Industry Revolution 4.0 Skills and Enablers in Technical and Vocational Education and Training Curriculum

Evarina Amiron, Azlan Abdul Latib, Kamalularifin Subari

Abstract: ***The research aims to identify Industry Revolution 4.0 (Industry 4.0) skills and enablers that should be included in TVET Curriculum namely the National Occupational Skills Standards (NOSS) which is developed by the Department of Skills Development, the government agency responsible for skills training in Malaysia. A Conceptual Framework has been developed to identify and confirm the list of Industry 4.0 Generic Skills and Enablers of an Industry 4.0 working environment. By identifying a list of generic skills required for an Industry 4.0 working environment regardless of the type of industry, the skills list can be included in TVET curriculum that will be able to facilitate the training of TVET trainees of entry level competency such as those at the certificate level, (Sijil Kemahiran Malaysia/Malaysian Skills Certificate) Level 1 till Level 3, because the technological competency required is not industry specific. The advent of a TVET curriculum enhanced with Industry 4.0 skills will also be able to facilitate other industries to develop their own industry specific TVET curriculum where this will subsequently produce a supply of ready to work graduates and also upgrade the skills of existing workers to perform competently in an Industry 4.0 working environment. By identifying the enablers for Industry 4.0 in TVET curriculum, TVET training institutions will be able to design and establish an Industry 4.0 training environment that will equip TVET trainees with the skills required.***

Index Terms: ***Industry Revolution 4.0 (Industry 4.0), Technical and Vocational Education and Training (TVET), Industry 4.0 Skills.***

I. INTRODUCTION

The pivotal aim of this research is to identify Industry Revolution 4.0 skills that can be embedded in Technical & Vocational Education and Training (TVET) curriculum. Industry Revolution 4.0 (Industry 4.0) has been changing the landscape of industries at a global scale. Although some countries are hesitant to embrace the industrial revolution as with any revolution before it, usually due to resistance to change and investment required, most countries and their industries will have to face the Fourth Industrial Revolution head on, because it is as persistent as is digital technology that advances at a fast changing pace.

Implementation of Industry 4.0 is highly dependent on the capability of the workforce to apply and optimiseusage of advanced technologies pertinent to an Industry4.0 working environment. The issue of human capital development is critical to ensure long-term sustainable economic growth and development. (**Ahmad, I.A. 2016). In order to develop human capital that will be able to perform in an Industry 4.0 working environment, the inculcation of Industry 4.0 skills is crucial.** Current literature shows that there has not yet been defined a clear cut set of Industry 4.0 generic skills and enablers to be included in TVET curriculum. Therefore, the researcher will define a set of Industry 4.0 generic skills and enablers that can be utilised and embedded in curriculum.

The role of TVET is imperative in terms of preparing students and existing workers to be prepared for an Industry 4.0 working environment. One of the main criteria of TVET curriculum development is that the input must be obtained from industry practitioners so that the input is in line with current industry demands and practices. This is an important contributing factor to this research, so that in order to identify the Industry 4.0 skills and enablers to be included in TVET curriculum, it has to be suitable for the industry and must be based on input from those in the industry.

The TVET curriculum that this research will focus on will be the curriculum included in the National Occupational Skills Standards (NOSS). The NOSS is under the purview of the Department of Skills Development in Malaysia. Other than including the Industry 4.0 skills in the curriculum, the learning environment must also be equipped with enablers of Industry 4.0 so that they will be accustomed to its usage in their work processes and work activities. Furthermore, these Industry 4.0 skills should be suitable for the different levels of competency as stipulated in the Department of Skills Development (DSD) Qualification Framework which is from certificate level (Malaysia Skills Certificate Level 1 till Level 3), Malaysian Skills Diploma (Level 4) and Malaysian Skills Advanced Diploma (Level 5). Hence is the need for generic Industry 4.0 skills that covers the skills required in an Industry 4.0 working environment for all types of industries. The Industry 4.0 skills which are specific for an industry should be based on the technologies that are available and applied in each respective industry.

II. PURPOSE OF RESEARCH

The aim of this research is to examine the relevant Industry 4.0 skills that should be included in TVET curriculum and the enablers that will simulate the learning environment of an Industry 4.0 working environment. The reason why the Industry 4.0 enablers are also to be identified is that under TVET training requirements by the DSD,

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training providers must provide the simulation of the working environment to train and assess trainees via TVET assessment methods before being deemed competent.

The expected outcome of this research is to identify the Industry 4.0generic skills required by a worker to perform competently in an Industry 4.0 working environment.

A. Objectives

This research aims to:

1) Identify Industry 4.0 generic skills required to perform competently in an Industry 4.0 working environment.
2) Examine a sample of industry specific Industry 4.0 skills; namely for the Manufacturing Industry to confirm the suitability of the generic skills to be adapted for any industry.
3) Identify the enablers of an Industry 4.0 working environment that should be provided by TVET training providers in order to simulate an Industry 4.0 working environment for training purposes.

B. Research Questions

Initially in the project, several research questions are developed to ensure that the research is focused and not too broad. The questions below have been formulated and will be used as a guide throughout the process of document analysis and data collection:

1) What are the skills required in an Industry 4.0 working environment?
2) Which of the Industry 4.0 skills are generic and suitable to be used in any industry?
3) What are the enablers that define an Industry 4.0 working environment?

C. Scope of the study

The scope of the study will include:

1) Suitable Industry 4.0 generic skill sets to be embedded in TVET curriculum, where in this research the TVET curriculum is the National Occupational Skills Standards (NOSS).
2) The Industry 4.0 enablers that are required to create an Industry 4.0 working environment.
3) A sample of Industry 4.0 skills for a specific industry to determine the suitability of the Industry 4.0 generic skills set to be adapted. For this research, the manufacturing industry has been chosen as the sample industry.

D. Significance of Study

The list of identified common generic skills required for an Industry 4.0 working environment will be proposed to be included in TVET curriculum. The generic Industry 4.0 skills set should be generic in the sense that it can be used by workers of any industry. This is so that it will be easier to train TVET trainees from any entry level of competency such as those at the Certificate Level 1 to Level 3 (SKM/MSC), as the technological competency required is not industry specific. By identifying generic Industry 4.0 skills, these skills will not only be able to be used in various industries but can also be scalable to be used for future technologies.

TVET curriculum that is enhanced with Industry 4.0 skills and the relevant enablers can be referred to by other industries to develop their own industry specific TVET curriculum. This in turn will produce a supply of ready to work graduates and upgrade the skills of existing workers to perform competently in an Industry 4.0 working environment.TVET training institutions will also be able to design and establish an Industry 4.0 training environment that will equip TVET trainees with the skills required.

E. Expected Findings

The findings expected from this research are based on the research objectives as follows:

Objective 1:

Identify Industry 4.0 generic skills required to perform competently in an Industry 4.0 working environment.

Expected Findings for Objective 1:

To confirm a concise list of Industry 4.0 generic skills which are required by a worker to perform competently in an Industry 4.0 working environment. These skills will be segregated according to the competency levels in the workplace such as operational, supervisory and management levels.

Objective 2:

Examine a sample of industry specific Industry 4.0 skills; namely for the Manufacturing Industry to confirm the suitability of the generic skills to be adapted for any industry.

Expected Findings for Objective 2:

To obtain a sample of industry specific Industry 4.0 skills for the Manufacturing Industry so as to confirm the suitability of the Industry 4.0 generic skills to be adapted for any industry.

Objective 3:

Identify the enablers of an Industry 4.0 working environment that should be provided by TVET training providers in order to simulate an Industry 4.0 working environment for training purposes.

Expected Findings for Objective 3:

To confirm the list of Industry 4.0 enablers used to establish an Industry 4.0 working environment that should be provided by TVET training providers in order to simulate an Industry 4.0 working environment for training purposes.

III. LITERATURE REVIEW

The term Industry Revolution 4.0 was coined by German economist Klaus Schwab in 2015.According to Schwab, the Fourth Industrial Revolution includes the emergence of the Digital Economy and use of automation and data exchange in industrial technologies. These technologies include the Internet of Things, synergy between networked machines and human beings in decision-making, and artificial

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intelligence for computerised technical processes, whereas Spottl (2016) describes Industry 4.0 as a convergence of technologies that cut across the physical, digital, and biological spheres. The Fourth Industrial Revolution is characterised by atechnological revolution which builds upon the Third Industrial Revolution which applied electronics and information technology to automate production (Spottl, 2016). The key characteristic of the Fourth Industrial Revolution is that it enhances the automation of manufacturing processes introducing customised and flexible mass production technologies where machines operate independently, or cooperate with humans while the machine constantly maintains itself.

Literature review has been conducted on Industry 4.0 and also on the relevant skills required for workers to perform in industries that apply Industry 4.0 technology in the working environment. Based on the document analysis/literature review conducted, Figure 1 shows the two elements of an Industry 4.0 working environment, which are:

1) Industry 4.0 Enablers (Comprises of Nine (9) Technology Pillars of Industry 4.0 and Six (6) Industry 4.0 design principles)
2) Ten (10) Industry 4.0 Generic Skills

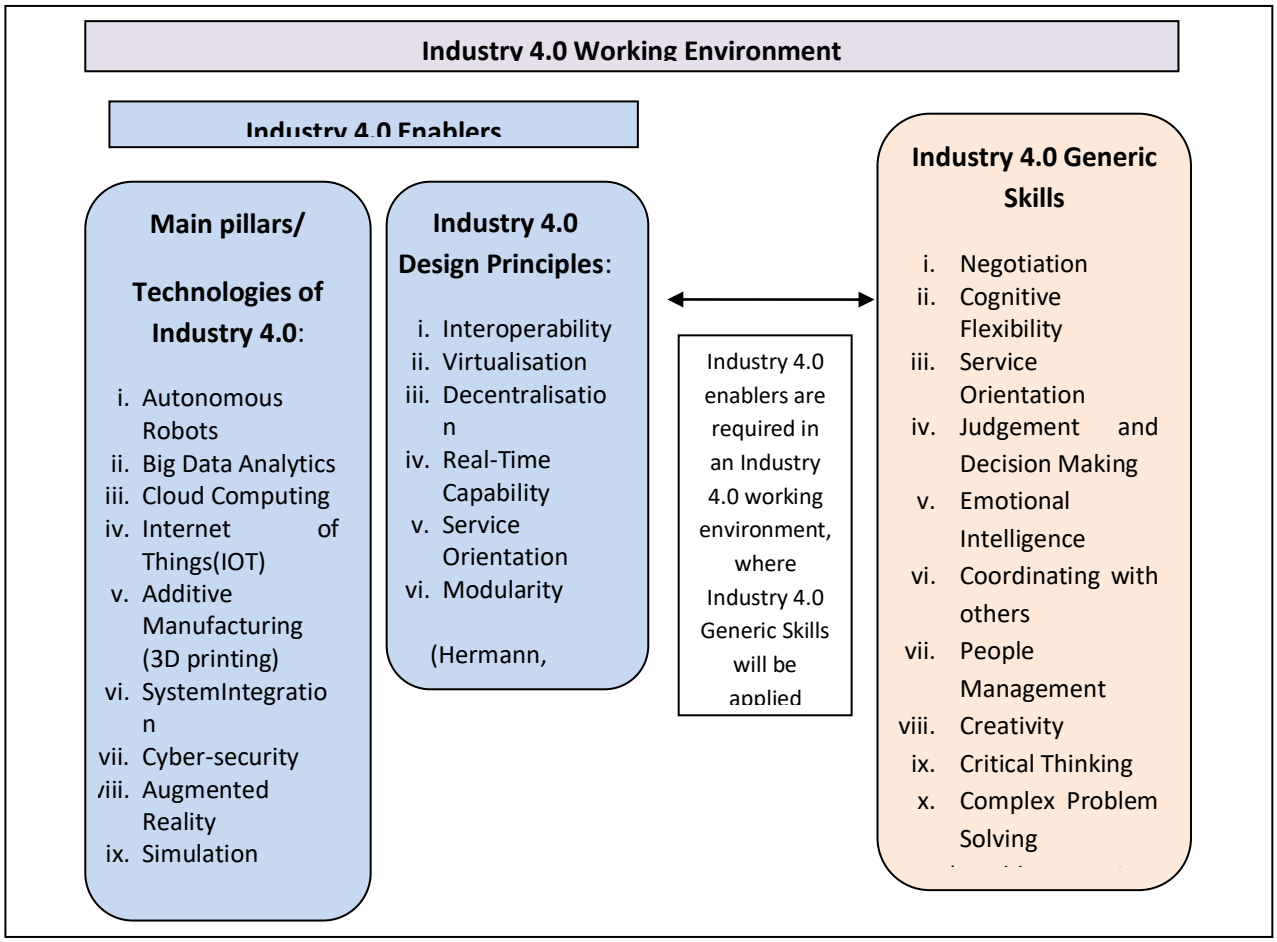

Fig. 1: Elements of anIndustry 4.0 Working Environment

The Industry 4.0 enablers and list of Industry 4.0 generic skills have been identified via available research as elaborated below:

A. Industry 4.0 Enablers

Main pillars/technology pillars of Industry 4.0

The main pillars (Technology Pillars) of Industry 4.0 have been defined by the Ministry of International Trade and Industry (MITI) (2016) and also via research done by Michael Rüßmann (2016). These technologies are as follows:

1) Autonomous Robots;
2) Big Data Analytics;
3) Cloud Computing;
4) Internet of Things(IOT);
5) Additive Manufacturing (3D printing);
6) System Integration;
7) Cyber-security;
8) Augmented Reality; and
9) Simulation.

Michael Rüßmann (2016) described the nine technologies above as the building blocks of Industry 4.0 that assist in enhancing production by integrating and automating isolated production processes or machines to optimise production flow, leading to greater efficiencies and changing traditional production relationships among suppliers, producers, and customers—as well as between human and machine.

It must be noted that not all 9 (nine) technologies are required to be implemented to establish an Industry 4.0 working environment, a combination of a few of the technologies are sufficient. The main goal is that the technology used can meet either one of the Industry 4.0 design principles (where suitable) as defined by Hermann, Pentek, & Otto (2015) that can facilitate companies in creating an Industry 4.0 working environment.

The enablers of Industry 4.0 may seem daunting and not common place for those in certain industries as they reflect highly advanced technology, therefore this may pose as an issue in the training of workers in certain industries that are not familiar with these technologies. However, it is important for employers and employees to realise that in the short term, the trend towards enhanced automation and other Industry 4.0 technologies will lessen the need for low-skilled workers who perform simple, repetitive tasks. In turn, workers with higher level cognitive skills such as decision making skills and analytical capabilities will be more in demand.This is where the role of skills training via TVET curriculum is imperative in facilitating the training process via the teaching practices and assessment applied by TVET trainers.

Industry 4.0 Design Principles

Hermann, Pentek, & Otto (2015) has defined Industry 4.0 (or named in the report as *Industrie 4.0)* "Is a collective term for technologies and concepts of value chain organisation. Within the modular structured Smart Factories of *Industrie 4.0*, Cyber-Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralised decisions. Over the Internet of Things (IoT), CPS communicates and cooperates with each other and humans in real time. Via the Internet of Services (IoS), both internal and cross-organisational services are offered and utilised by participants of the value chain."

It is from the definition above that the design principles were identified (Hermann, Pentek, & Otto, 2015) in designing an Industry 4.0 environment. This definition assists companies in identifying and implementing an Industry 4.0 working environment.

The Industry 4.0 Design Principles are elaborated below based on the report by Hermann, Pentek, & Otto (2015):

- **Interoperability**: The ability of machines, devices, sensors, and people to interconnect with each other via the Internet of Things (IoT) or the Internet of Services (IoS).
- **Virtualisation:** This includes the monitoring of physical processes through a virtual copy of the physical world with the use of sensor data linked to virtual and simulation models.
- **Decentralisation**: Embedded computers enable machines to make decisions on their own thus decreasing central planning and controlling.
- **Real-Time Capability**: Data is collected and analysed in real time so that critical decisions can be made for example in the failure of a machine, products can be rerouted to another machine.
- **Service Orientation:** Involves the offering of services of companies, Cyber Physical Systems, and humans over the IoS and can be utilised by other participants both internally and externally.
- **Modularity:** Modular systems are able to flexibly adapt to changing requirements by replacing or expanding individual modules.

The design principles above will be referred as the main enablers for an Industry 4.0 working environment that will be materialised with the usage and application of any of the aforesaid Industry 4.0 technologies.

B. Industry 4.0 Generic Skills: Emerging Skills and Soft Skills Required In An Industry 4.0 Working Environment

Kruchoski (2016) has stated in his article on the World Economic Forum website that Industry 4.0 is transforming the workforce and changing the nature of work to be increasingly collaborative, focused on solving complex problems in creative ways. In order to adapt to Industry 4.0 working environments, work demands will require trans-disciplinary skills that can be obtained by undergoing training of new skills, up-skilling or re-skilling.

Based on the 2016 World Economic Forum study conducted on Future Jobs, the emerging skills which are seen to be in demand in the future workforce, namely in an Industry 4.0 working environment are as listed below:

- Negotiation
- Cognitive Flexibility
- Service Orientation
- Judgement and Decision Making
- Emotional Intelligence
- Coordinating with others
- People Management
- Creativity
- Critical Thinking
- Complex Problem Solving

Workers will be required to be equipped with these skills in an Industry 4.0 working environment due to the shift of skills set required where work is not repetitive and require a certain level of decision making according to the worker's level of competency. The skills of judgment and decision making are seen as core skills that should be applied by workers at all levels but within a varying degree of cognitive and skills capability.

Based on the different levels of workers, the skills can be segregated according to levels of competency. For example, workers at the operator level may require the skills of coordinating with others, whereas at supervisory level may require skills of negotiation, people management and emotional intelligence. Workers at executive levels that are required to conduct designing and engineering work may require skills of cognitive flexibility, service orientation, critical thinking and complex problem solving. Personnel at management level may require all the skills above but at a high degree of application.

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IV. DISCUSSION: CONCEPTUAL FRAMEWORK

In order to meet the objectives and expected outcomes of this research, a conceptual framework was designed. The conceptual framework comprises of the Industry 4.0 Enablers and Industry 4.0 Generic Skills lists. The goal of this conceptual framework is to determine and confirm these two elements, so that they can be included in the TVET curriculum. It also aims to add value and context to the Industry 4.0 generic skills as to link these skills to the requirements of Industry 4.0. The overall conceptual framework can be seen in Figure 2.

The Industry 4.0 enablers and Industry 4.0 generic skills in Figure 2 will be compared to input from industry practitioners in the Manufacturing industry. The sample sub-sectors of the Manufacturing industry that will be used for comparison are as listed below:

- Electronic products manufacturing;
- Electrical products manufacturing;
- Aerospace Manufacturing.

The confirmed list of Industry 4.0 enablers and Industry 4.0 generic skills will be proposed to be embedded in the TVET curriculum which in Malaysia is known as the National Occupational Skills Standards (NOSS) for any given occupational area in the Department of Skills Development's NOSS registry.

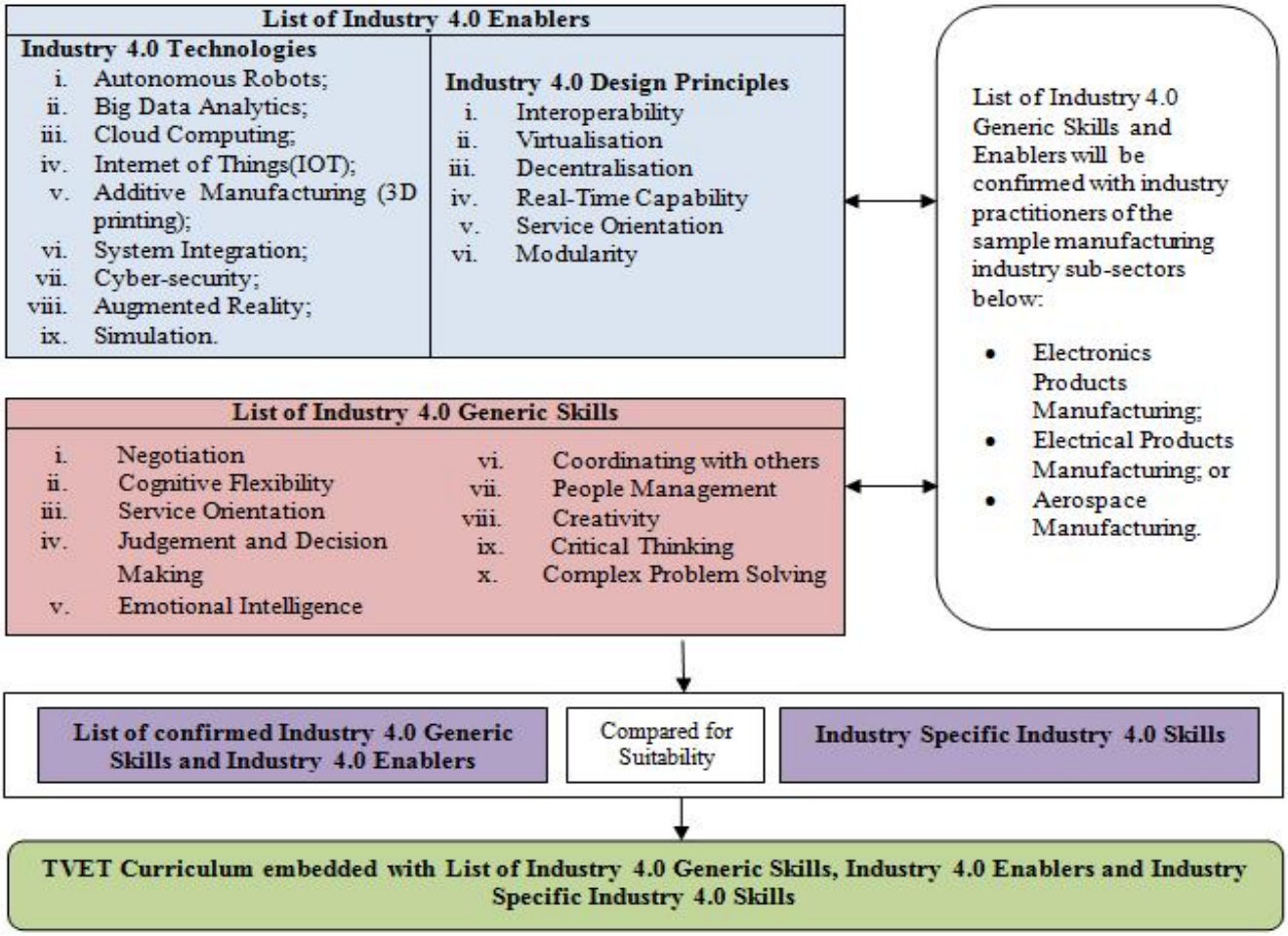

Figure 2: Conceptual Framework on Analysing and Confirming the List of Industry 4.0 Generic Skills and Industry 4.0 Enablers to Be Embedded In the TVET Curriculum (NOSS)

V. METHODOLOGY

Research was done via desktop research and document analysis focusing on the following key theme areas which are:

- Industry 4.0 generic skills
- Enablers to implement an Industry 4.0 working environment

These key theme areas were used as a guide to analyse the documents obtained via desktop research. Through document analysis, the documents were interpreted to further understand the key themes above. The documents found were scored based on the amount of pertinent information they provided and how widely they were cited by other researchers.

A. Data Sources

The main data sources were from publication databases (such as Researchgate and Google Scholar) and research articles on the internet. Although attempts were done to find information regarding Industry 4.0 enablers and skills in the library network, not many searches came up with the relevant information required.

As literature on the aspects of Industry 4.0 that this research focuses on has not been discussed at great length therefore, the research focused on the information provided by the most widely cited source which was from the World Economic Forum articles and reports on Industry 4.0. Another main source of information that was widely cited was the research paper done by authors from *Technische Universität Dortmund* and University of St. Gallen, entitled Design Principles for Industry 4.0 Scenarios: A Literature Review. Information on Industry 4.0 technologies was retrieved from the Ministry of International Trade and Investment (MITI) website (due to the fact that MITI is the main government body in Malaysia that oversees the development of Industry 4.0 in Malaysia) and also from a conference paper from the International Conference on Competitive Manufacturing entitled, Strategic guidance towards Industry 4.0 – a three-stage process model (Erol, Schumacher, & Sihn, 2016).

B. Limitations

Limitations faced during document analysis were that there were limited documents with relevant information that was specific to the research topic which was Industry 4.0 skills and Industry 4.0 enablers. Therefore keywords used to search for the key themes were changed to Industry 4.0 design elements and emerging skills. The use of the proper term for Industry 4.0 also played an important role in obtaining more relevant documents, instead of using the keyword, IR 4.0 or Fourth Industrial Revolution, Industry 4.0 was more widely used in various literature. Most relevant literature was by German authors, where the term *Industrie* 4.0 was mostly used by German authors which is similar to the word Industry 4.0.

C. Strategies for Minimising Bias and Error

Strategies that have been applied to minimise bias and error were as follows:

- To use various keywords for Industry Revolution 4.0 (i.e. IR 4.0, Industry 4.0, FIR 4.0)
- Grade and prioritise the documents to be referred based on credibility of author and how widely the documents were cited by other researchers.
- Relate the information in documents to the local context in Malaysia.

VI. CONCLUSION

The findings of this paper resulted in the Conceptual Framework which consists of the Industry 4.0 enablers and Industry 4.0 generic skills. There has not yet been literature that has tried to link these two elements as part of an Industry 4.0 working environment. Based on the methodology used, which was document analysis, the list of Industry 4.0 enablers and Industry 4.0 skills were identified. This has served as the basis of identifying the list of enablers and skills that will be further confirmed with practitioners in the industry.

By identifying the elements of an Industry 4.0 working environment, conducive training of skills required for workers to perform competently in an Industry 4.0 working environment can be implemented by including the finalised list in TVET curriculum.

The list of enablers for Industry 4.0 will guide TVET training institutions to design and establish an Industry 4.0 training environment that will equip TVET trainees with the skills required. Other industries will be able to develop their own industry specific TVET curriculum enhanced with Industry 4.0 skills, based on the list of Industry 4.0 generic skills derived in this research.

It is envisaged that by providing the list of Industry 4.0 generic skills and enablers, the workforce will have better employability and will progress in tandem with the technological advancements, thus contribute to the economic growth of the country and become competitive at a global scale.

VII. FURTHER WORK

Further work will include research to confirm the finalised list of enablers and generic skills. This will require interviews to be held with industry personnel such as employers, TVET training providers and workers regarding the required Industry 4.0 skills set and enablers for an Industry 4.0 working environment. The interviews/survey will be conducted using the strategies below:

1) The list of Industry 4.0 generic skills and Industry 4.0 enablers will be compared between sample sub-sectors of the manufacturing industry which are;
   - Electronics Products Manufacturing;
   - Electrical Products Manufacturing; or
   - Aerospace Manufacturing.
2) The list of Industry 4.0 generic skills required by various levels of the workforce to gauge which skills are suitable for entry level workers and which skills are suitable for higher level workers will be compared for the levels as listed below:
   - Operational
   - Supervisory
   - Management
3) Input will be obtained from various personnel in the industry which include:
   - Employers
   - Employees
   - Trainers
4) Results obtained regarding the Industry 4.0 generic skills and Industry 4.0 enablers will be embedded in a sample NOSS document and reviewed by personnel in the manufacturing industry and NOSS development personnel monitored by the DSD to assess the suitability.

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