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Conceptual framework for the development of 4IR skills for engineering graduates

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ABSTRACT: In this decade, the impact of changes caused by the industrial revolution 4.0 increasingly has been felt. These changes are due to the development of advanced technology that will replace the human workforce with automation and robotics. Existing skills no longer are able to prepare graduates for this. In this regard, engineering graduates should be given early exposure to, and be prepared for, the skills of 4IR. When there is a need to upgrade skills, the development of them becomes the key priority. The purpose of this study was to review the theories and models of skills development, especially for engineering graduates in Malaysia. A systematic review method was adopted in this study, in which previous studies on the skills development for engineering graduates were considered. The results of this systematic review lead to a conceptual framework for the development of 4IR skills in the engineering field. The proposed conceptual framework can act as a foundation and guideline for the future studies conducted by researchers.

Keywords: Fourth industrial revolution, skills development, engineering graduates, conceptual framework

INTRODUCTION

The industrial revolution 4.0 (4IR) brings about a paradigm shift in the economy, social life, health, education, lifestyle, employment and skills development. This is due to the development of advanced technology that will replace the human workforce with automation and robotics. A growing number of research bodies agree that technological changes can lead to huge job destruction [1-3]. According to Singh et al, 4IR will result in reduced job offers in various sectors, as well as changing the practice of jobs [4]. A recent report by the International Labour Organisation (ILO) estimated that automation will replace the jobs of 137 million people in Southeast Asia within the next 20 years [5]. Deloitte found that about 35 percent of jobs may disappear, because of new technologies in the next two decades [6]. The data suggested that nearly 12 percent of jobs will be replaced and nearly three-quarters of all jobs will be held by *cobots* (collaborative robots), with artificial intelligence as a partner [7].

The impact of 4IR on jobs is determined by skill level. When the skills of an individual no longer meet the skills required by jobs, unemployment among graduates may occur. The situation becomes worse when the existing skills are no longer in line with the technological developments in 4IR**.** In an effort to ensure that every individual can work in a 4IR setting, they have to develop a set of skills that will make them able to satisfy the future jobs market.

EXISTING SKILLS AND 4IR SKILLS

Skills development is often debated. It is undeniable that the development of skills appropriate for technological developments is able to reduce the unemployment rate among graduates. Engineering accreditation bodies are responsible for ensuring that graduates are equipped with appropriate skills. In previous studies the development of engineering skills in various countries was discussed [8-17]. In Table 1, a list of engineering skills is shown, set by the engineering accreditation bodies of 18 countries.

Based on the table, it can be seen that there are 10 most preferred skills by each engineering accreditation body; namely:

1) communications;
2) teamwork;
3) ethics and professionalism;
4) lifelong learning;

5) problem solving;
6) management;
7) technology;
8) decision making;
9) critical thinking;
10) leadership.

However, these skills no longer are adequate and need to be enhanced to be in line with the challenges of 4IR.

Table 1: List of engineering skills set by 18 engineering accreditation bodies.

Engineering accreditation board	Skills
Board of Engineers Malaysia (BEM) [18]	Problem analysis; technology; ethical principles; communication; teamwork; lifelong learning
Accreditation Board for Engineering and Technology (ABET) [19]	Communication; teamwork; lifelong learning; professionalism; problem solving
Institution of Engineers Singapore (IES) [20]	Communication; global mind set; lifelong learning; problem solving and decision making; professionalism; information and communication technology; management
Engineers Australia (EA) [21]	Communication; teamwork; learning; professional and ethical responsibility
Engineers Ireland (EI) [22]	Problem solving; ethical standards; team spirit; lifelong learning; communication
Engineering Council United Kingdom (ECUK) [23]	Problem solving; oral and written communication; team roles and work as a member; lifelong learning; professional expertise
Accreditation Board for Engineering Education of Korea (ABEEK) [24]	Information technology; project team; communication; ethics; lifelong learning; problem solving
Hong Kong Institution of Engineers (HKIE) [25]	Teamwork; problem solving; professional and ethics responsibility; communication; lifelong learning; computer and IT skill
Japan Accreditation Board for Engineering Education (JABEE) [26]	Thinking skills; technology; oral and written communication; lifelong; work in a team
Institution of Engineers Sri Lanka (IESL) [27]	Problem analysis; ethics; teamwork; communication; management; lifelong learning
Engineers Canada (EC) [28]	Problem solving; member and leader in team; communication; professionalism; management; learn continuously
National Board of Accreditation (NBA) [29]	Solve engineering problems; professional and ethical responsibilities; verbal and written communication; teamwork; self-education
Engineering New Zealand (EngNZ) [30]	Problem analysis; ethics; role in and diversity of team; communication; management; continuing learning
Engineering Council South Africa (ECSA) [31]	Problem solving; information technology; written and oral communication; teamwork; independent learning; professionalism; management
Institute of Engineering Education Taiwan (IEET) [32]	Management; communication; work in team; ethics; problem solving
Association for Evaluation and Accreditation of Engineering Programs (MUDEK) [33]	Problem solving; information technology; teamwork; Turkish proficiency; presentation skills; lifelong learning; ethical principles; management
Association for Engineering Education of Russia (AEER) [34]	Problem analysis; ethics; communication; leader or member in diverse teams; lifelong learning; management
Pakistan Engineering Council (PEC) [35]	Problem solving; ethics; leader or member in team; communication; management; lifelong learning

The World Economic Forum (WEF) has come out with a latest report [36] following a report published in 2016 [37]. In the present report, the majority of employers expected that most of the current skills will not be relevant by the year 2022, but note a huge difference in different fields of work. In Table 2 is a list of a comparison of skills in demand between the years 2018 and 2022.

Table 2: Skills in demand in 2018 vs 2022 [36].

2018		2022	
1	Analytical thinking and innovation	1	Analytical thinking and innovation
2	Complex problem solving	2	Active learning and learning strategies
3	Critical thinking and analysis	3	Creativity, originality and initiative
4	Active learning and learning strategies	4	Technology design and programming
5	Creativity, originality and initiative	5	Critical thinking and analysis

2018		2022	
6	Attention to detail and trustworthiness	6	Complex problem solving
7	Emotional intelligence	7	Leadership and social influence
8	Reasoning, problem solving and ideation	8	Emotional intelligence
9	Leadership and social influence	9	Reasoning, problem solving and ideation
10	Co-ordination and time management	10	System analysis and evaluation

Referring to Tables 1 and 2, there was a significant difference between existing skills and 4IR skills. The skills set required to perform today's jobs will be partly renewed by 2022. Illustrated in Figure 1 are the similarities and differences for both sets of skill. By 2022, seven skills; namely. analytical thinking and innovation; active learning and learning strategies; creativity, originality and initiative; critical thinking and analysis; complex problem solving; emotional intelligence; and system analysis and evaluation will be the preferred skills, as well as technology design and programming; leadership and social influence; and problem solving.

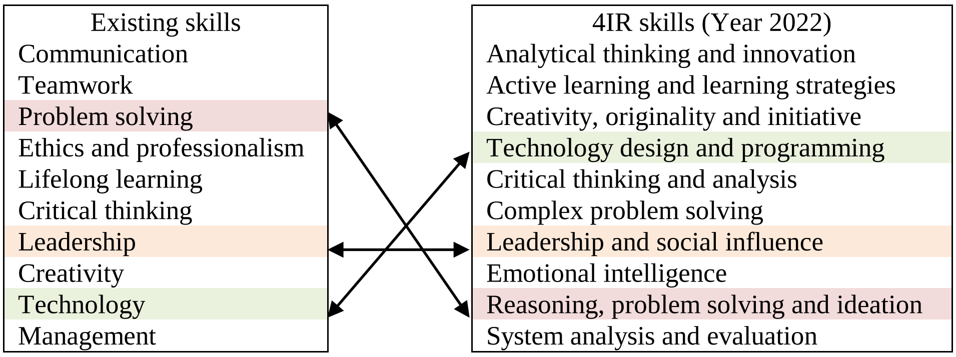

Figure 1: Comparison of existing engineering skills with 4IR skills.

In this context, there is a growing need for reskilling and upskilling to keep up with technological change in the fourth industrial revolution. Skills development should have a positive and effective impact. Hence, it is necessary to identify appropriate theories followed by proposing a conceptual framework for the development of the 4IR skills of engineering graduates in Malaysia.

OBJECTIVES

The objectives of this study are:

a) To investigate the theories and models to be used in the development of 4IR skills for engineering graduates in Malaysia.
b) To propose a conceptual framework for the development of 4IR skills for engineering graduates in Malaysia.

METHODOLOGY

A systematic review methodology was used to investigate suitable theories and models to underline the development of graduate skills in engineering. Generally, a systematic review methodology was applied to track, evaluate and synthesise the best studies on issues related to research problems by providing evidence and informative answers [38]. The same method has been used by Rosli and Rasul in exploring the education of a high-income community in Malaysia [39]. Ashari identified students' career choices in the Malaysian skills certification system [40]; Rahimi identified the elements, influences and entrepreneurial learning processes at vocational colleges in Malaysia [41]; and Adam identified organisational factors affecting industry involvement for the National Dual Training Systems programme [42].

Related information was obtained from various journal reports, books and electronic references. Five journals and article databases were referred to in conducting this study; namely, ProQuest, Science Direct, Wiley, Taylor & Francis and IEEE. Three keywords were used in the information search; namely, the industrial revolution 4.0, engineering skills and skills development. All of this helped in generating this study.

FINDINGS

Theories and Models for Engineering Graduates Skills Development

Discussed in this section are the theories and models used for the development of skills for engineering graduates. This study was conducted based on teaching and learning theories and skills development models. Three teaching and learning theories used in this study were: human capital [43]; education and economy development [44]; and behaviourism [45]. The relationship model between the institution and industry [46] and the Frye model 2000 [47] were the backbone of the framework development, which outlined the importance of relationships between institutions and industries in ensuring that engineering graduates can master new skills as they prepare for work in the 4IR setting.

Addressed in Table 3 is justification for the selection of the three theories for developing graduate skills in engineering. The description of each theory explains the suitability of it in this study.

Table 3: Justification of theory selection in this study.

Theory	Explanation	Justification of selection
Human capital [43]	i. Investment and education are interconnected with each other. ii. Formation and implementation of soft skills or employability skills would have a great impact on students who will soon enter the working world.	- Due to the emerging need to master new skills in line with the technological developments in 4IR. - Provide opportunities for responsible parties, such as employers, institutions of higher learning or students to equip and strengthen the required skills.
Education and economy development [44]	i. A balance between education and employment.	- Coincides with the understanding of the mismatch skills phenomenon between higher learning institutions and employers.
Behaviourism [45]	i. Priority to observable behaviours without considering logical reasoning. ii. Behaviour is organised and can be controlled.	- Applicable in this study as it involves the mastery of new skills conditioned and arranged for graduates through education and training by the institutions in line with the development of the industrial revolution 4.0.

Further, two skills development models were referred for this study. Figure 2 shows the model of relationship between institutions and industry [46]. This model highlights the relationship between employer (industry) and the education system (institution) in producing graduates and workers who possess the necessary knowledge and skills required by industry today. Industry will benefit from the education implemented by the institution, if it is in line with the latest advancements in technology. Therefore, the relationship between the institution and the industry is the key aspect of an education system. Generally, learning institutions are responsible for replicating and developing their graduates. However, the role of the industry towards learning institutions cannot be denied. Notwithstanding the quality of graduates, particularly the engineering graduates, they must be able to meet the demands of industry.

The skills upgrade element described in this model was selected for this study due to the difference between existing skills and the new skills in 4IR. Thus, it can be said that the model of the relationship between the institution and the industry underlies the theoretical framework of this study to develop a 4IR skills framework for engineering graduates in Malaysia.

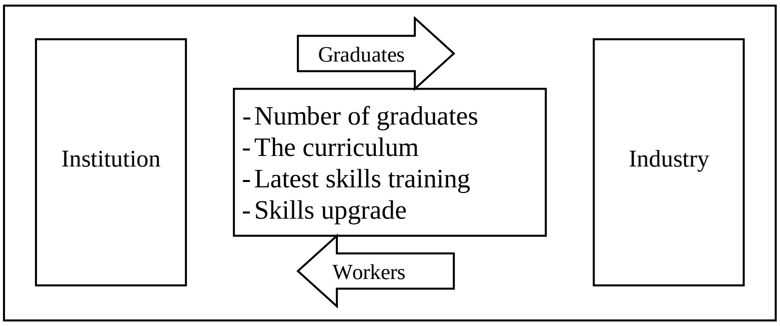

Figure 2: Relationship model between the institution and industry [46].

The strategic challenges for providers were identified to encourage the use of the skills framework [47]. The main concept of this model is supply and demand; when there is a demand from employers the education system through education and training needs to provide certain skills. The Frye model has three main components; namely, employers, suppliers and graduates [47]. The first component is the employers' demand and needs for certain skills, whereas the second component is the supplier that provides the skills through education and training. The third component is the students' demand for certain skills for entering the workplace. This model (Figure 3) is suitable for this study as it involves the three key parties in the development of 4IR skills, comprising the institution of higher learning as the supplier, the employers who are responsible for the selection of employees and the students who soon would become engineering graduates.

In summary, the development of 4IR skills in this study was based on three teaching and learning methods, which are the human capital theory [43], education and economy development theory [44] and behaviourism theory [45]. The selection of these theories aimed to achieve a common understanding between employers, suppliers and students. Based on two skills development models; namely, the relationship model between the institution and industry [46] and the Frye model 2000 [47], the three key parties (employers, suppliers and students) are responsible for ensuring that graduates meet the requirements and needs of industry. The results of this finding suggested a conceptual framework based on the theories and skills development models discussed above.

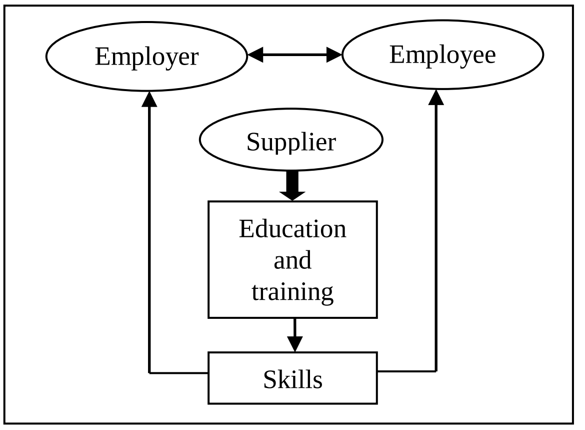

Figure 3: Frye model 2000 [47].

Conceptual Framework of the Study

The conceptual framework illustrates the network and the relationship between the institutions, industries, students' and employers' requirements. Figure 4 illustrates the conceptual framework of the study.

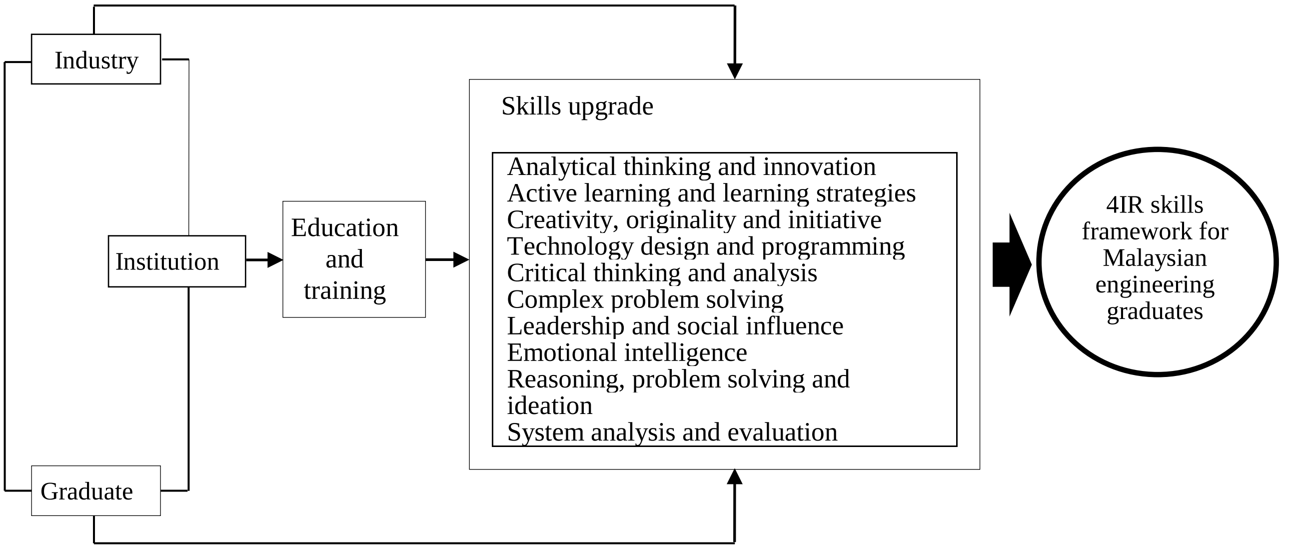

Figure 4: Conceptual framework for the development of 4IR skills.

The process of constructing this conceptual framework involved the following two steps:

Step 1

The conceptual framework of this study was developed based on the combination of two models, as discussed earlier. The two skills development models were:

- the industrial and institutional relations model [46],
- the Frye model [47].

The reason for combining these two models is that both models involved three main components, viz. employers, suppliers and graduates. Based on these two models, the institutions (suppliers) are the main source of new employees in various fields of work, and the employers (industries) evaluate educational activities and results through the graduates of the institutions.

Step 2

As previously mentioned, the impact of technology development will change the need for mastering new skills in 4IR. In this study, 10 skills were identified [36] as the main essence of the conceptual framework of this study. There were seven skills that have yet to be studied compared to three other skills; namely, leadership, problem solving and technology. The construction of attributes in the 4IR skills will form a skills development framework for engineering graduates that has not been suggested by previous researchers. This proposed conceptual framework is a foundation and guideline for the study that will be conducted by authors in the future.

CONCLUSIONS

The essence of this study is in highlighting the development of 4IR skills for engineering graduates. In ensuring that graduates are prepared to face the working world of 4IR, emphasis should be given to the development of skills that have not been prioritised. Effective skills development should be based on appropriate theories and models. This research has used three theories; these are: human capital; education and economy development; and behaviourism. In addition, two skills development models; namely, the relationship model between the institution and Frye model 2000, have been used as backup models in identifying the key components of skills.

The three main elements supporting the development of skills were employers, students and institutions. As a result of systematic reviews, a conceptual framework has been proposed to develop 4IR skills in engineering. Two steps have been discussed in the process of forming this conceptual framework. The first step was a combination of theory and a skills development model. The second step was related to the 4IR skills. Ten 4IR skills have been identified in this framework in which each skill attribute will be identified in the next study. The proposed conceptual framework of this study can serve as a reference point in the development of 4IR skills for engineering graduates.

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BIOGRAPHIES

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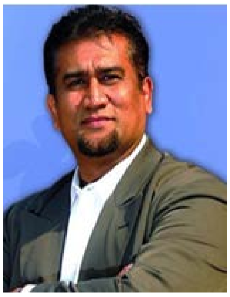

Associate Professor Dr Mohamad Sattar has been a lecturer in the Faculty of Education, Universiti Kebangsaan Malaysia since 2012. He also is Chairman of the STEM Enculturation Centre. His academic journey began with a Diploma in mechanical engineering in 1987 and a Bachelor of Education with Honours in technology and education (mechanical engineering) in 1996 from Universiti Teknologi Malaysia (UTM). He obtained a Master's degree and Doctor of Philosophy (PhD) degree in industrial engineering and system from Universiti Putra Malaysia (UPM) in 2004 and 2010, respectively. As an academic, he has a considerable array of achievements, awards and recognitions (Community Involvement Award; gold and silver medals in Innovation in Teaching and Learning; Best Award in Innovative Practices in Education and Industry Exhibition). Until now, he has produced more than 100 written works in indexed journals, as well as national and international proceedings. In addition, he has contributed to the writing of seven academic books published by the University.