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A SYSTEMATIC LITERATURE REVIEW: HUMAN ROLES, COMPETENCIES AND SKILLS IN INDUSTRY 4.0

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Abstract

Dependence on advanced technology due to the fully automated production line of the manufacturing industry in industry 4.0 is expected to demand different competencies, which are yet to be fully understood. Proper understanding of the required occupational competencies is necessary to prepare future workforce who can fulfil their roles in the Industry 4.0. The purpose of this systematic literature review is to ascertain the extent of workforce needs and the associated competencies and skills that are required by the Industry 4.0. The analysis of the selected literature indicates that human roles are still relevant in Industry 4.0 at all skills levels. Five clusters of technical competencies and skills were identified in addition to four clusters of non-technical competencies. While semi-skilled is required by some sectors, high-skilled workforces are consistently demanded by all sectors. The finding can be a source of reference for Technical, Vocational Education and Training (TVET) educator in improvising the TVET curriculum structure, with aim to produce the technical graduates that are capable to work in the Industry 4.0 work environment.

Keywords: Technical competencies and skills; Non-technical competencies and skills; Low skilled; Semi-skilled; Skilled; High-Skille

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1. Introduction

"The main goal of Technical, Vocational Education and Training (TVET) is to develop occupational competencies and enable its graduates to meet the requirements of their future work places" (Kurnia, Dittrich, & Ilhamdaniah, 2013, p.2). To meet Industry 4.0 human role requirement, it is necessary to define competencies and skills required by Industry 4.0 technologies. However, defining human roles in Industry 4.0 can be challenging, as there are conflicting information on it. Some studies suggest that unemployment is a surety for the low-skilled and semi-skilled workers while others remain positive that low-skilled and semi-skilled workers remain important despite the Industry 4.0 technologies (Hirsch-Kreinsen, 2016; Nelles, Kuz, Mertens, & Schlick, 2016; Ng, 2017; Prifti, Knigge, Kienegger, & Krcmar, 2017; Vinh, 2017). The lack of certainty on the specific competencies and skills needed by Industry 4.0 creates difficulties for TVET providers to develop curriculum that will meet the required competencies and skills. Lack of clear definitions for Industry 4.0 competencies and skills will result in a deficient curriculum that can lead to skills mismatch and inadequate training in TVET graduates. For example, a study on skills requirement for the automotive industry by Kamin, Ahmad, & Cartledge (2013, p.92) found that while the existing curriculum is relevant for the automotive industry, it does not meet the meet the requirement of up-to-date automotive technology.

The Industry 4.0 revolution is introduced with the fully automation and digitalization processes, and with the use of electronics and information technologies (IT) in manufacturing and services in a private environment (Roblek et al., 2016). Despite of various definitions of Industry 4.0, there are nine pillars of Industry 4.0 technologies that were used across the interdisciplinary areas, such as the Internet of Things (IoT), Cyber Security, Cloud Manufacturing, Big Data Analytics, Simulation, Additive Manufacturing, Simulation, Augmented Reality, Robotics and Horizontal and Vertical Integration (Bahrin, Othman, Azli, & Talib, 2016). Qualitatively, the implementation of the Industry 4.0 technologies such as Cyber Physical System (CPS) is depending on the needs of the technology and work organization from the manufacturing industry (Dworschak & Zaiser, 2014). Hence, the definition of Industry 4.0 may vary and comes with different concepts such as Cyber Physical System, Intelligent Manufacturing System (IMS), Internet of Things (IoT), and Smart Manufacturing (Pacaux-Lemoine, Trentesaux, Zambrano Rey, & Millot, 2017; Schumacher, Erol, & Sihn, 2016; Roblek et al., 2016).

1.1. Industry 4.0 Technologies across the Interdisciplinary Areas

By contrast, Industry 4.0 technologies are not limited to the manufacturing industry, but also come across in few other interdisciplinary areas such as in healthcare, construction, retail business and financial services, and administrative. For instance, the benefits of Internet of Things (IoT) can be found in the smart wearable devices, smart home with the ease of CCTV installation and monitoring, traffic and transportation system and supply chain system that able to monitor the deliveries and internet banking (Farahani et al., 2018). Meanwhile, the analytic data, cloud technology, robotic process automation for audit process, artificial intelligence (AI) and block chain, where to record transaction using a distributed ledger are widely used in the financial service sector.

According to Global Education Features, there are two main sectors with two different technology use; which are standardized output (fully automation) and customized output (human touch) (World Skills

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Russia, 2017). The standardized output (fully automation) are usually found in the mass-scale industrial manufacturing such as Cyber Physical System (CPS) or Cyber Physical Production System. This fully automation also can be integrated and digitalized in the service sector such as digital health, digital entertainment, unmanned transportation, and post retail, etc. From the customized output (human touch) perspective, the labour is highly required at the customized end-user manufacturing and highly personalized services. The examples of customized end-user manufacturing are consumer electronics, consumers. transport, apparel and furniture. Meanwhile, the examples of customized highly personalized services are wellness, fitness, tourism, and hospitality (World Skills Russia, 2017).

2. Problem Statement

According to World Economic Forum survey, the introduction to Industry 4.0 technologies may cause number of job losses in few sector such as in healthcare, energy, financial services, white collar and administrative role (Treanor, 2016). This scenario happens, when the manual routine task might be replaced with the use of digital data, digital customer interface and interconnectivity. For example, in the healthcare sector, the administrative role may replace by the data-driven business model, which used as to collect and connect the information (health-related data) for patient diagnostic and treatment. On the contrary, these job losses scenarios led to the creation of new jobs such as ICT, professional service, media, entertainment and information professional. To create a new job, the development of digital culture and training is crucial, where this is the biggest challenge towards Industry 4.0 transformation. Meanwhile, to understand the human role requirement in the manufacturing sector of Industry 4.0, there is much debate on the role of human and occupational competencies transformation that are needed in the Industry 4.0. Some literature supports the need for human workforce in Industry 4.0 while others claim otherwise. For example, this statement is supported by the findings from Khazanah Research Institute, who predict that about 90% of Malaysians, who work as semi-skilled workers may be affected by the automation (Ng, 2017). In other countries such as Germany and Thailand, much research has been conducted on the restructuring of job profile to avoid major disruptions at the low-skilled and semi-skilled level (Gennrich, 2017; Hirsch-Kreinsen, 2016).

A 2016 report by Klynveld Peat Marwick Goerdeler (KPMG) indicate that it is not essential for workers to master all previously known skills but it is necessary to identify the specific human related task that can be designed for Industry 4.0 purposes (Klynveld Peat Marwick Goerdeler, 2016). The KPMG's finding is fully supported by Stern & Becker (2017) research, which claims that although the number of existing known jobs in manufacturing will be decreasing due to automation, new jobs will be created around the machines (Stern & Becker, 2017). Thus, it is necessary to understand the Industry 4.0 technology in use before determining the human role and occupational competencies required by the Industry 4.0. The idea that human role is relevant despite full automation is supported by some literature (Becker & Stern, 2016). Human role in the automated production line can be found at the human-machine interface, in the loop control role, and in the coordination role (Fantini et al., 2016). However, to define human role according to technology use is not easy. Identifying the integration skills is necessary to define the human role based on the technology used (Hartmann & Bovenschulte, 2014; Kinkel, Schemmann, & Lichtner, 2017). The skills to be identified must take into account the nine pillars of Industry 4.0 technologies. The nine pillars of

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Industry 4.0 technologies are Augmented Reality (AR), Big Data, Cloud Computing, System Integrator, Addictive Manufacturing, Internet of Things, Cyber security, Simulation and Autonomous Robot (Bahrin et al., 2016; Malaysia Automotive Institute, 2017). While the need for low skilled workers is under discussion, the need for high-skilled workforce for Industry 4.0 has been consistently supported by the literature. High-skilled competencies often refers to the non-technical competencies such as problem solving and decision-making skills (Chryssolouris, Mavrikios, & Mourtzis, 2013; Hecklau, Galeitzke, Flachs, & Kohl, 2016; Lorenz et al., 2015; Prifti et al., 2017).

3. Research Questions

Based on the literature, few questions were arisen;

- Research Question 1: What is the current state of human role requirement in the Industry 4.0?
- Research Question 2: What are the competencies and skills required in the Industry 4.0?

4. Purpose of the Study

The specific aim of this systematic literature review is to identify the human role, competencies and skills required by the Industry 4.0 at all skills levels. To achieve the aim, the following research questions are constructed]. This identification of human role, competencies and skills required by Industry 4.0 will be a valuable input to design and development of TVET curriculum and training structure in future.

5. Research Methods

The systematic literature review is the effective method; to extract, synthesize and organize data as to identify the research gap (Oesterreich & Teuteberg, 2016). There are five main stages of systematic literature review, which are conducting studies, scoping review, searching bibliography, screening, eligibility and final studies for data extraction (Booth & Papaioannou, 2012). The Problem, Phenomenon of Interest and Time (ProPheT) Model is used, with the inclusion and exclusion criteria.

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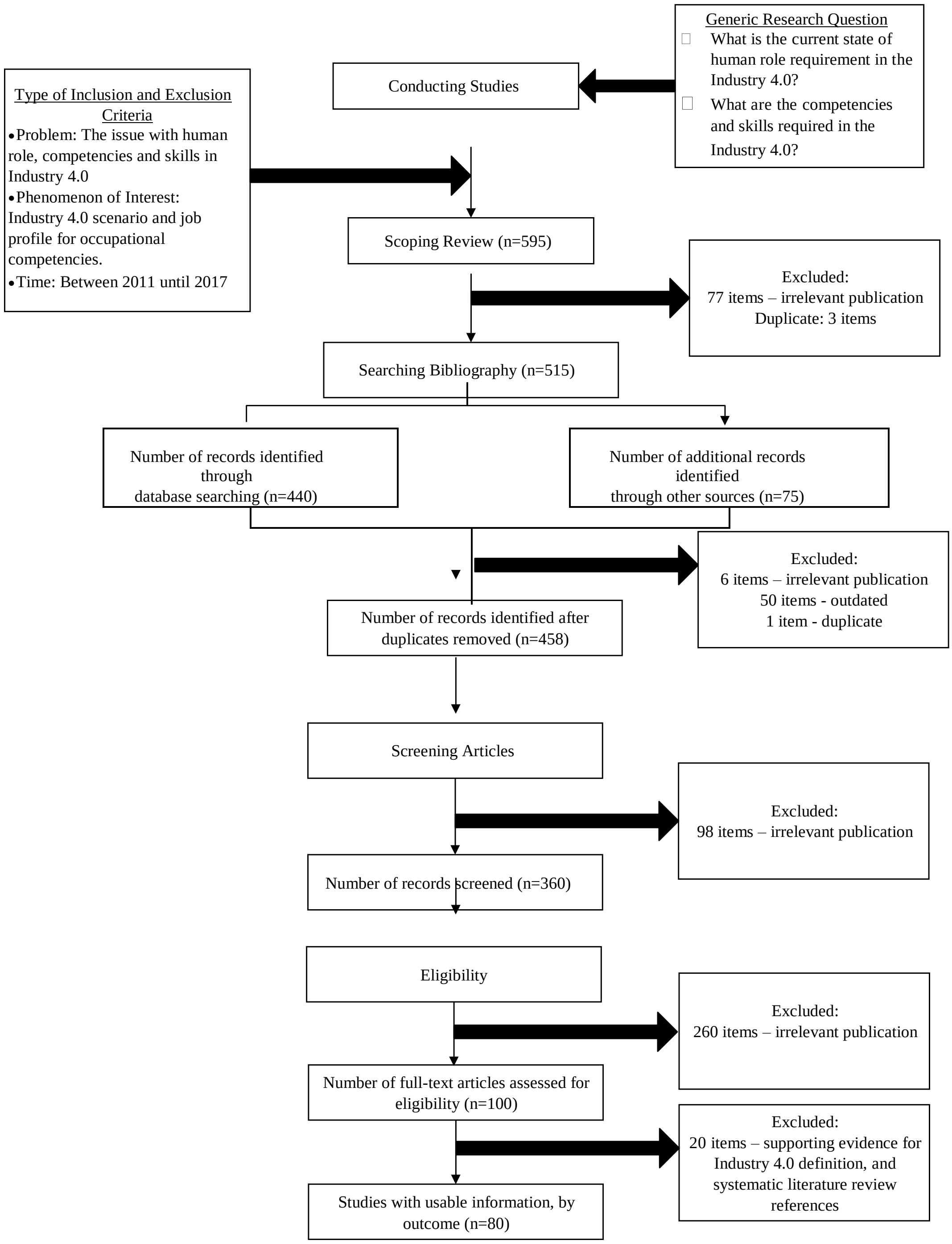

Figure 01. The systematic literature review process

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5.1. Stage 1 Scoping Review

Figure 1 illustrates the systematic literature review process. To begin with, the Google search and Indexed Journal website were used such as Science Direct and IEEE with keyword "Industry 4.0" "Human Role in Industry 4.0", "Skills in Industry 4.0", "Competencies and skills in Industry 4.0", "Technical Skills in Industry 4.0", and "Industry 4.0 Engineering Education". The scoping review summarized 595 papers of the Industry 4.0 technologies. Some of the literatures are also sourced from "grey literature" such as the Industrial Report, Government Policy and Blueprint, Business Summary, and Industrial Case Study. The information related to Industry 4.0 is usually found via case study and company presentation compared to high-indexed publication. This is because of industry people has different interest with academician, who

prefer to publish the new findings through journals publication. Meanwhile, for industry people, the interest is more on profits and knowledge sharing within people in the organization.

5.2. Searching Bibliography

At the searching stage, the reading process was made towards the, the Problem, Phenomenon of Interest and Time (ProPheT) Model. This model is used to identify the human role, competencies and skills required by the Industry 4.0 (Booth & Papaioannou, 2012) which are;

- Problem: The issue with human role, competencies and skills in Industry 4.0
- Phenomenon of Interest: Industry 4.0 scenario and job profile for occupational competencies.
- Time: Between 2011 until 2017

Based on the ProPheT model, the Stage 2 has summarized 515 papers (where 440 articles from SCOPUS, Science Direct and IEEE database and 75 articles from the industry report, government policy, case study, business executive summary and seminar (grey literature). The number of duplicate is one item, outdated publication, 50 items and irrelevant publication is six items. The numbers of excluded papers are 57 items in total.

5.3. Stage 3: Screening Stage

At the screening stage, based on the ProPheT Inclusion and exclusion criteria model, the inclusion criteria including the topic within Industry 4.0, duration that is the published journals or related documents are from 2011 and above. Then, the literatures must have the information regarding Industry 4.0 task situation with human role description such as "operator", "production workers", "shop floor employees", "skilled labour", "semi-skilled" and "high-skilled". The competencies also must be described within task situation at the shop floor production (such as at the Industry 4.0 fully automated assembly lines). At this screening stage, there are 98 items is excluded due to irrelevant content and an unidentified sources, which resulting 360 papers in total.

5.4. Stage 4: Eligibility

About 260 articles were excluded at this stage, as these articles only specify the concept and definition of Industry 4.0, the issue and challenges of Industry 4.0 and no further explanation related to human role,

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competencies and skills in Industry 4.0. Thus, the remaining 100 articles are used for final studies for data extraction.

5.5. Stage 5: Final Studies

At the final stage, about 20 articles were excluded. These 20 articles are the supporting evidence for Industry 4.0 comprehension. The final studies summarized 80 articles that highly mentioned about the human role, competencies and skills in Industry 4.0. The summary of the identified publication and grey literature is described in Table 1. The findings from the grey literature review and the publication shown a similarity in competencies and skills required by Industry 4.0. However, in grey literature cited more non-technical competencies compared to technical competencies requirement. The analysis also indicates the good similarity of competencies and skills stated between established publications and the "grey literature". Thus, the "grey literature bias" shows good agreement on competencies and skills in both publication and internet sources.

Table 01. The summary of identified publication and grey literature

Sources	Identified Publication and Grey Literature	Number of Records
Publication	Journal	16
	Conference Proceeding	33
Grey Literature	Industrial Case Study	1
	Documentation (Working Paper/Discussion Paper/Policy)	17
	PowerPoint Presentation (Industrial)	5
	Website	7
	Magazine article	1

6. Findings

The analysis on human role requirement was according to the needs of two major industry sectors namely, the manufacturing and services sector. There are four main clusters identified based on their output, either standardized output (largely automated) and customized output (requiring human touch) namely; mass scale industrial manufacturing, customized end-user manufacturing, digitalized and machine assisted massive use services and customized highly-personalized services (Luksha, 2016; World Skills Russia, 2017). Later on, the skills categorization is defined accordingly to the job profile, academic qualification and occupational competencies required (International Labor Office, 2012; Kurnia et al., 2013).

6.1. Manufacturing Sector

About 50 papers mentioned the Industry 4.0 technology in the manufacturing sector. The identification of this human role is made based on the Industry 4.0 current scenario, job profile and occupational competencies. The skills categorizations in manufacturing sector are based on the standardized output (largely automated) and customized output (human touch) (Luksha, 2016; World Skills Russia, 2017). The standardized output usually found in the mass scale industrial manufacturing such as Cyber Physical System at the shop floor production. In this mass scale industrial manufacturing, the low-skilled and semi-skilled workers are not required due to full automation and robotics use. The example can

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be seen in the USA factory automation where most of the low-skilled and semi-skilled workers are affected by the automation (Schlenker, 2017). By contrast, there are manufacturing sectors that are still relying on the work force such as the cosmetic, apparel, furniture, and consumer electronics (Luksha, 2016; World Skills Russia, 2017).

6.2. Understanding the human role requirement in Industry 4.0

To answer the Research Question 1, the guidance on skill categorization process is referred to the International Labour Organisation (International Labor Office, 2012). However, for establishing the roles of human, types of skills and levels of skills needed for Industry 4.0 is challenging as multiple terminologies are being used in the literature. Most of the literature interchangeably uses job description and terms such as "operator", "skilled labour" "semi-skilled", "high-skilled", "engineer" and "professional" to denote same and different concepts. Thus, to define the skills level according to these terms is quite challenging. Sometimes, different meaning is attached to the same terminology. For example, Sulaiman (2017) use the term technical occupation to refer to middle skilled (or semi-skilled), while others, use the terms "semi-skilled" and "skilled" to denote the same thing. Beaudry, Green, & Sand (2013) use the term skilled employee or skilled manufacturing personnel when referring to engineers, or workers at the professional level. Meanwhile, Pfeiffer (2016) and Rothwell (2015) uses the term middle-skilled to refer to skilled technical worker, which require vocational certificates. Usage by Rothwell (2015) is agreed upon by Dworschak & Zaiser (2014) when discussing the "*automation scenario*". According to Dworschak & Zaiser (2014), the autonomy of skilled worker is limited whereas the high-skilled workers are responsible for installation, modification and maintenance of Cyber Physical System (CPS). By contrast, the "technician" job description described by Motyl, Baronio, Uberti, Speranza, & Filippi (2017), are those from high school education, specialized in mechanical, electrical and automatization. The high school education, specialized in mechanical, electrical and automatization as stated by Motyl, Baronio, Uberti, Speranza & Fillippi (2017), is not clearly defined and may be interpreted as vocational college, which offers technical and vocational certificates and training. Thus, due to the various definition of the "*semi-skilled*" and "*skilled*" worker from the literature, the identification of the human role and competencies must be supported by the findings on the task situation and the academic qualification (Dworschak & Zaiser, 2014; Hertle et al., 2017; International Labor Office, 2012; Ministry of Human Resources Malaysia, 2013; Sulaiman, 2017).

In this systematic literature review, the *"low-skilled"* is referred to *Level 1* and *Level 2, "medium-skilled"* or also known as *"semi-skilled"* is referred to Level 3 and *"high-skilled"* is referred to Level 4. All these skill levels and academic qualifications are referring to ISCO-08 Skill Level and ISCED-97 group as stated in the International Standard Classification of Occupations (International Labor Office, 2012). The academic qualification for "*low-skilled worker*" is referred to the primary, secondary and post-secondary school (International Labor Office, 2012), the "medium-skilled worker" is referred to first stage of tertiary education and "high-skilled worker" is referred to the first degree and second stage of tertiary education (International Labor Office, 2012; Ministry of Human Resources Malaysia, 2013) . These clarifications on the human role definitions are important in order to give a clear message to the reader and to avoid the misinterpretation between "*skilled*" and "*semi-skilled*" definition. For example; "The production technician with the high-school education in electrical engineering require skills such as

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language skills, logical thinking flexibility, autonomy, responsibility, ability and willingness to learn new things: Media skills" (Benešová & Tupa ,2017). The term of "Production Technician" is referring to Level 3 ISCO-08 Skill Major Group; however, the academic qualification is referring to high-school education. Thus, the clarification shall be made on high-school education since different countries might have different academic qualification, rules and regulations (UNESCO, 2014). Meanwhile, the key word for "*low skilled*" and "*high-skilled*" is clearly understood during the data extraction in the systematic literature review process.

To define human role, integration skills are the core skill that can be used when working in the Industry 4.0 interdisciplinary production areas (Klynveld Peat Marwick Goerdeler, 2016). Within technical context, the skill formation is usually constructed based on direct demonstration, by mimicking and by shared hands-on doing (Pfeiffer, 2016). The supporting evidence on the skills formation process proposed by Ryberg and Christiansen (2008) cited from Rus et al. (2015), described the learning processes are at four stages, begin with mimicking, gradual mastery, confident increased and ability to teach others (Rus et al., 2015). In conjunction to human role in production, this learning processes is usually classified as routine task for low-skilled and semi-skilled workers.

From the customized output (human touch) perspective, the low-skilled and semi-skilled workers are still required in the manufacturing sector such as in the apparel, cosmetic beauty, consumer electronics industry. As for low skilled and semi-skilled worker, the knowledge can be taught via direct demonstration on the equipment use (Hirsch-Kreinsen, 2016). For example, there is few researches on Decision-Making database and Augmented Reality (AR) that can be used by the low-skilled human workforce as an assisted tool to perform the task in the shop floor (Hirsch-Kreinsen, 2016; Nelles et al., 2016; Prinz, Kreimeier, & Kuhlenkötter, 2017). Another example, the semi-skilled worker can use the Virtual Reality (VR) glasses to operate and supervise connected devices within the production line (Dittrich, 2016). They are also able to work with the machine with basic troubleshooting skills for simple machine malfunctions. Other study also described that the skilled worker usually require assistance system or Cyber Physical System tool to assist their work at the production line (Dworschak & Zaiser, 2014).

In contrast, high- skilled job tasks are associated with those that involve installation, maintenance and modification, which require problem solving and decision making skills (Dworschak & Zaiser, 2014). Furthermore, in discussing high-skilled workers, the non-technical competencies and skills are more frequently cited compared to technical competencies in the literature. Others recognise high-skilled workers as quality workers when they have both technical and non-technical competencies and skills (Nasir et al., 2011). The summary of human role, technical and non-technical competencies and skills in Industry 4.0 (within manufacturing sector) is described in Table 2.

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Table 02. Summary of the human role, technical competencies and skills required by Industry 4.0 – Manufacturing Sector

Manufacturing Sector	Human Role	Description	Scholar
Standardized Output (Largely automated) Mass scale industrial manufacturing. For example Cyber Physical System, machinery and equipment.	Low skilled workers are predicted no longer required at the fully automated shop floor production	[illegible]	(Ng, 2017; Vinh, 2017)
	Semi-skilled workers such as technician are still required at the fully automated shop floor productions	They may able to work together with the robot, at the same station and responsible for services, repair and maintenance.	(Dittrich, 2016; Dworschak & Zaiser, 2014; Klynveld Peat Marwick Goerdeler, 2016; Lewin, 2016)
	High Skilled workers such as engineer are still required at the fully automated shop floor production	They are responsible for the repair, maintenance and installation software. Require good problem solving and decision-making.	(Büth et al., 2017; Dworschak & Zaiser, 2014; Gronau, Ullrich, & Teichmann, 2017; Hertle et al., 2017; Kinkel et al., 2017; Müller-Frommeyer, Aymans, Bargmann, Kauffeld, & Herrmann, 2017)
Customized Output (Human Touch) Customized end-user manufacturing. For example, transport, apparel, furniture, consumer electronics and beauty cosmetics industries.	Low Skilled workers are still required at the shop floor production.	They require learning and using the assistance system such as Augmented Reality (AR), RFID, or Decision Making database.	(de Giorgio, Romero, Onori, & Wang, 2017; Hirsch-Kreinsen, 2016; Nelles et al., 2016; Pacaux-Lemoine et al., 2017)
	Semi-Skilled workers such as technician are still required at the shop floor production.	They are responsible for repair, services and maintenance (similar to mass scale industrial manufacturing).	(Dittrich, 2016; Dworschak & Zaiser, 2014; Klynveld Peat Marwick Goerdeler, 2016; Lewin, 2016)
	High Skilled workers such as engineers are still required at the shop floor production.	They are responsible for the repair, maintenance and installation software. Require good problem solving and decision-making (Similar to mass scale industrial manufacturing)	(Büth et al., 2017; Dworschak & Zaiser, 2014; Gronau et al., 2017; Hertle et al., 2017; Kinkel et al., 2017; Müller-Frommeyer et al., 2017)

6.3. Technical Competencies and Skills in Industry 4.0

To answer Research Question 2, there are 52 technical competencies and skills derived from the literatures. The results of analysis indicate the similarity in competencies from the previous findings made by Prifti et al., (2017) on A Competency Model for Industry 4.0 Employee and A Discussion paper of Qualifications and Skills in the Factory of Future written by Gehrke & Kühn, (2015) where most competencies and skills mentioned are Computer Science and Information Technology. These Computer Science and Information Technology competencies and skills are also found in the various research paper written by Golightly, Sharples, Patel, & Ratchev, (2016); Neugebauer, Hippmann, Leis, & Landherr, 2016; Yu, Xu, & Lu, 2015).). Even though there are differences in technologies and research area, the Information Technologies (IT) competencies are seen as a key driver in integrating information from computerization/computation to the physical component (machines) and robotics (Hartmann & Bovenschulte, 2014; Meissner, Ilsen, & Aurich, 2017). For instance, there are Cyber Physical Production System (CPPS), Machine 4.0, Smart Manufacturing and Intelligence Manufacturing System (IMS) which require Information Technology (IT) for its operation (Liu & Xu, 2017; Monostori et al., 2016; Pacaux-Lemoine et al., 2017). Knowledge in Information Technology (IT) is an essential in good practices of IT skills. These IT knowledge include the big data analysis and interpretation, and the Internet of Things (IoT) applications, where it is used as information storage for the whole production process (Bahrin et al., 2016; Hecklau et al., 2016; Karre, Hammer, Kleindienst, & Ramsauer, 2017; Prifti et al., 2017; Roblek et al., 2016) . The knowledge on IT security and data protection and app development is required due to the risk of cyber-attacks, which aims to access the unauthorized networks, programs and data (Bendovschi, 2015). To overcome the cyber security issues, the personnel must have a good fundamental knowledge towards IT and its application architecture such as Cyber Physical System architecture, big data construction, cloud manufacturing, Internet of Things and in-memory database (Günther, Rezazade Mehrizi, Huysman, & Feldberg, 2017; Lee, Bagheri, & Kao, 2015; Prifti et al., 2017). The readiness towards IT usage is also essential (Scharnhauzen, 2017).

Meanwhile, in computer science competencies and skills, some of the competencies in computer science also belong to information technology requirement and vice versa (Prifti et al., 2017). These differences in competencies and skills can only be achieved by having the integration skills. An example of the integration between Computer Science and Information Technology can be seen in visual computing such as in embedded system, programming and coding, Artificial Intelligence (AI), machine learning, computer vision algorithm, and data acquisition (Gehrke & Kühn, 2015; Liu & Xu, 2017; Monostori et al., 2016). Another example of these integrations in Computer Science field is the knowledge and integration skills in upgrading the existing programmable logic controller is highly demanded in industrial automation (Chen, Tai, & Chen, 2017). These programming and coding knowledge is required in interpreting data to the physical components and robotics (Dittrich, 2016; Posada, Toro, Barandiaran, Oyarzun, & Eisert, 2015; Prifti et al., 2017). With the knowledge use in data acquisition such as RFID Tags, cameras, signal processing device and network system, the information from big data analysis can be acquired on a real time basis (Günther et al., 2017; Karre et al., 2017; Liu & Xu, 2017; Prifti et al., 2017). Examples of physical components and robotics are human-machine interfaces, robot arms, actuator and sensors such as intelligence and (re) configurable sensors and networked actuators (Karre et al., 2017; Nelles et al., 2016; Prifti et al., 2017). The personnel also must have systemic skills such as integrating heterogeneous technologies, familiar use with the system development and mobile technologies, (Aichholzer, 2015; Scharnhauzen, 2017; Liebrecht, Jacob, Kuhnle, & Lanza, 2017; Prifti et al., 2017).

To apply these computer science and information technologies competencies and skills in the Industry 4.0, having fundamental knowledge on robotics and automation is thus essential. Robotics and automation technologies are the basis of the industrial manufacturing and known as a standardized output (Bahrin et al., 2016; Luksha, 2016). The use of Men-Are-Better-At/Machines-Are-Better-At (MABA-MABA) principle allows an optimal combination of the specific abilities and characteristics of humans and machines (Cummings, 2014; Nelles et al., 2016). Pfeiffer (2016) suggests the need for work transformation analysis at the automotive assembly lines where the non-routine task that is usually handled by high-skilled workers can now be carried out by the low-skilled workers (Pfeiffer, 2016). According to Mládková (2015), the knowledge worker that are highly regarded by the employers, are the one who are creative and innovative in his/her work. Creativity and innovation is a main parameter in the Industry 4.0, as the human creativity cannot be replaced by the robotics and automation system. As per suggested by Jaeger, Vienna, Ranz, & Reutlingen, (2014), human creativity is required to design and configure system, have an

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experience to analyse, assess and solve the problem. The use of robotic and automated system however, may reduce the human error in the production line (Pacaux-Lemoine et al., 2017). This is because of the robotic and automated system are more autonomous, flexible and cooperative (Gehrke & Kühn, 2015). Thus, the adoption of human-machine or (human-robot) symbioses makes the manufacturing process more effective. To add, workers must have cognitive abilities and systemic thinking in order to apply the integrated Computer Science and Information Technology knowledge within the fully automated production line (Scharnhauzen, 2017; Prifti et al., 2017; Roblek et al., 2016; Vinh, 2017; Wee, Kelly, Cattel, & Breunig, 2015).

Meanwhile, the results of literature analysis for manufacturing competencies and skills indicates that the Industry 4.0 personnel must able to work and control machines such as Computer Integrated Manufacturing (CIM), Computer Numerical Control (CNC) and be knowledgeable in production planning and design process (Chryssolouris, Mavrikios, & Rentzos, 2016; Jaeger et al., 2014). For example, the personnel must fully understand the Industry 4.0 integration such as Vertical Integration, Horizontal Integration and End-to End Integration (Qin, Liu, & Grosvenor, 2016). The personnel must have specialized knowledge in manufacturing activities and processes such as Additive Manufacturing (AM) (Gehrke & Kühn, 2015; Karre et al., 2017). The personnel must also be familiar with the use of Design for Manufacture and Assembly (DFMA) principles for the ergonomics in the manufacturing processes (Karre et al., 2017). Finally yet most important, the personnel should able to understand and conduct the quality control for reject or non- reject of parts produced (Pfeiffer, 2016). There are several Industry 4.0 applications such as Intelligent Manufacturing System (IMS), Cyber Physical Production System (CPPS), Computer Integrated Manufacturing (CIM), Internet of Things (IoT), and Cyber Physical System (CPS) being used. Although these technologies are similar in their use of computation, but they are different in their manufacturing applications (Kolbeinsson, Thorvald, & Lindblom, 2017; Liu & Jiang, 2016; Yu et al., 2015). Thus, it is very important for the personnel to understand the manufacturing processes and its requirement within the Industry 4.0 context.

The State-of-the-Art Knowledge is a fundamental to the integration competency and skills in the Industry 4.0 (Hecklau et al., 2016). The integration skills are frequently mentioned to cater the interdisciplinary areas within the Industry 4.0 (Jeschke, 2015). These integration skills must be supported with the knowledge management in order to integrate the knowledge and skills effectively (Gehrke & Kühn, 2015). The personnel must have ability to apply knowledge related to the workplace (Müller-Frommeyer et al., 2017). For example, the personnel must have knowledge in science and mechanics, which requires strong STEM fundamental and this knowledge is highly important in mechanical field (Forfás, 2012; Ministry of Indonesia, 2017; Müller-Frommeyer et al., 2017). On top of that, the high level of literacy and numeracy and the ability to understand complex written material is a basis of any occupation related to technical works (International Labor Office, 2012). The personnel must also have the human machine-interaction knowledge and understand to use the human-machine interface such as Virtual /Augmented Reality (Gehrke & Kühn, 2015; Karre et al., 2017; Krugh et al., 2017). To some extent, there are limitation on the robotics and automated system such as the requirement for human responses to uncertainties or urgent requests (Pacaux-Lemoine et al., 2017). Thus, the personnel must have the trouble shooting and problem solving skill in order to do the installation, modification and maintenance in the fully automated

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production line (Dworschak & Zaiser, 2014; Jeschke, 2015). The summary of technical competencies and skills in the Industry 4.0 is given in Table 3.

Table 03. Summary of the Overall Technical Competencies and Skills in Industry 4.0

	Major Competencies	Type of Competencies and Skills	Scholar
Technical Competencies and Skills	State of the Art Knowledge Competencies and Skills	Knowledge management, ability to apply knowledge, knowledge in science and mechanics, level of literacy and numeracy, ability to understand complex written material, human-machine interaction knowledge, know how to use the human-machine interface, trouble shooting, problem solving skill, basic installation, modification and maintenance.	(Dittrich, 2016; Gehrke & Kühn, 2015; Hirsch-Kreinsen, 2016; Ministry of Indonesia, 2017; Müller-Frommeyer et al., 2017; Prifti et al., 2017)
	Manufacturing Competencies and Skills	Able to work and control machines, knowledgeable in production planning and design process, understand the Industry 4.0 integration, specialized knowledge in manufacturing activities and processes, familiar with the use of DFMA principle, quality control, understand the manufacturing processes and its requirement.	(Aichholzer, 2015; Bahrin et al., 2016; Gehrke & Kühn, 2015; Golightly et al., 2016; Hertle et al., 2017; Jaeger et al., 2014; Liu & Xu, 2017; Lorenz et al., 2015; Monostori et al., 2016; Pfeiffer, 2016; Prifti et al., 2017; Serrano, Prades, Bruscas, & Abellán-Nebot, 2013; Toro, Barandiaran, & Posada, 2015)
	IT Competencies and Skills	Big data analysis and interpretation, Internet of Things (IoT) application, knowledge on IT security and data protection, apps development, IT architecture, Cyber Physical System (CPS) architecture, big data construction, in-memory database, readiness towards IT usage.	(Acatech, 2017; Aichholzer, 2015; Elka-Walsh, 2017; Gehrke & Kühn, 2015; Gronau et al., 2017; Lee et al., 2015; Marilungo, Papetti, Germani, & Peruzzini, 2017; Lorenz et al., 2015; Neugebauer et al., 2016; Prifti et al., 2017; Yu et al., 2015)
	Computer Science Competencies and Skills	Integration skills, embedded system, programming, coding, Artificial Learning, machine learning, data acquisition, RFID, signal processing device, network system real time, systemic skills, system development, mobile technologies, decision making database, Augmented Reality, Virtual Reality	(Aichholzer, 2015; Deloitte, 2015; DLG-Expert, 2015; Scharnhauzen, 2017; Gehrke & Kühn, 2015; Jaeger et al., 2014; Liebrecht et al., 2017; Lorenz et al., 2015; Cardin et al., 2016; Prifti et al., 2017)
	Robotics and Automation Competencies and Skills	Creative, innovative, able to design and configure system, knowledge on robotics and automation, cognitive abilities	(Dworschak & Zaiser, 2014; Scharnhauzen, 2017; Cardin et al., 2016; Chase, 2017; Roblek et al., 2016; Vinh, 2017; Wee et al., 2015)

6.3. Non-Technical Competencies and Skills in Industry 4.0.

There are 31 non-technical competencies and skills derived from the literatures. Problem solving, creativity, decision-making and adaptive skills are the most common non-technical competencies and skills

mentioned by scholars. Four main categories of competencies required by the Industry 4.0 have been suggested namely, the Personal, Social, Professional and Methodological competencies (Buth et al. (2017); Müller-Frommeyer, Aymans, Bargmann, Kauffeld & Herman, 2017). They propose that Personal Competencies must be possessed by all personnel irrespective of level; low skilled, semi-skilled and high skilled workers. It has even been suggested that the Personal Competencies is the key success factor in the Industry 4.0 era (Prifti et al., 2017). In the Industry 4.0 work environment, all personnel must have the cognitive abilities such as self-awareness, self-regulation, self-organizing and self-discipline (Büth et al., 2017; Prifti et al., 2017). Furthermore, they must have positive work attitudes, are proactive, has the ability to learn, and the ability to adapt as the nature of the Industry 4.0 technologies is constantly changing. Finding from the systematic review analysis also indicates that there is a strong requirement of social

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competencies and skills within the Industry 4.0. These competencies and skills can be defined as the ability to work in a team, have good communication skill, and able to work in an interdisciplinary areas. In the Industry 4.0 engineering practices, the high-skilled workers is usually responsible for installation, modification and maintenance of CPS (Dworschak & Zaiser, 2014). To perform the high-skilled Industry

4.0 tasks, the personnel must have the methodological competencies such as analytical skills, complexity skills, problem solving skills, planning skills, creativity, decision-making skills, integration skills, negotiation and critical thinking skills (Acatech, 2017; Forfás, 2012; Gennrich, 2017; Kinkel et al., 2017; Ministry of Indonesia, 2017; Müller-Frommeyer et al., 2017). Furthermore, high-skilled tasks personnel must have leadership skills, presentation skills, project management skills, business strategy, customer orientation and relationship management, persuasion, coordinating with others, training and teaching others (Hecklau et al., 2016; Ministry of Indonesia, 2017; Vinh, 2017). In short, there is no skill polarization for non-technical competencies between all skills level, exceptional to the leadership and professional competencies for high-skilled workers (Luksha, 2016). The summary of non-technical competencies and skills in the Industry 4.0 is given in Table 4.

Table 04. Summary of the non-technical competencies and skills of Industry 4.0

	Major Competencies	**Type of Non-Technical Competencies and Skills**	**Scholar**
Non-Technical Competencies and Skills	Personal Competencies and Skills	Cognitive abilities, Self-awareness, self-regulation, self-organizing, self-discipline, positive work attitude, proactive, ability to learn, ability to adapt	(Büth et al., 2017; George Chryssolouris et al., 2013; Dittrich, 2016; Gronau et al., 2017; Müller-Frommeyer et al., 2017; Prinz et al., 2017)
	Social Competencies and Skills	Ability to work in a team, have a good communication skill, able to work in an interdisciplinary areas.	(Büth et al., 2017; Forfás, 2012; Gehrke & Kühn, 2015; Gronau et al., 2017; Ministry of Indonesia, 2017; Müller-Frommeyer et al., 2017; Prifti et al., 2017)
	Professional Competencies and Skills	Leadership skills, presentation skills, project management skills, business strategy, customer orientation and relationship management, persuasion, coordinate with others, training and teaching others.	(Büth et al., 2017; Gronau et al., 2017; Müller-Frommeyer et al., 2017; Chase, 2017)
	Methodological Competencies and Skills	Analytical skills, complexity skills, problem solving skills, planning skills, creativity, decision making	(Acatech, 2017; Dittrich, 2016; Fantini et al., 2016; Forfás, 2012; Ministry of Indonesia, 2017; Prifti et al., 2017; Richert et al., 2016)

6.4. Service Sector

According to the Bureau of Labor Statistic towards 2024, US Department of Labor, there are 12 main areas of the service sectors, which are utilities, wholesale trading, retail trade, transportation and warehousing, information, financial activities, professional and business services, private education, healthcare and social assistance, leisure and hospitality, federal government, state and local government and other services. The decline in employment needs is expected in the utilities and information areas, where fewer workers will be required in printing and publishing area as customer move towards digital subscription and web publishing in line with technological transformation (Henderson, 2012). Meanwhile, in the ASEAN region, a major consideration is placed on the business process of outsourcing and retails as human employment is most affected by the use of Cloud Technology and e-Commerce (Chang, Rynhart, & Huynh, 2016).

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6.5. Understanding the human role, competencies and skills requirement in service sector of Industry 4.0

According to (Luksha, 2016), cited from Frey & Osborne (2013), over 2 billion of the existing jobs may be destroyed by the automation around 2030. The most affected jobs are the white collar and administrative task such as telephone salesperson, typist or related keyboard worker, legal secretary, financial account manager, grader and sorter, routine inspector, sales administrator, wages clerk and finance officer. The digital transformation in the administrative task and business process outsourcing is replaced by the use of cloud computing, software automation, and knowledge process outsourcing. The other services sector such as retails, the low-skilled workers are may be substitute with the use of e-Commerce, Internet of Things (IoT) and big data analytics. The use of RFID sensor and tag in retail also can ensure the inventory can kept at the minimum level (Chang, Rynhart, & Huynh, 2016).

Interestingly, the service sectors witnesses the biggest creation of new jobs. To add, the statistic on US employment data shown that the highest occupational employments are the transportation, production, office/administrative, sales and related, services, healthcare and management (Bonekamp & Sure, 2015). The high skilled worker, such as IT data analyst with software competencies and digital skills is mostly mentioned throughout the grey literature (Rüßmann et al., 2015). The need for highly trained professionals such as IT engineers, maintenance employees and operation analyst to manage these highly automated operations (supply chain and fully automated distribution center) may increase (Taliaferro & Guenette, 2016). The following skills for ICT job profile such as business analysis, programming software and development and IT governance and management is briefly described by (Shankararaman & Gottipati, 2016). However, until present, there is no supporting evidence on the polarization of competencies and skills between semi-skilled and high skilled worker (Luksha, 2016; World Skills Russia, 2017). The summary of human role, technical and non-technical competencies and skills in Industry 4.0 (within service sector) is described in Table 5.

Table 05. The human role, technical and non-technical competencies and skills in Industry 4.0 - Service Sector

Service Sector	**Human Role**	**Technical Competencies and Skills**	**Non-Technical Competencies and Skills**	**Scholar**
Standardized Output (Largely automated) Digitalized and machine assisted massive user services. For example, digital health, digital entertainment, post retail distribution etc.	Low skilled and semi-skilled workers are predicted no longer required in the service sector.		Able to work in the uncertainty and multidisciplinary environment, creativity, system engineering, green	(Henderson, 2012; Luksha, 2016; Ng, 2017; Vinh, 2017)
	High-skilled workers are still required.	Software competencies, digital skills, machine learning, data analytics, Artificial Intelligence (AI). Engineering of socio-technical systems Sustainable design Green design.		(Kramer, 2016; Luksha, 2016; Newman, 2017; Rüßmann et al., 2015; World Skills Russia, 2017)

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Customized Output (Human Touch) Customized highly-personalized services. For example, fitness and tourism, psychotherapy and personalized art and entertainment.	Low skilled and semi-skilled workers are predicted no longer required in the service sector.	[illegible]	thinking', foreign languages, Able to unlearn / relearn (supported by mind-stimulation).	(Henderson, 2012; Luksha, 2016; Ng, 2017; Vinh, 2017)
	High-skilled workers are still required.	Software competencies, digital skills, machine learning, data analytics, Artificial Intelligence (AI). Authentic serving Psychology skills Ethics of service Storytelling		(Kramer, 2016; Luksha, 2016; Newman, 2017; Rüßmann et al., 2015; World Skills Russia, 2017)

7. Conclusion

High skilled workers are reported to be consistently in demand by all industry sectors while the low skilled and semi-skilled workers are only said to be relevant in specific sectors such as within the customized end user of the manufacturing sector (for example, the apparel, and furniture and consumer electronics industry). In the manufacturing sector massive job (low-skilled and semi-skilled workers) are expected due to the technological change involving the Internet of Things, Cloud Technology and big data analytics. To some extent, the skill polarization in the manufacturing sector can be determined according to the occupational competencies and level of automation. Meanwhile, in the service sector, there is no supporting evidence on the skill polarization between skilled and high-skilled worker. However, the new jobs of the service sector may require more high-skilled worker due to the complexity, creativity, problem solving and decision making competencies needed. To sum up, the findings on the human role required by the Industry 4.0 suggest that the low skilled and semi-skilled workers are still relevant in the manufacturing sector of Industry 4.0 but with new task directions such as the introduction of the human-machine interface, advanced computation and digitalization. The digitalization skills seem to be integrating the technical competencies at all skills levels.

The Computer Science and Information Technology competencies and skills are often mentioned in both sectors; manufacturing and service. Low skilled and semi-skilled workers are mentioned in conjunction with the use of tools and assistive system such as decision-making database, Augmented Reality (AR) and Virtual Reality (VR) glasses in performing task of the Industry 4.0. Meanwhile, for skilled and high skilled workers, repair, maintenance, system installation, modification and maintenance are frequently mentioned. Most of the competencies related to high skilled worker are referring to the non-technical competencies and skills such as problem solving, decision making, professional competencies and methodological competencies. In the nutshell, the non-technical competencies (generic competencies) are expected to be applicable at all skills levels with the exception of the Professional and Methodological Competencies, which is associated with the high-skilled workers only.

Despite the relevance of human role, competencies and skills in Industry 4.0, there is a grey line dividing the technical and non-technical competencies required by the Industry 4.0. For instance, to what extent should the low-skilled and semi-skilled human workforce be competent in problem solving, decision-making and creativity in the Industry 4.0? To what extent are the technical competencies and skills defined at all skills level? This systematic review has raised many questions in need of further investigation.

Nevertheless, this review is the first step towards enhancing understanding of the competencies required by the manufacturing Industry 4.0 work force. Consequently, by understanding the human role in Industry 4.0, knowledge on the competencies and skills identified for Industry 4.0 are useful to education and development. Specifically, having this understanding is valuable in preparing appropriate TVET curriculum ford preparing future talents who will be competent workers of Industry 4.0.

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