutera Konsultant (SEA) Sdn. Bhd. Prof. Chin was an outstanding engineer in geotechnical, structural and hydraulic engineering and is always remembered for his leading role in the design and construction of the first Penang Bridge, the Penang KOMTAR building foundation rectification work and many other important projects such as the North-South Expressway.

Professor Chin's significant contributions benefited the engineering fraternity nationally, regionally and internationally and his success was recognized worldwide. Prof. Chin passed away in 1990 and in recognition of Prof. Chin's outstanding achievements and contributions, the Prof. Chin Fung Kee Memorial Lecture was inaugurated in 1991 and jointly organized by The Institution of Engineers, Malaysia (IEM) and the Engineering Alumni Association of the University of Malaya. Also a Prof. Chin Fung Kee Gold Medal was established in UM to recognize the top engineering student with the best result in the final year common subject on Management (and later was changed to award for the best engineering graduate).

The author had the honour to be invited by the Organizing Committee to deliver the 30th Prof. Chin Fung Kee Memorial Lecture. The author presented his lecture on 17, October, 2020 and this paper is a write-up on his presentation. This paper is an updated version of the author's paper entitled "Developing Engineering Work Force, Designing a Better Future" presented at the 3rd Chiam Teong Tee Memorial Lecture in March 2019.[2] Incidentally Mr. Peter Chiam Teong Tee was also a student of Prof. Chin and was encouraged by Prof. Chin to teach at UM in 1963, and was also the Dean of Engineering in 1973.

The author received his education all from Malaysia, starting from primary education to PhD. He was honoured to be a recipient of the Professor Chin Fung Kee Gold Medal in Management subject in University of Malaya during his final year electrical engineering course. In this paper, the author shares his experience as a researcher, educator and engineer in Malaysia. The paper also attempts to explain the technological revolutions in human civilization and the global trends in the Digital Revolution. Various challenges and trends in the globalized world are discussed, particularly population increase, urbanization, energy, clean air and clean water, inequality in wealth, food distribution and environmental issues. The new Digital Revolution requires a brand new breed of engineers, technologists and technicians. As there will be many disruptive technologies, and new jobs will be created while many old jobs will become obsolete, engineering education must be reviewed. The industry, academia and society are in anxiety as the technological advancement is progressing and changing so fast that no one can really anticipate what new technologies are coming. The author proposes that engineering education should aim to train "ready-to-evolve" graduates rather than "ready-to-market" graduates so that they are able to adapt to changes and new technologies in future. Thus, it is imperative to prepare the young generation with solid science, mathematics and engineering principles based on natural laws. They will need a strong foundation to be self-learners and to be able to keep abreast with the new technologies throughout their careers. At the same time, it is also important for us to educate our future engineers and technologists to be responsible, ethical and professional.

The author presents the trends in tertiary education, the USA and Malaysian scenarios in Science, Technology, Engineering and Mathematics (STEM) education. There is an urgent need to promote STEM education among the young children even as early as primary or lower secondary school level as there is a decline in the number of upper secondary school students taking Science subjects. The author also presents the skill sets and emerging clusters of professionals for 2022 by the World Economic Forum. He also proposes what professional bodies like the IEM can do to help the government, the Ministry of Education and the institutions of higher learning to train future engineers. Future engineers are expected to deal with complex problems, providing solutions which are novel and innovative. Mobility of the engineering workforce is another important issue that the author discusses in the paper, particularly for engineering services. For mobility, it is necessary for the engineering degree programmes to be recognized regionally and globally. It is also necessary for practicing engineers to attain experience which is of substantial equivalence to their counterparts worldwide. The author also proposes 3 IC's for the engineering profession: Integrity and Competency; Integration and Communications; and Internationalization and Cooperation. If every engineer carries with him/her these 3 IC's, the author is sure that the engineering profession will be highly regarded by the society and all engineers will be able to contribute to humanity as what Professor Chin Fung Kee had done.

2.0 AUTHOR'S EXPERIENCE IN MALAYSIA

The author takes pride in being a 100% made in Malaysia engineer. He completed all his primary, secondary and tertiary education (from degree to PhD) in Malaysia. He started with his primary education in a Chinese school, Hu Yew Siah, in Penang. He then continued with his lower, higher secondary education and sixth form study in Chung Ling High School in Penang. In 1986 he completed his four year electrical engineering degree programme in the Electrical Engineering Department of University of Malaya. Then he proceeded to complete his master's degree by research in 1988 while working as a tutor in the department. After completing his Master's, the author was actually awarded full scholarship from University of Cambridge UK, University of California San Diego, and University of Texas at Arlington to pursue his PhD degree. However, family circumstances stopped him from going overseas. Thus he decided to stay back in Malaysia. In 1988 he started his career as a lecturer in the Electrical Engineering Department of UM while pursuing his part time PhD programme in the same department. The author is very fortunate to have both his Master's and PhD projects supervised by Professor Tan Hong Siang, another renowned electrical engineering professor in UM. The author completed his PhD in 1992 after publishing eight international journal papers based on his PhD work. Then he continued to teach and conduct research in UM, before he was offered as a full Professor and founding Dean of Engineering of the first private university in Malaysia, Multimedia University. The author spent 11 years in MMU as the Dean, Director of Research and later as Vice President (Academic and Research & Development). In 2008-2019, the author was appointed as the President of Universiti Tunku Abdul Rahman. As a Malaysian trained engineer and as an educator in Malaysia, the author learnt a few things which he would like to share.

While he was doing his research projects in late 80's and early 90's in UM, research funding was scarce and difficult to get. He only managed to obtain a total of RM10,000 for 3 years under the Vote F grant in UM. Thus he could not afford expensive equipment nor a super workstation to work on his project. Both his supervisor and he decided on a theoretical project on multiple scattering mechanisms in random media for application in microwave remote sensing. The formation of the problem based on High-order Renormalization Method ended up with a 36-fold integral equation. He did not give up but persevered and finally managed to solve the equation until the last 6-fold integration which he had to resort to numerical technique using the available computing facility in the laboratory then – an IBM 8088 computer. Yet they managed to produce results which are able to match with experimental data available in the literature. While he was solving his theoretical problem at Master's level, after about four months, he re-formulated what his PhD supervisor did during his sabbatical leave in USA in 1980. The author detected an error in the original solution based on Second-order Renormalization Method provided in a published paper by his PhD supervisor and his co-researcher in USA. The author went to see his PhD supervisor Prof Tan. Instead of questioning the author, Prof Tan was quick to admit there was a mistake and encouraged the author to quickly submit a paper to IEEE Transactions on Geoscience and Remote Sensing with the right solution. The paper corrected the error in the Second-order Renormalization Method and further included the solution the author proposed based on High-order Renormalization technique (the 36-fold integral solution!). His solution was able to produce simulated radar backscatter results which could match with the experimental data in the field, for both the co- and cross-polarizations. The author learnt from his supervisor that to move the frontier of knowledge, we must be open minded and accept that our own students could know more than ourselves in certain aspects – that is what advancement of knowledge and research is all about. The author's favourite quote to all his undergraduate and postgraduate students and colleagues is: "If a person can only work when given everything under the sun, he is just mediocre. If a person can perform within constraints, he is a real achiever". One must have the commitment, passion and right attitude in doing one's job. It is not the method that is important, it is how we apply the method to solve problem and to find a solution which has not been done before. Another lesson he learnt is about being humble and do not look down on anyone, even your own student.

While serving as a lecturer in the Electrical Engineering Department, the author was assigned different subjects to teach: Field Theory, Electromagnetics, Quantum Mechanics, Machine Theory, Microprocessor, Communication Theory, Electronics, Engineering Mathematics, Instrumentation and Control. He never objected. The best way to learn is to teach. When we teach, we shall push ourselves to learn what we do not know and we shall continue to know a subject better and in greater depth. Thus another of his favourite quote is "Learning never stops: Keep learning new knowledge". Don't just simply complain. Whatever we learn now, even if it appears to be not useful, it will enhance our knowledge. For example, many electrical engineering students now argue why they should learn thermodynamics which appears to be not relevant to an electrical engineer. But engineering problem is now more and more multi-disciplinary. Our knowledge on Laws of Thermodynamics, for example, will make sure we do not aim to design and produce a perpetual motion machine! Also many engineering students feel it is a waste of time to learn accounting and management, but we must remind ourselves that engineers are expected to be good project and resource manager – both in technical and financial aspects.

The author spent his sabbatical leave in University of Texas at Arlington in 1994 for a period of nine months as a Fulbright Scholar. During that period, he was involved in a research on electromagnetic wave scattering in random dense media. His interaction with co-researchers in USA enhanced his belief that it does not matter where one graduates from. It is the attitude, the desire to continue learning, the ability to work with others with cultural intelligence and the right mindset that will differentiate between a successful person and a failure.

3.0 DIGITAL REVOLUTION AND ENGINEERING EDUCATION

3.1 Waves of Technological Revolution

Over the past few centuries, human civilization has gone through several major technological revolutions (see Figure 1), starting with the first phase of the Agricultural Revolution in the Middle Ages. One significant implement during this period was the heavy plough, which could plough deep and turn over the heavy fertile clay soils in Northern Europe. Economies and cities grew and prosperity came along. Another phase of the Agricultural Revolution came in the 1700s and it brought great changes in the way farming was done. The technological advancements via mechanization had eased the work of farming while scientific methods allowed for the improvement of crop yields and livestock.

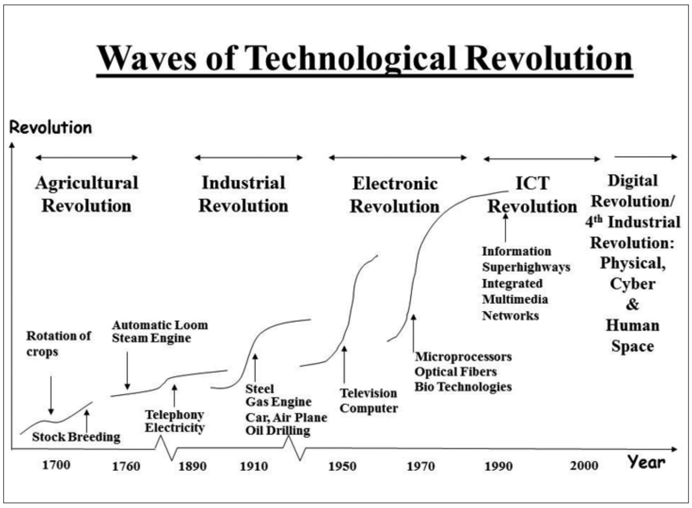

Figure 1: Waves of Technological Revolution

During the Industrial Revolution which took place in the late 18th century, the economy began to shift towards industrial and machine manufacturing. The invention of the steam engine was crucial in the Industrial Revolution. Goods were mass produced in factories, moving away from the home-based, hand-made industry. The mass production of goods led to the cheaper prices of goods. The mushrooming of factories during this period brought about drastic social, economic and environmental implications.

The Electronic Revolution, which heralded the coming of the Information Age, began in the late 1940's and 1950s. It marked a technological shift from analog and mechanical to digital. The invention of the transistor in 1947 paved the way for the computers and supercomputers that we use today. We began to enjoy telephones, televisions and computers. The Information and Communications Technology (ICT) Revolution, which started in the 1990s and which is still on-going, relies on the foundations built during the Electronic Revolution. It alters the way we communicate and also the way we generate, process and share information. The ICT Revolution affects almost all aspects of our daily lives, bringing profound effect to humankind.

The next wave of revolution, which is happening now as the ICT Revolution begins to spread across wider economy sectors, will see technologies being embedded in societies and even human bodies in whole new ways. Many call this the Fourth Industrial Revolution. However, the author would like to call it the Digital Revolution as it not only affects the Industry, but cuts across all sectors. Also, one should not forget about the First Revolution (The Agricultural Revolution). The Digital Revolution brings about advanced robotics and autonomous transport, artificial intelligence and machine learning, advanced materials, biotechnology and genomics. It is all set to transform our way of life and also way of work – at an exponential rate.

As we take a deeper look into the time frame of these technological revolutions, we will realize that the time span for each wave of technological revolution is becoming shorter and shorter. This means that technology is changing at a faster and faster pace. It is crucial that we should take heed of this development lest we are drowned by the technological waves.

3.2 Widening Trends and World Challenges in the Globalized World

We now stand at the unfolding of a technological revolution that has the immense power to affect all aspects of our lives. The changes are taking place at an unprecedented pace and no slowdown is in sight.

About 20 years ago, the pace of the already globalized world was accelerated by a new transformative creation – the Internet. Geographical borders melted away and the world evolved into a borderless global village. Due to recent advancements in transport and also technology, the effects of globalization are even more profound. The economic event of one nation will have ripple effects in another remote nation across the globe. This presents opportunities for the initiated. We are not looking at local market itself, but regional and world markets.

Things are becoming miniature in size and advanced in features. As technology becomes more and more advanced, the functions of multiple electronic devices begin to converge towards a single one. For example, the radio, television and personal computer merged into a small smartphone in our hands. Fast forward ten years, affordable mobile communication and devices put communication and the Internet into the hands of billions of people anytime, anywhere – whether for business or play. With web and mobile applications, people can get almost anything, from computers, T-shirts and phone covers to food and transport – all in a personalized manner. For example, one can order via the internet one's own designed T-shirt and it can be custom-manufactured by an AI-controlled machine and delivered to your door step within a few days. With seamless information and communication technology in hand, we have become better informed and thus, our expectations begin to grow.

As technology advances, the cost of doing things has been greatly brought down by the increased effectiveness of processes. Technological breakthroughs and progress have basically pointed to one thing: the power of knowledge.

As at April 2020, the world population stood at 7.7 billion, and counting. By the year 2050, it is estimated that it could reach more than 9 billion. The population growth has been so rapid that it will most definitely pose serious social and economic challenges. It calls for greater efforts in meeting the basic needs for food, clean water, energy, housing, decent work, healthcare and education.

The challenges faced by a world which plays host to more than 7 billion inhabitants are aplenty. The global wealth report published by Credit Suisse in 2017[3] highlighted the widening gap between the have's and have-not's where the globe's richest 1% own half of the world's wealth.

As a whole, the global population becomes more urban. In 2010, 50.5% or 3.5 billion people lived in cities. The rising level of urbanization will reach 84% in North America and 64% in Asia by 2050. In Malaysia, it is projected that by 2050, our population will reach 42 million and 86% of the population will be concentrated in urban areas.

With the increase in human population, human activities, which are the major contributors to the air pollution problem plaguing the world, will increase in tandem. Air pollution – the biggest environmental risk to human civilization – causes one in nine deaths.[4] Other shocking statistics on fatalities linked to air pollution include the following:

- 6.5 million people die annually due to poor air quality including 4.3 million due to household air pollution
- 52 million years lost or lived with disability annually caused by lower respiratory infections due to household or ambient air pollution, including second-hand tobacco smoke
- 32 million years life lost or lived each year with disability due to chronic obstructive pulmonary diseases as a result of household air pollution and workers' exposure
- By 2030, ground level ozone pollution will reduce staple crop yields up to 26 per cent

As the world continues to grow and progress, a lot of people are still without access to clean and safe water.[5] In 2015, 2.1 billion people were without safely managed drinking water services – that is, they had no access to improved water sources located on premises, available when needed, and free from contamination. Those people included:

- 1.3 billion people with basic services, meaning an improved water source located within a round trip of 30 minutes
- 263 million people with limited services, or an improved water source requiring more than 30 minutes to collect water
- 423 million people taking water from unprotected wells and springs

- 159 million people collecting untreated surface water from lakes, ponds, rivers and streams

In a world where we intend to produce enough food to feed everyone, 821 million people – one in nine – still go to bed on an empty stomach each night. Even more – one in three – suffer from some form of malnutrition.[6] Ironically, as people go hungry every day, around a third of the world's food is lost or thrown away each year. We waste 1.6 billion tons of food annually, worth about $1.2 trillion dollars.[7]

As the earth plays host to more and more inhabitants, the big question arises, "Will the earth's resources be able to sustain this population boom?" We have already seen clear signs of the environment bearing the brunt of it. The U.S. Energy Information Administration's latest International Energy Outlook 2017 (IEO2017) projects that world energy consumption will grow by 28% between 2015 and 2040, and three-quarters of the world energy consumption through 2040 will still come from fossil fuels.[8] In Malaysia, the energy consumption has increased almost three-fold from 17,728 ktoe in 1993 to 51,584 ktoe in 2013 while the energy consumption for petroleum products increased from 13,075 ktoe in 1993 to 29,190 ktoe in 2013.[9]

The increased consumption in fossil fuels will cause an upward trend in greenhouse gas emission resulting in the increase in global temperature. According to the Earth Policy Institute 2010 Report, from 1880 to 1970, the Global Average Temperature increased 0.03°C/decade. In fact since 1970, it has increased 0.13°C /decade. 2/3 of the increase of 0.8°C happened in the last 40 years. This will cause sea levels to rise and change the amount and pattern of precipitation, and we have to brace ourselves for the coming of more natural disasters. On 26 December 2004, a magnitude 9.3 temblor struck the undersea off the west coast of Sumatra creating a massive tsunami that left an estimated death toll of between 230,000 to 280,000 in 14 separate countries in its wake. In 2011, East Africa was hit with the worst drought in 60 years and in November of the same year, Thailand experienced its worst flooding in half a century.

Improvements in healthcare have vastly contributed to the increase in life expectancy. As of 2018, the average life span of a Malaysian was estimated at 74.7 years; in 2000, it was 72.2 years. We have to come to terms with the fact that Malaysia is heading towards an aging nation. The United Nations Economic and Social Commission for Asia and the Pacific's 2016 population data sheet shows that in 2016, Malaysians aged 60 and above comprised 9.5% of the population. This is projected to increase to nearly a quarter of the population (23.5%) by 2050.[10] Nevertheless, does living longer means having a better quality of life? Well, not necessarily. While the rates of infectious diseases may have gone down, various National Health and Morbidity surveys show the worrying continuous upward trend of the number of those afflicted with lifestyle/non-communicable diseases such as diabetes, hypertension, obesity and cancer.[10] This will add more stress to the country's healthcare system as it struggles to take care of the increasing number of aging and ill patients. Ultimately, the overall cost of healthcare will go up.

In 1940's and 1950's, Tuberculosis (TB) was considered as number one cause of death in Malaysia. With the introduction of National TB Control Programme in 1961, and with vaccination and good medical treatment, TB has not been a treat anymore since the 90's. However, as public awareness of TB dwindled away and with presence of illegal immigrants who did not seek treatment for fear of actions being taken against them by the authorities, TB has now resurfaced as a contagious disease killing about 1500-2000 lives annually in Malaysia.[11] A National Strategic Plan for TB Control's goal of making Malaysia TB-free by 2035 has been in place by the Ministry of Health. Thus we must not overlook the possibility of coming back of old diseases. The recent highly infectious and deadly COVID19 is an example of new diseases and its effects on the world are unprecedented. No country is an island in this global village. We may initially think it was just confined to a country, but very soon we realize that every corner of the globe is affected. The extent of the spreading of the virus, the health care pressure, the shortage of medical supplies and equipment especially personal protective equipment due to lock down of cities and movement control by different countries, the closing down of businesses, the melting down of the stock markets etc are some of the consequences of such a new disease. Thus we need to be more well prepared for such emergency cases and international collaboration is certainly required to tackle such cases.

As the cyber world plays a bigger role in people's lives, cybercrimes are also on the rise. Data-destroying software, ransomware, network attacks and data thefts are becoming commonplace nowadays. Large corporations and governments are not spared from suffering massive data and consequential financial losses. E-mail and mobile phone scams have resulted in identity thefts and system frauds. Besides financial losses, there are increasing instances where cybercrimes unfold into real physical-world harms. Stalking, harassing and blackmailing, cyber-bullying, online romance scam and fake news are some of the examples.

3.3 The Digital Revolution (Fourth Industrial Revolution)

The winds of change have been constantly blowing and we are now staring right into the advent of a Fourth Industrial Revolution as indicated by how technologies are emerging and impacting our lives. The author would like to call it the Digital Revolution instead of the Fourth Industrial Revolution. This is to register the fact that we should not miss the First Revolution – The Agricultural Revolution. The Digital Revolution is built on previous Revolutions, particularly the Electronic and ICT Revolutions with the development of digital systems and communication, and rapid advances in computing power. In this Revolution, we will see technologies being embedded within societies and even human bodies in whole new ways. It will bring about advanced robotics and autonomous transport, artificial intelligence and machine learning, advanced materials, biotechnology and genomics, transforming our way of life and also way of work.

The Digital Revolution will affect our job or career in ways that are unprecedented. It is predicted that over one-third of the skills that are considered important in today's workforce will change. Current skills will become obsolete and new skills that are previously unheard of will leap into centre stage. "The Future of Jobs" Report published in 2016 by the World Economic Forum[12] highlighted that digital technologies, combined with other socio-economic and demographic changes, will transform labour markets in the next five years, leading to a net loss of over 5 million jobs in 15 major developed and emerging economies.

Two million new jobs will be created in the digital industrial and services sectors while 7 million jobs will be lost in traditional industrial and service sectors. It is also predicted that 65% of children entering primary school today will ultimately end up working in completely new job types that do not exist yet.

Various countries have adopted national initiatives in response to this Digital Revolution in order to propel their countries ahead of looming competition as in the following chart:

Initiatives by Various Countries for Digital Revolution

- **Industrie 4.0 of Germany**
- **Reindustrialisation of USA**
- **New Industrial of France**
- **Rejuvenation Plan of Japan (Building Society 5.0 by 2050)**
- **China**
  "Internet Plus" Action Plan;
  Big Industry Country 2015;
  Made in China 2025;
  Primary Industry Power 2025;
  Medium Industry Power 2035;
  Leading Industry Power 2045
- **Manufacturing 4.0, Korea**

Figure 2: Initiatives by Various Countries for Digital Revolution

3.4 Education – The Driver in Digital Revolution

At the core of an innovative and productive high income economy is its human capital. Education, and thus human capital development, will need to train inquisitive and creative minds to tackle the growing global challenges and uplift the standard of living. Education can be the catalyst of change and innovation, and the driver for economic growth.

As the number of institutions of higher learning and programmes offered increase, the quality and standard of the programmes have become more critical and there is a need for some kind of quality control or assurance. Quality assurance needs to be done to ensure that the graduates produced by the institutions of higher learning are indeed competent and able to compete not only in the local scene, but also in the international arena.

Solid financing goes a long way in sustaining the well-being of institutions of higher learning. Due to the rise of overall living costs and budget cut by government on education, there arises the pressing need to adjust the tuition fees accordingly. Nevertheless, institutions of higher learning need to strike a balance between maintaining their existence and avoiding higher education being exclusive to people from higher income groups. This is where new technology such as e-learning can come into play to address the rising cost of education.

Faced with constant disruption of the labour market and the fast pace of change, we need to ensure that our engineering and technical education is broad and diversified enough to tackle future trends. Extra focus and effort should be put into Technical and Vocational Education and Training (TVET) to prepare graduates for the real world of work. It is indeed a challenge for institutions of higher learning to tailor curricula that cater well to the demands of industries or employers in order to enhance the employability of their graduates. And it is crucial for the institutions of higher learning to continue generating fresh ideas and keep on innovating in all aspects, from programme design to delivery.

To allow students from all walks of life equal access to higher education, an understanding of the underlying concerns and the setting up of an efficient student loan/aid system have to be in place.

When all the issues surrounding higher education are properly addressed, only then will the institutions of higher learning be well poised to produce graduates who are ready to take on the task of contributing to the nation and propelling it forward.

3.5 The U.S. Experience

In 2005, the U.S. realized that their competitiveness in the global economy was declining in comparison to some rising Asian countries such as China, Singapore and South Korea largely due to globalization. The U.S. National Academies was then commissioned by the U.S. Congress to study the phenomenon and to offer recommendations. The result – a report entitled "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" identified the areas that are in dire need of revamps, which include the knowledge capital, human capital, and the existence of a creative ecosystem. During that period of time, the facts and statistics in higher education and research in U.S. showed a worrying trend. Financial allocations for higher education and research were significantly lower than those rising Asian countries. A huge portion of the doctoral degrees were awarded to foreign students. Also, more than a third of the workforce with PhD qualifications in the fields of science and technology were foreign born. Moreover, it was found that a third of U.S. students with initial intention to major in engineering ended up switching their majors before graduation. In fact, they found that the interest in science and engineering had been dwindling in the prior decade.

3.5.1 The U.S. Experience Revisited 2010

Five years later, the follow-up report entitled "Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5" made even more startling discoveries. In 2009, U.S. consumers spent significantly more on potato chips than energy research and development – \$7.1 billion versus \$5.1 billion. 51% U.S. patents were awarded to non-U.S. companies. Federal funding on research in physical sciences fell by 54% in 25 years after 1970, while engineering funding declined 50%. Even more worrying was the fact that 69% of U.S. public school students in the 5th-8th Grade were taught Mathematics by teachers without a degree or certificate in Mathematics while 93% of U.S. public school students in the 5th-8th Grade were taught Physical Sciences by teachers without a degree or certificate in Physical Sciences.

3.6 Engineering Education in Malaysia

An engineering personnel is a person with an analytical mind who can think logically and provide solutions based on fundamental principles of natural laws. The engineering workforce is the prime mover behind nation building. As Malaysia develops into a knowledge-based and innovation-driven economy, it is crucial that we continue to strengthen our engineering education and stimulate the growth of the engineering population. Currently, Malaysia still lags behind developed countries such as France, Germany, Canada and United Kingdom in terms of engineer-population ratio. It is estimated that the ratio for Malaysia now stands at about 1:150 and the targeted ratio by 2020 is 1:100.

As at April 2020, there were 56 institutions of higher learning (17 public and 39 private) offering 270 active accredited engineering programmes in Malaysia. In 2017, enrolment in engineering programmes only made up about 20% of the overall enrolment in degree programmes. The ratio of male to female engineering enrolment was about 1:0.68 (see Figures 3-5).

Current Scenario in Malaysia:

1. **Total Number of IHL's with Engineering Degree Programmes (April 2020):**
    - **17 Public**
    - **39 Private**

    offering 270 active accredited programmes

2. **Total Number of Engineering Disciplines: 28**

2017 (IHL's)	Engineering, Manufacturing and Construction (% of Overall Degree) (Male:Female)
Intake	33409 (17.8%) (1:070)
Enrolment	122932 (20.3%) (1:0.68)
Output	27142 (20.3%) (1:0.74)

Source: EAC & Higher Education Statistics 2017, MOHE

Figure 3: IHL's with Engineering Degree

Current Scenario in Malaysia

Statistics of Bachelor Degree Students in Public Universities 2017

	Bachelor Degree (M:F)	Science-based (M:F)	Engineering, Manufacturing & Construction (M:F)
Intake	96483 (1:1.77)	49027 (1:1.37)	23669 (24.5%) (1:0.88)
Enrolment	332023 (1:1.77)	168873 (1:1.36)	83792 (25.2%) (1:0.86)
Output	79725 (1:1.94)	39356 (1:1.51)	19092 (23.9%) (1:0.94)

Source: Higher Education Statistics 2017, MOHE

Figure 4: Statistics of Degree Students in Public Universities 2017

Current Scenario in Malaysia:

Statistics of Malaysian Students in Private Institutions of Higher Learning 2017

	Total (M:F)	Degree (M:F)	Estimate of Engineering, Manufacturing & Construction (%) (M:F)
Intake	222315 (1:1.10)	91033 (1:1.09)	~9740 (10.7%) (1:0.39)
Enrolment	565852 (1:1.08)	274787 (1:1.06)	~39140 (14.2%) (1:0.39)
Output	149857 (1:1.25)	54120 (1:1.15)	~8050 (14.9%) (1:0.40)

Source: Higher Education Statistics 2017, MOHE

Figure 5: Statistics of Malaysian Students inPrivate Institutions of Higher Learning 2017

Every year in Malaysia, about 230,000 students graduate from institutions of higher learning. Shockingly, one out of five graduates remain unemployed, with the majority being degree holders. These graduates make up 35% of those who are unemployed. The reasons boil down to the following:[13]

- Asking for unrealistic salary/benefits (66%)
- Choosy about the job/company (58%)
- Poor character, attitude or personality (58%)
- Poor command of English (52%)
- Poor communication skills (49%)

Institutions of higher learning have to be responsive and rethink how best to train and prepare engineers to answer the challenges posed by the fast paced, competitive, and global environment of the 21st century. As a start, emphasis should be placed on strengthening the fundamentals of engineering where solutions to most complex problems can be designed.

A wholesome engineering education should also focus on nurturing engineers who have the ability to think logically and analytically and make wise decisions or propose constructive and practical solutions based on fundamental principles of engineering. Also, engineering students should have the insatiable thirst for knowledge and the institutions of higher learning should steer them towards the path of knowledge exploration and self-development. No man is an island and engineering students would do well to have linkages to social networks that provide them the avenues for discourses and exchanges of ideas and information.

Institutions of higher learning should provide engineering students with greater experiential preparation to work under constraints. Instead of being brought down by constraints, engineers should be inspired by them as most of the time, they may well be the building blocks that hold the key to creativity and innovation.

As Albert Einstein once said, "Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid". Thus the institutions of higher education must allow the academic staff more flexibility in delivering of the curriculum to the students, making full use of the flexibility inherent in online technologies.

Admittedly, engineering education may at times be viewed in a 'not-so-positive' light. When it comes to engineering education, people always think that it is tough, boring and too technical with simply too many problems that need to be solved. This misconception is something that needs to be tackled and managed right from the early stages if Malaysia is to achieve its targeted engineer-population ratio.

3.7 Main Challenges in Malaysia

Efforts to increase the engineering workforce in Malaysia may well be an uphill task. For example, statistics showed that in 2014, only about 21% of students in upper secondary schools chose to study in science subjects, and this is one of the main contributors for the shrinking engineering workforce in Malaysia. It has also been the current trend for school leavers to rush for degree courses only. This has left a great void for technicians at diploma levels.

An analysis of the Science, Technology, Engineering and Mathematics (STEM) enrolment among students in Malaysia shows a worrying trend. In 2012, a total of 441,883 students enrolled in Form 1.[14] However, in 2016, only 48.6% of those students continued on in STEM streams (23.7% in science, 8.8% in vocational and 16.1% in technical streams). It showed a leakage of 17,755 students in Form 3 and another 34,037 in Form 5. And after the Form 5 *Sijil Pelajaran Malaysia* (SPM) examination, in 2017, only 19.8% of the students managed to continue on in Matriculation, Form 6 and Vocational College in STEM. This was only 8.5% of the Form 1 enrolment in year 2012 (see Figure 6)!

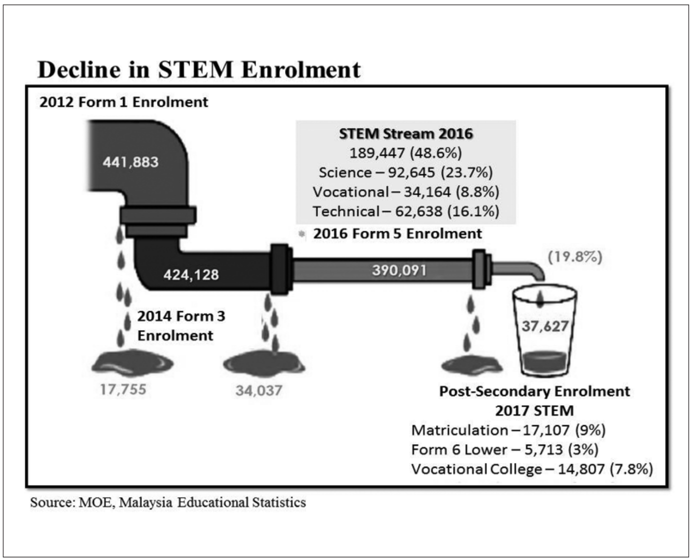

Figure 6: STEM Enrolment in Malaysia

The teaching profession seems to have lost its past glory and social status, and it has been quite a challenge to get qualified and experienced teachers and lecturers to teach and guide future generations of engineering students. To add on to the challenges faced by engineering education, top down governance mechanism in schools and institutions of higher learning has more often than not restricts freedom for innovation.

As Malaysia moves towards a knowledge-based digital economy, its requirement for a bigger pool of highly skilled engineering workforce will naturally increase. This has led to the increased demand for higher education, and consequently, to cater to the increasing demand, the number of institutions of higher learning will also increase, leading to keen competition and the constant struggle for survival. We must ensure quality of education is not compromised.

In this era of globalization and internationalization where everyone and everything become more and more interconnected and interdependent, it is imperative that institutions of higher learning take on a global approach and explore new emerging areas. Not only that, they should also strive to enhance their graduates' employability by equipping them with skills fit for this globalized world while guiding them towards building a global human network for healthy exchanges, collaboration, and support.

3.8 Future Job Trends

Based on a survey of trends expected in the 2018-2022 period in 20 economies and 12 industry sectors, the following five important findings are reported:[15]

(i) The focus, adoption and applications of automation (including AI), robotization, digitization and big data analytics will vary across different industries (see Figure 7).

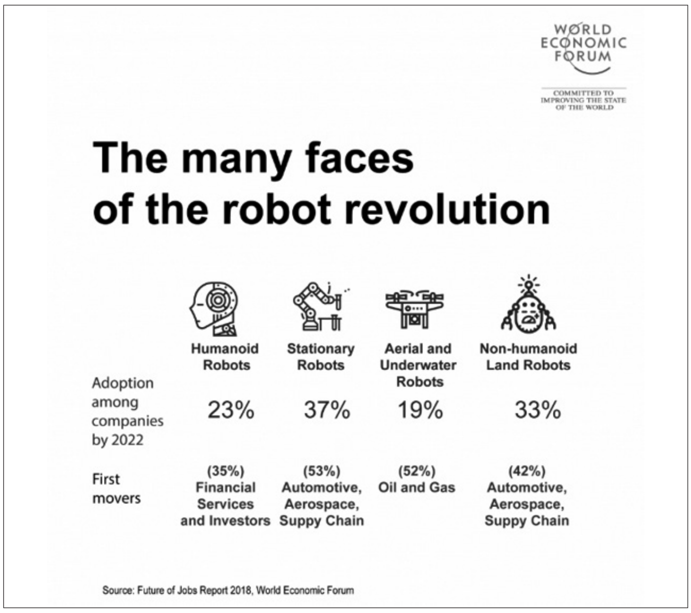

Figure 7: Many Faces of the Robot Revolution (Image from Future of Jobs Report 2018, World Economic Forum)

(ii) Though there is a major disruption in job market, there will be a net positive outlook for jobs – by 2022, emerging occupations will grow from 16% to 27%, while jobs affected by technological obsolescence will decrease from 31% to 21%. In short, 75 million current jobs will be displaced, while there will be 133 million new jobs emerging (see Figure 8). Jobs that require innovation, people and culture, and human touch will continue to grow while those clerical and mundane and repetitive jobs will be replaced with robots.

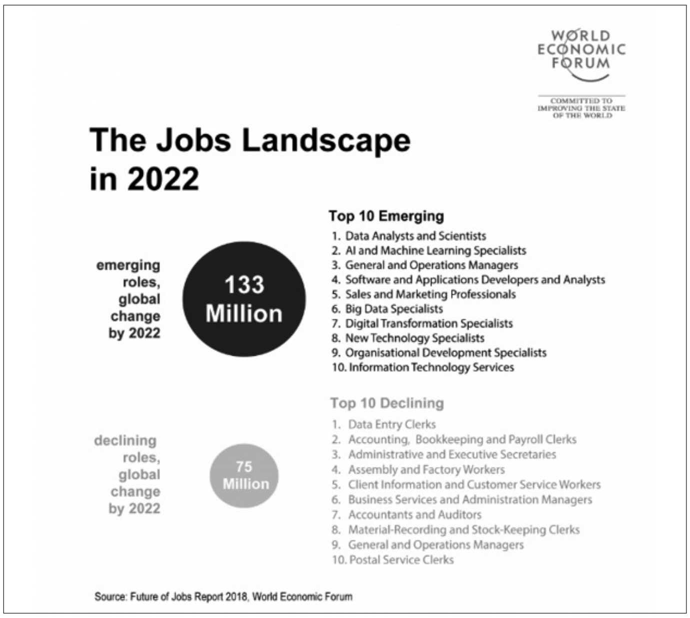

Figure 8: Job Landscape in 2022 (Image from Future of Jobs Report 2018, World Economic Forum)

(iii) There is a rapid shifting in the division of labour between humans and machines/algorithms – currently only about 29% of the total task hours are performed by machines or algorithms; while 71% are by humans. By 2022, it is expected to be 58% by humans and 42% by machines/algorithms (see Figure 9).

(iv) New skill sets are demanded by the new job scopes – there will be a significant shift from core skills of about 58% to workplace skills of 42% by 2022. The workplace skills include analytical thinking, active and self-learning, creativity, originality and taking initiative, negotiation and persuasion, cognitive flexibility, complex solving, leadership, emotional intelligence as well as social and cultural intelligence (more details in Section 3.10).

(v) Life-long learning is a necessity. Learn, unlearn and re-learn will be the trend. Re-skilling and Up-skilling will be the key factor for survival of management and companies. It is estimated that employees require 101 days of re-training and up-skilling for the period up to 2022.

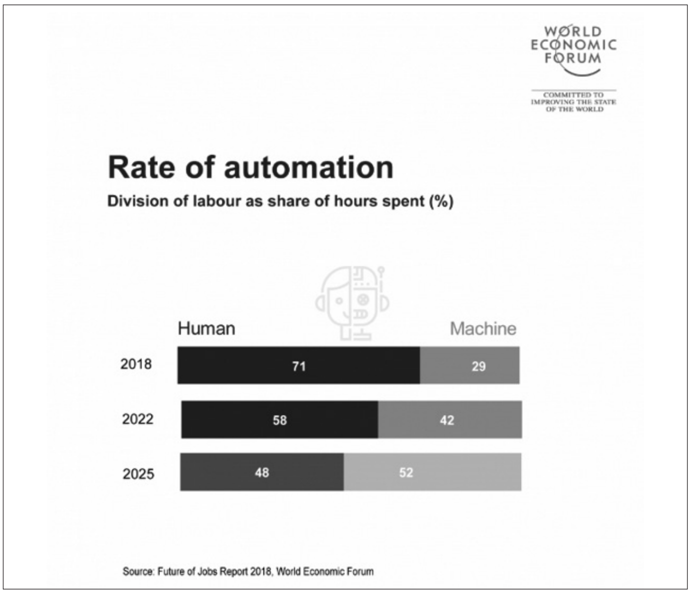

Figure 9: Division of Labour between Human and Machine (Image from Future of Jobs Report 2018, World Economic Forum)

3.9 Clusters of Professionals in 2020-2022

As job landscape will change due to the disruptive technologies in the Digital Revolution, there will be emerging clusters of jobs. From the World Economic Forum 2020 report "Jobs of Tomorrow: Mapping Opportunity in the New Economy"[16] (see Figure 10), some key findings include:

(i) Seven key professional clusters are emerging in tandem with demand of professionals of the future who require both "digital" and "human" skills. These are: Data and AI; Engineering and Cloud Computing; People and Culture; Product Management; Sales, Marketing and Content; Care Economy; and Green Economy.

(ii) It is estimated that in 2020, the featured 7 professional clusters will represent 506 out of every 10,000 job opportunities; and 715 out of every 10,000 job opportunities by 2022.

(iii) Based on the World Economic Forum's 2018 Future of Jobs Report, a total of 133 million new jobs will be created over the 2018–2022 period. Then using the survey done for the report in 2020, the seven emerging professional clusters are estimated to create 1.7 million new jobs in 2020, and growing to 2.4 million jobs by 2022. From 2020-2022, 37% of projected job opportunities will be in the Care Economy; 17% in Sales, Marketing and Content; 16% in Data and AI; 12% in Engineering and Cloud Computing; 8% in People and Culture and 1.9% in Green Economy.

(iv) Within the high-volume jobs, the following are the highest growth professionals: Artificial Intelligence Specialists, Medical Transcriptionists, Data Scientists, Customer Success Specialists and Full Stack Engineers. Within the lower-volume jobs, the highest growth is in Landfill Biogas Generation System Technicians, Social Media Assistants, Wind Turbine Service Technicians, Green Marketers and Growth Hackers.

	Number of Opportunities (per 10000)	
Professional Clusters	2020	2022
Data and AI	78	123
Engineering and Cloud Computing	60	91
People and Culture	47	58
Product Development	32	44
Marketing, Sales and Content	87	125
Care Economy	193	260
Green Economy	9	14

Figure 10: Emergence of Clusters of Professionals of the Future, 2020-2022[16]

From these studies and reports, engineering profession is no exception as far as future jobs are concerned. New emerging technologies require us to train our students with new technical skill sets. In addition, human skills are also important and should not be overlooked.

3.10 Top Skills Required for Future Graduates

Based on Annual Meeting of the New Champions (2018) by Vesselina Stefanova Ratcheva and Till Leopold, World Economic Forum,[15] the following ten skills will take centre stage come 2022 as shown in the following chart:

2022 Skills Outlook

- Analytical Thinking and Innovation
- Active Learning and Learning Strategies

Creativity, Originality and Initiative

- Technology Design and Programming
- Critical Thinking and Analysis
- Complex Problem Solving
- Leadership and Social Influence
- Emotional Intelligence ***(+Cultural Intelligence)***
- Reasoning, Problem-solving and Ideation
- Systems Analysis and Evaluation

Source: World Economic Forum 2018

Figure 11: Top 10 Skills Required in 2022

If we take a close look at the skills outlook, we would realize that mere memorizing of facts and information is no longer sufficient for our future graduates. We need to train students with analytical, logical and critical mind, self-learners with creativity and innovativeness. The future graduates need to have leadership skills and must be pro-active. They need to be able to provide practical solutions in a more wholesome manner. With rapid technological changes that we are experiencing, problems and challenges will take on a more complex outlook, and solving them will require a different or new approach.

In addition to technical and professional skills, it is imperative that future graduates also master certain general skills. Social skills seem to occupy one of the prime spots. In the ten skills for future graduates listed in the "10 Trends – Transformative changes in higher education" published by the British Council in June 2017 (see Figure 12),[17] social intelligence is one of the top three skills that future graduates should possess. Social intelligence is all about building relationships and finding one's way around social environments. The author also thinks that cultural intelligence is going to be an important skill set. We are going to deal with different people from different countries, with different religious beliefs and cultural backgrounds. Malaysians do have an advantage due to our multi-ethic, multi-cultural, multi-lingual and multi-religious environment. We must capitalise on our strength so that we can perform in this globalized environment.

10 Key Skills for Future Graduates

- Sense Making
- Social Intelligence
- Novel and Adaptive Thinking
- Cross-Cultural Competency
- Computational Thinking
- New Media Literacy
- Trans-disciplinarity
- Design Mindset
- Cognitive Load Management
- Virtual Collaboration

Source: The Institute for the Future, British Council (2017), 10 Trends Transformative Challenges in Higher Education

Figure 12: 10 Skills for Future Graduates

3.11 Ready-to-Evolve Graduates – A Proposal

The advent of the Digital Revolution has brought along a frenetic sweeping change that makes the task of predicting the future requirements of jobs almost utterly impossible. When industrial development is progressing much faster than the academia, the academia and the society in general are in anxiety. We are not sure of the future technologies, and neither are we sure what kinds of graduates are required by future job markets. Faced with this, institutions of higher learning should realign themselves to produce graduates who are highly flexible and adept in working with new paradigms. Future graduates should be trained to be "ready-to-evolve" in line with evolving labour market requirements. As such, high priority should be given to the solid fundamental of engineering sciences such as mathematics, material sciences, electromagnetics, thermodynamics, dynamics and kinetics in the first two years of the engineering programmes. Additionally, in the first two years, while training students on the basics, more engineering application examples should be incorporated into lectures. As technology changes, more elective options should be introduced for students in the third and fourth years, and the Faculty should have the flexibility to review, introduce and remove these elective options as and when the need arises. At the same time, the training of skill sets should be integrated into lectures/tutorials. There is also a need for a soft skills certificate system as an added incentive for students to develop and enhance their soft skills. Additionally, students should be encouraged to participate in exchange programmes within Malaysia and internationally on a credit transfer basis to gain a broader perspective and outlook, and a deeper understanding of other cultural and global issues. While technological training is important, tertiary education must also not forget the very basic of education: training a wholesome and ethical individual who will be useful for the society. Thus ethics and professionalism, the ability to work as a team, social responsibility to our society and good universal values must be imparted onto the students as a social norm. The author always shares with his colleagues and students: "the harm that a highly educated person will bring to the society, if he is not ethical, is going to be much more than an uneducated person".

3.12 Complex Problem Solving Skills

One of the important engineering graduate attributes expected by engineering programmes under the Washington Accord is that the graduates must have complex problem solving skills. There are different understanding and interpretation of this requirement.

Real life problems are not just scientific nor technical in nature. They encompass different aspects, from technical to environmental, to social and economic; from scientific to financial and cost-effectiveness of solutions. Many a times, there may not be definable problem boundary, and it may involve confusing and contradictory factors, interdependent elements, cognitive flexibility and compromise between what is best and what is available, what is ideal and what is practical and affordable, and conflicting stakeholder views or interest. There maybe a few optimal solutions, and some of which have not existed or tested before. Thus it needs a person's creativity and innovativeness, discretionary judgement, negotiation and leadership skills to come up with best possible practical solution which is acceptable by the stakeholders at the material time.

Take for example, the designing of a dam. An engineer needs, for example, to calculate the water flow and pressure, and work on the engineering design based on latest code of standards and by-laws. This is not considered complex problem solving if he/she is only looking at it from a technical aspect. However, if the engineer takes into consideration the efficiency of the dam design, the environmental impact of the dam on natural habitat, the social economic impact on local community, the financial sustainability of the project, as well as compromise between development and conservation of nature, then the engineer is considered to have engaged in a complex problem solving process.

Institutions of higher learning could have more open-ended and contemporary problems incorporated into the assignment, integrated design projects and final year projects. This kind of complex problem solving skills requires scientific, technical and engineering knowledge, which are acquired via lecture, tutorial, laboratory and field work, individual and group assignment. It also involves many other professional and social skills such as decision making and sound judgement based on facts and figures, negotiation skills, management and communications skills, cultural and emotional skills, which need to be acquired via extra-curricular activities, social and society activities, and life-long training.

3.13 What is Next After Covid19?

Recent Covid19 pandemic has made institutions of higher learning to start switching to various on-line teaching platforms during the Movement Control Order in Malaysia. Change of mindset is necessary in the mode of delivery of lectures/tutorials to our students. We need to look into a new norm for dissemination of knowledge and for teaching and learning. However, we cannot over simplify the effectiveness of online teaching and learning. We need to study the advantages, disadvantages and challenges in such a new norm. For examples:

(i) The speed and cost of the internet in different parts of Malaysia
(ii) Would the students be able to concentrate on online delivery method? And if so the optimum period of focus and attention.
(iii) Efficiency and effectiveness of such learning modes
(iv) Interaction of students with course-mates and instructors
(v) Group discussion and assignment
(vi) Assessment tools to judge attainment of learning outcomes by students
(vii) Laboratory experiments and field work. This should not simply be substituted by computer simulation work as we need to train engineering students with practical and field experience.
(viii) Recreational and social activities by students. This should not be downplayed as it forms a very important part of our tertiary education. We need to train wholesome graduates.
(ix) Human-networking for students, not only between classmates and course-mates, but also with peers in other faculties. After all, a major part of our tertiary education is to allow students to build their character and personality and to work with others.

3.14 Working with Industries and Professional Bodies

Institutions of higher learning should forge mutually beneficial collaborations with industries and professional bodies. Being at the forefront of technology, the industries and professional bodies are in a position to provide institutions of higher learning a better understanding of the latest and future technological trends and human resource needs.

Industrial attachment in industry plays an important part in any education curriculum as it allows students to gain hands-on experience in applying their learnt knowledge and skills in a real working environment. It is also beneficial for the industry as the students carry fresh ideas and quality assistance with them. These students could also be valuable human assets for the industry in future. As an encouragement for closer collaboration with industries and professional bodies, academic staff members from institutions of higher learning with work or projects undertaken with industries and professional bodies should be granted sabbatical leave.

Undoubtedly, the industries and professional bodies have an integral role to play in engineering education and it will only make sense if the curriculum development takes into consideration the inputs from industries and professional bodies as after all, they are in a position to know better the knowledge and skills that an engineer should possess. Additionally, professionals in industries could share their knowledge and experience by giving guest lectures in institutions of higher learning and join forces to conduct R&D activities for a better outcome.

Last but not least, academic staff members from institutions of higher learning could also share their knowledge and research outcomes with the industries for continual professional development of the practicing engineering personnel.

Stakeholders such as the Institution of Engineers Malaysia (IEM), the industries and the Ministry of Education Malaysia (MOE) should work hand in hand in nurturing competent and ready-to-evolve graduates. Each IEM branch could form an Advisory Committee to interact with institutions of higher learning within the State while IEM volunteers could be in the Advisory Committee of MOE to review the engineering, technologist and diploma programmes. At the same time, MOE should also work closely with IEM to promote Science, Technology, Engineering and Mathematics at school level.

4.0 MOBILITY OF ENGINEERING WORKFORCE

Globalization and internationalization through international trade, relations and treaties have set aside what once was an immobility of labour and capital between or among nations. More than ever, barriers to international trade have been considerably lowered through international agreements. This is also true for cross-border engineering works and services. According to industry analysts, demand for engineering services grew substantially across most sectors and geographies through 2010, with only about 10% of the world's work being based in the U.S. and other developed countries, versus about only 40% back in the 1990's. So what does this entail for the engineering workforce? As the maxim goes, "*With prosperity comes opportunity*". For engineers, now would be the perfect opportunity to soar and spread their wings globally.

4.1 Modes of Services

The General Agreement on Trade in Services (GATS) which came into effect in January 1995 is a multilateral agreement which covers international trade in services. The GATS has created a borderless world for professionals, and engineers can take advantage of the vast opportunities offered under GATS to expand the reach of their professional services beyond their local scenes. The following are the four modes of supplying services under the GATS:[18]

4.1.1 Mode 1: Cross-Border Supply

Cross border supply covers the flows of services from one jurisdiction into any other jurisdiction. A user in economy A receives services from abroad via telecommunications or postal services. Such supplies may include market research report, tele-medical advice, distance training or engineering consultancy.

4.1.2 Mode 2: Consumption Abroad

A consumer moves into another jurisdiction to obtain service. The consumers (Nationals of A) move abroad as tourists, students or patients to consume the respective services in Nation B, for example.

4.1.3 Mode 3: Commercial Presence

The service supplier of one jurisdiction, through commercial presence, supplies services in the territory of any other jurisdiction. The service is provided by a locally established affiliate, subsidiary, or representative office of a foreign-owned and controlled company. Examples include banks, hotel groups, construction companies, universities, etc.

4.1.4 Mode 4: Presence of Natural Persons

Persons of one jurisdiction enter the territory of any other jurisdiction to supply a service. A foreign national provides a service within an economy as an independent supplier (e.g., consultant or health officer) or employee of a service provider (e.g., consultancy firm, hospital, or construction company).

4.2 Global Mobility of Engineering Workforce

For the development of a nation, we need many engineers – for infra and info structure development, for development of creative systems to improve human lifestyles, for proper management of natural resources, etc. The kind of engineers we require should not only excel in a particular nation, but they must also be competent and must stay competitive regionally and globally.

We live in a borderless world brought about by regional integration, technological advancements, a free world ideology and borderless enterprises. This setup presents new opportunities and challenges to the engineering sector. To tap these opportunities, the mobility of the engineering professionals becomes crucial.

In the 21st century and beyond, engineering professionals need to work as a team to solve problems and improve the quality of life for humanity. This is a global effort not confined to a particular country or economy. It is therefore important for us to develop not only regional, but also international agreements on accreditation of engineering programmes. This will be a necessary step for mutual recognition of substantial equivalence of engineering education to fulfil the basic academic requirements for mobility of engineering personnel.

Within the globalization setup, various cross-border understandings/agreements for the mobility of engineering professionals have been established. Examples of such understandings/agreements are as follows:

- Previously known as the Engineers Mobility Forum (EMF), the International Professional Engineers Agreement (IPEA) is a multi-national agreement between engineering organizations in the member jurisdictions which creates the framework for the establishment of an international standard of competence for professional engineers, and then empowers each member organization to establish a section of the International Professional Engineers Register.
- The APEC Engineer Agreement is an agreement in place between a number of APEC countries for the purpose of recognizing "substantial equivalence" of professional competence in engineering. APEC countries can apply to become members of the agreement by demonstrating that they have in place systems which allow the competence of engineers to be assessed to the agreed international standard set by the APEC Engineer agreement.
- Formerly known as the Engineering Technologists Mobility Forum (ETMF), the International Engineering Technologist Agreement (IETA) allows for the mutual recognition of the substantial equivalency of standards establishing the competency for practicing engineering technologists.
- Agreement for International Engineering Technicians (AIET) allows for the mutual recognition of the substantial equivalency of standards establishing the competency for practicing engineering technicians.

Nearer to home, the formal establishment of ASEAN Economic Community in December 2015 paves the way for a fully integrated ASEAN with 622 million people and a combined GDP of US$2.6 trillion. In the regional landscape, engineering is one of the active service sectors in the ASEAN economic integration. In fact, the signing of the Mutual Recognition Arrangement (MRA) on Engineering Services in December 2005 by the ASEAN Economic Ministers reflected a shared interest between the governments and the engineering community in ASEAN to improve and enhance the competitiveness of engineering services quality as well as facilitating the free flow of engineering professionals within the region. Under the MRA, an engineering professional who is a national of an ASEAN member country and who possesses the required qualifications and experience may apply for inclusion in the ASEAN Chartered Professional Engineers Register (ACPER) and accorded the title of ASEAN Chartered Professional Engineer (ACPE). The Engineering Register set up under these various international forums and agreements is an engineer's gateway to trade liberalization in professional services.

5.0 THREE IC's – ANOTHER PROPOSAL

In his Presidential Address of the Institution of Engineers Malaysia in 2010,[19] the author proposed that in order to thrive in this fast advancing global market, engineers need to constantly keep three IC's in mind. The first IC is Integrity and Competency; the second IC is Integration and Communications; and the third IC is Internationalization and Cooperation.

5.1 Integrity and Competency

Integrity is consistency between one's action, values, methods, measures and principles. The value of a person is defined by the knowledge in the mind, the worth of the character and the principles upon which he/she builds his/her life. Handling ethical dilemmas and making ethical decisions are important parts of being a professional. Engineering is a profession that has specialized knowledge, the privilege of self-regulation, and a responsibility to the public. As engineers, it is important that we maintain a high ethical standard as the decisions we make will have a direct impact on society. It is the awareness of these heavy responsibilities and obligations that lies at the professional code of conduct and ethics that govern the engineering profession. In the practice of the profession, engineers must adhere to high principles of ethical conduct on behalf of the public, clients, employers and the profession.

Engineers must be competent to provide professional service and advice in order to protect the safety, health and welfare of the public. In such a technically complex field, new discoveries and changes in practice occur frequently. Engineers need to fully equip themselves to thrive in this competitive world. Engineers will have to be equipped with the highest standards of R&D skills, keep abreast with global technological trends, be strategic thinkers and planners and develop market driven services and high-tech products/ systems.

5.2 Integration and Communication

The world is becoming increasingly integrated by information systems, economic markets and political and social issues. These pose challenges that are growing in complexity and transcend specific disciplines and are driving the emergence of multidisciplinary and interdisciplinary thinking. Thus, it is imperative that engineers master an overwhelming array of technical knowledge.

As we move towards a more knowledge-based and innovation-driven economy, engineers too will move beyond being technically equipped, towards obtaining an even wider range of expertise, such as in research and development, consulting, regulatory knowledge, leadership, management, etc. Thus inter- and multidisciplinary approaches are becoming more prevalent in engineering.

To operate successfully in a multidisciplinary environment, it requires a broad intellectual perspective. Equally important is the ability to manipulate information into knowledge as well as understand and communicate across disciplines. Similarly, engineers are tackling multifaceted problems that require solutions beyond the reach of any single discipline. Thus, much of the work will involve teams of people from different disciplines and in some cases, from different locations around the world. It is imperative that engineers are able to collaborate and work in multidisciplinary and multicultural teams as well as communicate well in order to be effective in engineering itself.

The engineer's ability to communicate, both in writing and orally, will determine the chances of being successful as an engineer and advancing his/her career. Technical expertise alone is not sufficient if the engineer is not able to communicate useful information to colleagues, supervisors and clients, and to express his views and opinions convincingly.

5.3 Internationalization and Cooperation

Globalization, characterized by the increase in international trade, mobility of labour and capital, as well as borderless communication, presents new opportunities and challenges for the engineering sector. It opens up boundless opportunities in the mobility of technical expertise within the region and the global community. Engineers should aim at achieving engineering excellence not only in their home countries, but also contribute to the development of the region and the world. Local professional engineers should look beyond national boundaries and create winning partnerships with foreign professionals and high technology industry leaders abroad. Cooperation and smart partnership, capitalizing on strength of each other, is the key to conquer regional and world markets.

6.0 CONCLUSION: WHAT WE COULD DO COLLECTIVELY

Different stakeholders in Malaysia such as the education institutions, industries, society and policy makers have to come together and work hand in hand to strengthen engineering education in order to develop a strong engineering workforce.

For a start, institutions of higher learning should strive to gain accreditation and professional recognition for their programmes. Such accreditation and professional recognition provide those programmes with international recognition, and create benchmarks against the global standards in the respective fields. Setting standards for programmes will follow naturally as standards will serve to ensure the continuity of the accreditation and professional recognition. At the same time, they provide the necessary assurance and confidence to prospective students, graduates, employers, graduate schools, licensing agencies and government.

With the current communication technology, the ability for educators to share experiences exists on a scale never before possible. Experience and knowledge sharing is a great avenue for solving complex cross-regional problems. We should also encourage the networking of people with similar interest such as among students or educators, so that their projects and goals are more exciting and encompassing. Consequently, the energy level and success rate would be higher.

It would be too late for students to be interested in STEM the day they step into institutions of higher learning. Their interest in STEM should be cultivated during their early days in school. Therefore, a fair amount of effort should be invested in going back to schools to promote STEM and to share the relevance of STEM education to young students in primary and lower secondary levels.

The word "engineer" brings up different impressions in different people. We should improve the image of engineers by showing more real examples of people in the engineering field, rather than leaving it to archetypes in movies and fictions. Wrong expectations may not be a good thing for motivation. People in the engineering community, be they educators, students or working professionals, should be more vocal in speaking up in order to be leaders and trend setters in their own fields. After all, they are the ones who know well where innovation can lead to. ■

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