Engineering Education in Malaysia for the Fourth Industrial Revolution (4IR)

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***Abstract*—The Fourth Industrial Revolution (4IR) has impacted our lives in many ways through the technological advancements it brings such as robotics, Internet of Things (IoT), Artificial Intelligence (AI), 3D printing and other life-changing inventions. The landscape of future job market will drastically change and need to be addressed by the Higher Education Institutes (HEIs) for graduate employability. This paper presents engineering education for 4IR in the context of Malaysia. The initiatives taken by the Ministry of Education Malaysia (MoEM) in addressing the challenges of 4IR for the higher education sector is discussed. This is followed by an overview on the approach taken by one of the public universities in Malaysia in addressing the needs of 4IR through its undergraduate engineering programs.**

Keywords—*engineering education, 4IR, Malaysia, fourth industrial revolution*

I. INTRODUCTION

The recent years have seen the impacts of the Fourth Industrial Revolution (4IR) or also known as Industry 4.0 on various aspects of our life which includes manufacturing, business and education. In general, the 4IR involves disruptions in technology that links to terms such as digitization, automation, Artificial Intelligence (AI) and the Internet of Things (IoT). The era of the 4IR not only alters the lifestyle of the people but also drastically changes the future scenario of job markets. Many tasks in business and manufacturing are known to be rapidly taken over by robots and intelligent machines. Thus, jobs that are currently available may cease to exist in the near future and replaced by new or yet to be created jobs. This calls for the need to prepare for the development of graduates of Higher Education Institutes (HEIs) who are multi-disciplined and multi-skilled. The expected characteristics of future-ready graduates are as summarized in Fig. 1[1].

The Malaysian Higher Education Framework 4.0 [2], has highlighted Future Ready Curriculum (FRC) as one of the main initiatives in preparing graduates of HEIs in Malaysia towards 4IR. The recently released Malaysia Qualification Framework (MQF) 2nd Edition [3], has addressed five clusters of learning outcomes for each of the eight MQF levels as follows:

i. Knowledge and understanding

ii. Cognitive skills

iii. Functional work skills with focus on:

a. Practical skills

b. Interpersonal skills

c. Communication skills

d. Digital skills

e. Numeracy skills

f. Leadership, autonomy and responsibility

iv. Personal and entrepreneurial skills

v. Ethics and professionalism[1]

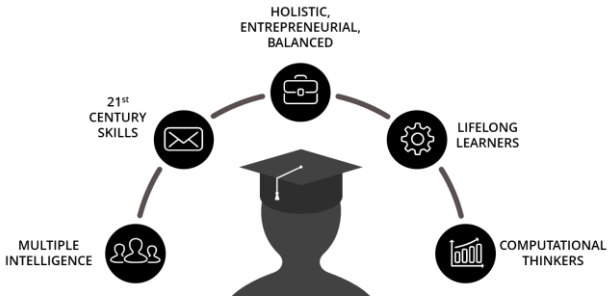

Fig. 1. Characteristics of future ready graduates

In this case, digital and numerical skills have been added as learning outcomes for all educational programs offered in Malaysia at various MQF levels as the functional skills required in fulfilling the requirements of future job market. In addition, the Engineering Educational Council (EAC) as a coordinating body on accreditation of engineering programs in Malaysia has outlined twelve learning outcomes in its Engineering Programme Accreditation Manual 2017 [4] that map to the MQF 2.0 learning outcomes. It is important to highlight that in the latter, aside from the five learning outcomes that relate to the technical aspects of an engineering program, the other seven represents the professional skills of future engineers.

This paper presents engineering education for 4IR in the context of Malaysia as a developing country in the South-east Asia. The initiatives taken by the Higher Education Department at the Ministry of Education Malaysia (MoEM) in addressing the challenges of 4IR for the higher education sector is discussed with focus on FRC. This is followed by an overview on the approach taken by one of the public universities in Malaysia in addressing FRC in its

[1] Embedded within the five clusters are clear expectations that learners will demonstrate ethical and civic responsibilities through contributions to their local and global communities

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undergraduate engineering programs. The paper is then concluded with the way forward on engineering education for 4IR in Malaysia.

II. Higher Education 4.0

A. *The framework*

Fig. 2 shows the Malaysian Higher Education 4.0 Framework [1], which comprises of four elements namely Future Ready Curriculum, Research and Innovation, Talent Planning and Agile Governance. The framework is developed on the basis of producing "ethically and morally upright citizens who are spiritually grounded to cope with the demands of the 4IR" [1]. This is in alignment to the needs of the Malaysia Education Blueprint 2015-2025 (Higher Education) [5].

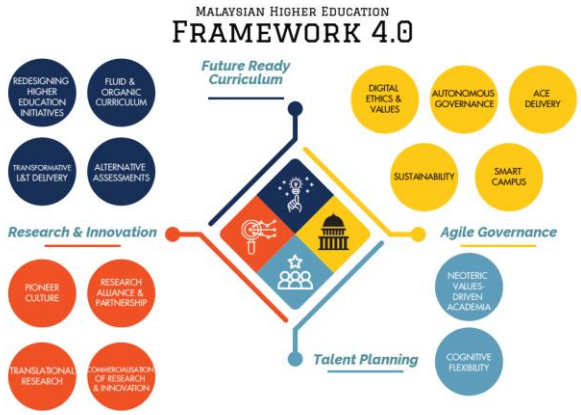

Fig. 2. Malaysia Higher Education 4.0 framework [1]

B. *Future Ready Curriculum (FRC)*

Referring to Fig. 2, this paper focuses only on the aspect of FRC in the context of engineering education. According to the framework, FRC covers 4 aspects which include redesigning higher education initiatives, fluid and organic curriculum, transformative Learning and Teaching (L&T) delivery and alternative assessments. In 2017, the MoEM has embarked on various initiatives as part of redesigning higher education, particularly on developing and strengthening of talents through CEO@Faculty Program, Malaysia Massive Open Online Courses (MOOCs), Accreditation of Prior Experiential Learning (APEL), Gap Year, Malaysia English Assessment (MEA) and E-Portfolio [1]. The framework for FRC introduced in 2018 is as shown in Fig. 3 [1].

As mentioned earlier, FRC is a framework that highlights three elements namely the curriculum structure, L&T delivery and assessment. In order to prepare the graduates of an educational program for the challenges of 4IR, its characteristics in terms of fluid and organic curriculum structure needs to consider the convergence of disciplines, flexible and non-conventional, industry partnership and global, as highlighted in Fig. 3. Fluid and organic in general refers to a curriculum with a flexible structure that grows naturally, not requiring systematic and structured approaches. It can be restructured (updated and shaped) as and when necessary in order to respond to changing needs of the industry and students' educational experience [1]. Convergence of disciplines relate to the content of the curriculum which can be multidisciplinary, interdisciplinary or transdisciplinary which differs from each other based on the key words additive, interactive and holistic respectively. Examples of academic programs that address those keywords are Bachelor of Psychology with Human Resource Development, Bachelor of Arts in Interdisciplinary Social Science and Bachelor of Mechatronics Engineering respectively.

On the other hand, flexibility in terms of the curriculum structure relates to academic programs that promotes education at any time and any place through MOOCs and Open Distance Learning (ODL), curriculum that is based on a particular learning model, personalized as well as with leaner engagement through immersive experiential learning. A curriculum that supports a particular learning model include those developed based on Project Oriented Problem-based Learning (POPBL), Problem-based Learning (PBL) and Conceive-Design-Integrate-Operate (CDIO). These learning model based curriculum not only covers the technical skills of the discipline but also the professional or generic skills required through the L&T activities such as communication, team-work, adaptability, problem-solving, creativity, work ethics, interpersonal skills and leadership as highlighted in [3] and [4].

The curriculum structure of an FRC should also consider partnership with the industry in enhancing students' exposure to the "real-world" related to the discipline through immersive experiential learning including work-based learning. With a strong and established partnership, an academic program curriculum can be developed involving the industry on the aspect of curriculum design, L&T activities and assessment, aside from work placements with better effectiveness and sustainability as part of the curriculum structure.

Global is also one of the sub-elements of a fluid and organic curriculum structure as shown in Fig. 3. A global curriculum advocates cooperation with international universities through Transnational Education (TNE) involving academic programs in the form of double, dual or joint. These types of programs promote students' adaptability which is one of the essential 4IR-ready employability skills.

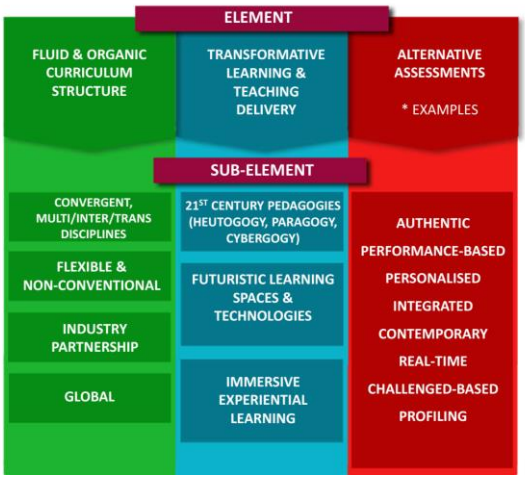

Fig. 3. Malaysia FRC framework [1]

In addition, a transformative L&T delivery is promoted by embracing the 21st century L&T methods involving students' self-directed or self-determined learning known as heutagogy [6], interaction with peers in accomplishing educational goals or peeragogy/paragogy [7] and creating engaged learning online or cybergogy [8]. Transformative

L&T delivery needs to be supported by investing on futuristic learning spaces, leveraging on the latest 4IR technologies and promoting immersive experiential learning towards the achievement of learning outcomes.

FRC also encourages alternative rather than traditional assessment methods which gives emphasis to what students can and cannot do through assessment of not only the learning outcomes but also the learning process, rather than focusing on the mastery of knowledge [1]. The various sub-elements of the alternative assessment are given in Fig. 2.

The following parts of the paper focus on the initiatives taken by Universiti Teknologi Malaysia (UTM), a public university in the southern state of Malaysia in addressing FRC as outlined by the MoEM, in its undergraduate engineering programs. This is to ensure that UTM is able to produce engineers who are 4IR relevant not only on the aspect of the technical skills but also on the professional or generic skills with the overall characteristics as shown in Fig. 1.

III. FRC in Undergraduate Engineering Programs

UTM's own FRC framework based on that of Fig. 3 is as shown in Fig. 4. New undergraduate engineering programs are expected to fulfil the attributes of the FRC in terms of transformative structure (which ever applicable), innovative delivery and alternative assessment.

A review on all undergraduate engineering programs has been conducted in 2017 with the required changes listed out as given in Fig. 5, in addressing the 21st century curriculum. Each undergraduate engineering program at UTM has managed to identify courses in the respective curriculum that would carry out the practices deemed necessary in preparing the students for future engineering job markets. For example, element 06 in Fig. 5 calls for the implementation of Academic Service Learning (ASL) and Co-curricular Service Learning in the curriculum. Engineering programs' owners need to identify courses in their program curricular that will be conducted via service learning. Service learning is a form of immersive experiential learning which is one of the sub-elements in the FRC framework given in Fig. 3. The benefits of service learning are clear in not only enhancing students learning but also developing most of the functional work skills [3] that are required in the context of 4IR.

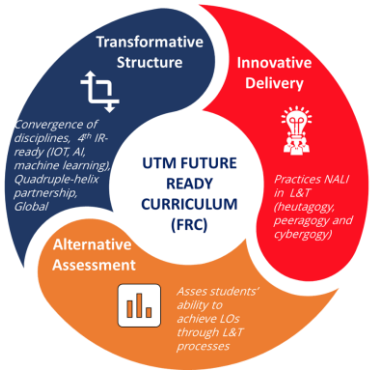

Fig. 4. UTM's FRC framework

TRN: Teaching Research Nexus
NALI: New Academia Learning Innovation
WIL/WBL: Work Integrated Learning/Work Based Learning
ASL: Academic Service Learning
CoQSL: Co-curricular Service Learning

Fig. 5. UTM's engineering programs review checklist

IV. Academic Program Transformation in the Context of 4IR

UTM's academic program transformation in the context of 4IR is divided into three categories which are (i) talent (ii) process, program and product (iii) infrastructure.

A. *Talent*

Talent in this case relates to a group of UTM's faculty who has been given the opportunity by MoEM to spearhead a task force on Public University Academic Program Transformation in 2017 to produce the framework on Future Ready Curriculum (FRC). Hence, the development of the FRC framework shown in Fig. 3, which is applicable to all public universities in Malaysia.

In addition, to support the development of new engineering academic programs based on FRC, it is important to ensure that the talents that can support its implementation particularly in running the L&T activities are available. Thus, UTM has recently introduced a strategic road map to produce the so called Future Ready Educators (FREE) as illustrated in Fig. 6. Aside from the regular L&T training provided to the faculty by UTM's L&T unit, FREE is deemed as a catalyst for them to become competent in practising L&T strategies that are relevant to the engineering students in the context of 4IR such as cooperative learning, project-based learning and problem-based learning [9].

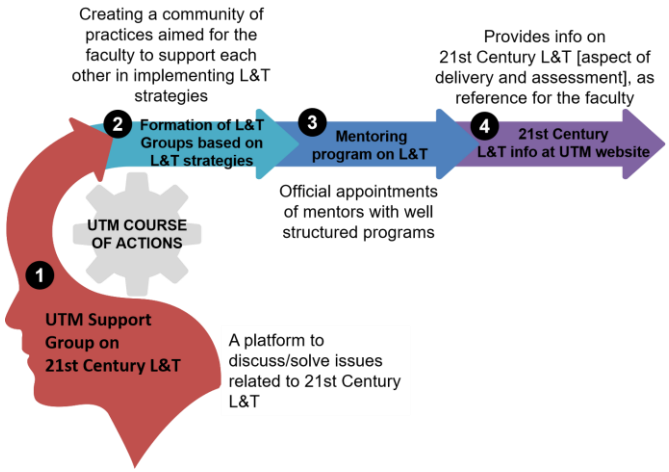

Fig. 6. UTM Strategic road map for Future Ready Educators (FREE)

B. *Process, Program and Products*

Table I gives a few of the process, program and products that UTM has embarked on since early 2018 as part of its initiatives on academic program transformation in the context of 4IR. All the items listed in Table I have been completed except for item 4. which is an on-going initiative. For the engineering discipline, items 3 and 4 is quite challenging as it is subject to the approval of the EAC as the accrediting body.

TABLE I. PROCESS, PROGRAM AND PRODUCTS

Item	Process, Program and Products
1.	Review of all undergraduate engineering programs curriculum addressing the 21st century skills
2.	Introducing UTM's Holistic Student Development Framework (HSDF) as the foundation for all undergraduate program curriculum
3.	Introducing a compulsory course in all undergraduate program curriculum known as Extra Curricular Experiential Learning (ExCEL)
4.	Focusing on the development of new non-singular discipline undergraduate academic programs (multidisciplinary, interdisciplinary and transdisciplinary)
5.	Development of a new multidisciplinary undergraduate academic program with a personalized curriculum

C. *Infrastructure*

Another aspect of academic program transformation in the context of 4IR at UTM is the commitment given by the management to provide the 21st Century L&T Eco-system with focus on learning spaces and environment to support ubiquitous learning. The near future will see the availability of centralized global/future classrooms with 4IR related L&T technology as an addition to the existing L&T spaces as well as common learning spaces to support formal and informal learning. Work is currently being carried out to materialize the above-mentioned infrastructure.

V. CONCLUSIONS

This paper has presented engineering education for 4IR in the context of Malaysia. The literature has indicated that Malaysia is well-aware of the challenges ahead for 4IR in higher education. Various initiatives have been taken by MoEM to provide the proper direction to the HEIs towards preparing for the development of graduates who are multi-disciplined and multi-skilled to fit the requirements of future job market. This is to ensure that Malaysia's manufacturing industry will remain competitive in this region at the height of the 4IR.

In the case of Universiti Teknologi Malaysia, proper actions have been taken in addressing the needs of the 4IR through its academic program transformation. The way forward is to have multidisciplinary or interdisciplinary engineering academic programs offered with accreditation from the Engineering Accreditation Council (EAC) in the spirit of the 4IR.

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