Industry 4.0: A Systematic Review in Technical and Vocational Education and Training

Siti Zaharah[1]
Mohd Nasir Selamat
Khadijah Alavi
Kadir Arifin

Fakulti Sains Sosial dan Kemanusiaan
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor

[1]Corresponding author: [zaharah.alias@moe.gov.my]

Industry 4.0 is the digital transformation of industrial markets (industrial transformation) with smart manufacturing currently on the forefront. For this reason, Industry 4.0 is a new industrial reform that has been linked to industrialization studies, initiated high-tech strategy, real-time data processing and cyber-physical systems. The main goal of this paper is to address the gaps by studying in depth the research articles from different journals and conferences on the topic of Industry 4.0 in technical and vocational education and training (TVET), thus making it easier for future references. This study centered on incorporating the articles published in the recent years to establish knowledge on the topic, further identifying areas for future research. Hopefully, from this report, technical and vocational students would be exposed to new inventions of technology revolution as well as to create the innovative worker for a better future. In addition, this paper offers a set of guidelines to policy makers for the successful integration of Industry 4.0 in TVET.

Keywords: industry 4.0, technology revolution, industrial reform, technical and vocational education and training

Industry 4.0 is a synonym for the fourth industrial revolution. The Industry 4.0 revolution refers to the transformation of production structures into digital systems using information technologies. Industry 4.0 is focused on creating intelligent products, processes and procedures. Industry 4.0 is the label given to the gradual combination of traditional manufacturing and industrial practices with an increasingly technological world around us. Factories will become increasingly automated and self-monitoring as the machines within are given the ability to analyse and communicate with each other and their human co-workers, granting companies much smoother processes that free up workers for other tasks (Mike, 2018).

Associated with this flexibility, Industry 4.0 aims at overcoming contemporary challenges, such as intensifying global competition, volatile markets and demands, required customization, as well as decreasing innovation and product life cycles. Industry 4.0 serves as a useful and targeted approach to deal with these challenging requirements (Julian & Daniel, 2017).

Within the context of Industry 4.0, it cannot be denied that work organisation and work processes will change along with automation and real-time oriented control. The same is true for work contents and the interaction and communication between man and technology, which have many consequences for users and providers of

the TVET system. According to Gennrich (2017), TVET must be modernised and able to cooperate with companies. The skill sets of technical and vocational personnel need to be upgraded significantly towards higher qualifications and more cooperative behaviour. It seems to be proven that experience-based TVET models are most consistent in supporting highly efficient and effective human capacity building for Industry 4.0. The manufacturing industry has transformed to fourth revolution expected to affect entire industries by transforming the ways goods are designed, produced, delivered, paid and consumed. As a result, education needs to be the focus specifically in TVET (Nor Aida et al., 2017).

TVET providers are encouraged to align themselves to the latest skills standard and curriculum to ensure the Fourth Industrial Revolution is well-understood and learned. In Malaysia, the government has allocated RM50 million from the 30% pool fund for TVET to increase competitiveness and improve the caliber of the workforce and the nation's economic development. Failure to recognize and adapt Industry 4.0 would bring serious repercussions on the nation's ability to be competitive. By looking into the future, Malaysia is also embarking on this trend and targets to increase such collaborations with the industry. Most TVET graduates will be working in small-and-medium enterprises (SMEs). However, according to the Malaysian Productivity Corporation (MPC), ICT adoption by SMEs in Malaysia is a mere 10%. This is in stark contrast to other developed countries where the adoption stands at 50%. To meet the technological demands of Industry 4.0, ICT education must be taught to TVET students as well (Bernama, 2017).

Therefore, the focus of this paper presents a systematic review on the integration of Industry 4.0 in TVET. The main goal of this paper is to address the gaps by studying in depth the research articles from different journals and conferences on the topic of Industry 4.0 in TVET thus making it easier for future references. This paper attempts to consolidate the literature reviews available on the topic to be presented in the form that researchers and academicians can focus and establish their knowledge on the topic, further identifying areas for future research.

History of Industrial Revolutions

Before the advent of the Industrial Revolution, most people resided in small, rural communities where their daily existence revolved around farming. Life for the average person was difficult, as incomes were meagre, malnourishment and disease were common. People produced the bulk of their own food, clothing, furniture and tools. Most manufacturing was done in homes or small, rural shops, using hand tools or simple machines. The Industrial Revolution begins in Britain, spreads to other countries, and has a strong impact on economics, politics, and society. There are four stages in the ongoing process called the Industrial Revolution (Mohd, 2016). The first revolution occurred towards the end of the 18th century which was mechanical production on the basis of water and steam. The second Industrial Revolution at beginning of the 20th century happens during the introduction of conveyor belts and mass production, to which the names of icons such as Henry Ford and Mercedes Benz are linked. The third revolution takes place in the digital automation of production by means of electronics and information technology (IT) system.

At the beginning of 1970s, the automation of production processes, along with the intensive use of electronic technology, led to digital transformation,

making the production processes in the industry faster (Ali & Abdulkadir, 2017). Today, the industrial landscape is again being transformed to the fourth stage with the rise of autonomous robots, contemporary automation, cyber-physical systems, the internet of things, the internet of services and so on (Mohd, 2016). In summary, these processes led to a shift from muscle strength to mechanical strength. This revolution, which accelerates the production processes by making all the units in the production systems communicate with each other over the internet, promises that intelligent systems will be used in all areas.

All these industrial revolutions have resulted in economic growth, increased productivity, and advanced welfare at the country that manages to reap most of its positive impact, including high-quality goods and services (Morrar et al., 2017).

Technical and Vocational Education and Training

Technical and Vocational Education and Training (TVET) plays a significant role in supporting human capital development in any industries across the globe. TVET should provide the students with appropriate information equipment in accordance with the requirements of the advanced age in their general skills. TVET in our country should have a system that aims for social and economic development of the country, providing a possibility to meet the needs of everyone who wants to be a professional with practical training in laboratories equipped with new technologies and cooperate with all common working partners. In accordance with that, programme effectiveness in meeting job market needs depends importantly upon the links between training providers and industry as consumers of TVET graduates on the one hand, and research institutions which produce up-to-date pedagogies and

generate information on future skills on the other.

Among public sector providers, the first link has seen a strengthening over the decade in review, with industry given a major role in curriculum design. Links between training providers and research institutions have also increased, albeit from an almost non-existent base in 2000. Curriculum relevance can also be enhanced by in-service training in industry settings of instructors, especially since they tend to come from the public sector (Lee & Kee, 2016).

The development of TVET is becoming popular to both international and national policy, and also to both developed and developing country. This is because it is market driven and most importantly it supports the emergence of industry 4.0. In 2020, it is expected that 60% of 1.5 million jobs would require skilled workers. Unfortunately, for Malaysia to achieve its goal, skilled human resource is still lacking (Nor Aida et al., 2017). Having identified it is as a main issue in our education system, the government through Budget 2017, has allocated a total of RM4.6 billion to focus on TVET education, worth RM270 million is allocated to upgrade educational equipment in TVET institutions while RM360 million has been allocated for the Skills Development Fund Corporation (Nor Aida et al., 2017).

TVET should have a system that aims for social and economic development of the country, provides a possibility to meets the needs of everyone who wants to be a professional, provides a practical training in laboratories equipped with new technology and cooperates with all working partner (Ali & Abdulkadir, 2017). As a result, an education system designed for an industrial economy that is now being automated requires transformation, from a system based on facts and procedures to

one that actively applies that knowledge to collaborative problem solving. The creativity, the innovation and the entrepreneurship skills also need to be included in the TVET in order to ensure our Malaysian students are ready to serve with 4.0 industry skills.

Method

The objective for conducting systematic reviews should be made explicit at the start of the process, as this is likely to influence the methods used for the review. A systematic review is described as an overview of primary studies or "secondary" research (Stewart, 2014) conducted according to explicit and transparent methods (Teing, 2007). Teing (2007) further emphasises the fact that the study should be conducted in such a manner that it could be reproduced. A systematic review does not seek to create new knowledge but rather to synthesize and summarize existing knowledge (Edoardo & Pearson, 2014). A systematic review will answer the question and highlight the gaps in the research and literature, and indicate the way forward for future research.

Sources and Searching

Systemic literature review consists of a four-step process adopted from Mayring (2014). It is one of the successfully used methods in many literature reviews in operations management (Figure 1). Okoli and Schabram (2010) defined a systematic review as a review of the literature according to an explicit, rigorous, and transparent methodology. Such a step-by-step model can be a point of reference for quantitative, qualitative and of course for mixed methods research. And in this way perhaps the unfruitful "science war" in social science methodology can be overcome (Mayring, 2014).
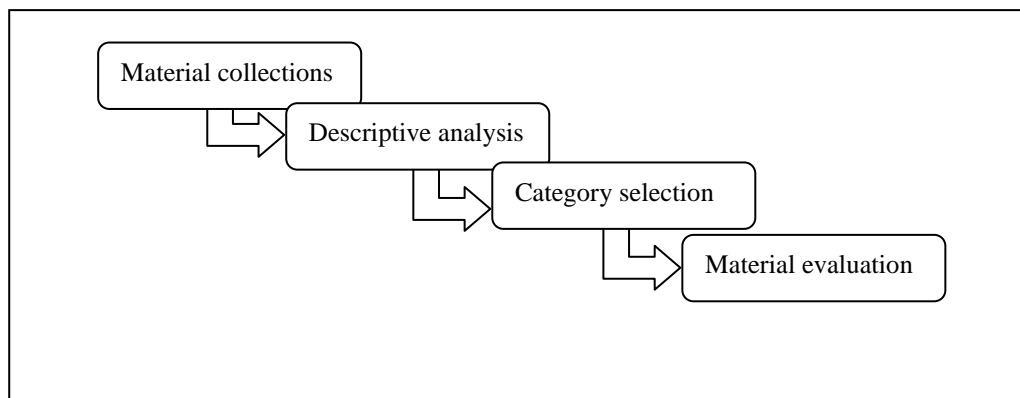

Figure 1. Four-step process of systematic review

The search for studies was performed using the electronic database. This systematic review does not seek to create new knowledge but rather to synthesize and summarize existing knowledge, and therefore relevant research must already exist on the topic. In the first phase leading databases such as Emerald, IEEE, ProQuest and Google Scholar were searched to congregate papers related to Industry 4.0 in TVET using keywords such as "Industry 4.0". "Smart factories", "TVET", "Industrial reform", and so on. The published and unpublished literature is carefully searched for the required studies relating to an intervention or activity. For an unbiased assessment, this search must seek to cover all the literature. During the second phase, the contents of these papers were studied and classified based on their

author's profile, keywords, research methodology and country of research and year of publications. On the third phase, keywords of the papers were gathered to understand as to how authors have positioned their articles. Keywords conveying Industry 4.0 and TVET attributes were selected and grouped together. From this, articles written in English published from 2015 to 2018 were eligible for inclusion.

The initial search identified 46 articles. After review of titles and abstracts, 32 studies remained for a detailed reflection. Reference tracking, internet searches, and expert consultation yielded eight additional articles. Of the 40 articles subjected to full-text review, 28 articles met at least one exclusion criterion, leaving twelve articles for inclusion in the review. Following a full-text selection stage, the remaining studies were assessed for methodological quality using a critical appraisal framework. Finally, a manual search was conducted of the reference lists of all retrieved papers to identify any studies missed during the database searches. The search should also target unpublished studies to help minimize the risk of publication bias. Poor quality studies were excluded but were usually discussed in the review report.

The findings from this aggregation of an unbiased selection of studies then needed to be discussed to put them into context. During study selection, the authors looked to match the studies found in the search to the review's inclusion criteria, and identified those studies that were conducted in the correct population, used interventions of interest, and recorded the predetermined and relevant outcomes.

Limitations

The spread of articles is narrow in which currently Industry 4.0 is a new concept in TVET and the implementation of Industry 4.0 in TVET is still scarce Therefore, there is a lack of sources in systematic review of the topics. Most of the articles have a theoretical approach rather than data driven or problem-solving approach. Hence, future research can be done by focusing on the obstacles and critical success factors of Industry 4.0 in TVET.

Discussion

From the review, the authors have found gap from the articles. They are as follows:

1. Vocational training institutions should re-examine their course content, course descriptions, and curriculum and program outputs, focusing on trained human resources that Industry 4.0 already needs (Ali & Abdulkadir, 2017; World Economic Forum, 2017).

2. Modelling and simulation-based laboratories have to be established in all sectors, especially in the production and service sectors of Industries 4.0 technologies (World Economic Forum, 2017).

3. Curriculums of technical and vocational school need to be re-audited so that they can keep pace with the rapidly changing industry (Ernest et al., 2016; Ali & Abdulkadir, 2017; Sommer & Kreibich, 2017).

4. Education and training are often restricted by a lack of teachers trained to deliver quality technical education and shortage of TVET facilities and infrastructure (Milio et al., 2014; World Economic Forum, 2017).

5. Evolving certification and credentialing systems based on agreed industry standards and the identified needs of both learners and employers and updated on a rolling basis to ensure

continued relevance (Mehmet Baygin et al., 2016; World Economic Forum, 2017).

6. Improve the social status of TVET as a viable education pathway among learners, families, employers, policymakers and other stakeholders (Milio et al., 2014).

7. Policy makers, investors and politicians should balance more evenly between academic and TVET education reform and funding, and better understand the linkages and complementary nature of both routes, both for individuals and for businesses and economies (Morrar et al., 2017).

8. As new approaches and new technologies emerge, funding and experiments are necessary for identifying the most effective models with potential to scale and create meaningful change in TVET (Sabine, 2015; World Economic Forum, 2017).

This implies that TVET is a type of education given to individuals to develop their creative and manipulative potentials for the benefit of humanity. The goal of education and TVET is therefore to fight ignorance and illiteracy so as to produce competent human resources for economic and social development, in line with the concept of Industry 4.0. When applied successfully, this approach nurtures a virtuous circle in which more and better education and training fuels innovation, investment, economic diversification and competitiveness, as well as social and occupational mobility and thus the creation of more but also productive and more rewarding jobs.

Effects of Industry 4.0 on Technical and Vocational Education and Training (TVET)

Industry 4.0 is not about the new technology in industry but about multitude of new technologies and forms of application with different degrees of new form application, technical maturity and systematic effects. TVET student should be embedding to highly skilled worker, promote learning, preserve health and environment safety (Sabine, 2015).

It also builds talent to meet needs of industry 4.0 Malaysia TVET revolution. TVET in Malaysia should evolve in line with technological and economical development to ensure relevancy of the product produced by the system. The future requires not only technically-sound workforce but also an independent, innovative and enterprising talent (Mazliham, 2017). According to Mazliham (2017), higher TVET (HTVET) is an innovative education model that is designed to produce graduates who are needed globally and educated in ways to fulfil societal and occupational needs. This model also emphasizes strong connection with relevant industries and organizations. This symbiotic and dynamic relationship between academia and industry adds value to our integrated application-oriented curriculum. It provides a fertile ground to produce independent, creative and innovative graduates who are able to contribute to, and reap the benefits of, an innovation-driven high-income nation. Cheng Hwa (2017) stated that in the next production revolution, Malaysia needs more humans as innovators rather than just more robots.

As Industry 4.0 changes traditional manufacturing relationships, more high skilled labours are needed to monitor and manage the factories of the future. This requires not only technical competencies but also communication, collaboration, critical thinking and creativity. Countries must "educate for autonomy" so that individuals can constantly update their skills and knowledge. Thus, problem-based learning, a flipped classroom, and curriculum design can be tools to help

improve learning outcomes and better prepare people for continuous learning in the 4.0 world of work.

According to Siti Hamisah (2017), digital disruptions are happening every single day. Core values, ethical principles and Malaysian identity should be preserved to embrace the Industrial Revolution 4.0. Innovation amongst Malaysian universities and TVET is key competitive factor of Digital for Malaysia to provide a Code of Ethics and Responsible Conduct to guide institutions and individuals in their exploration of these Industrial Revolution 4.0 technologies. Furthermore, Siti Hamisah (2017), suggested that Malaysia needs to find ways to incorporate the elements of the Industrial Revolution 4.0 in the approach to address challenges faced in the bio-based sector. Traditional manufacturing and service industries, and the rural hinterland would be dangerously left behind if Malaysia does not take heed of the possible technological revolution aftermath.

Conclusion

This study offers contribution by enhancing current knowledge on the importance of implementing the Industry 4.0 in TVET. From the survey, technical and vocational institutions curriculum should emphasize more on work environment habit inculcation into students in order to make them abreast with the emerging trends in the occupation of work. TVET must be able to anticipate and respond accordingly by offering relevant programmes, suitable curriculum, suitable facilities and infrastructure and new ways of teaching-learning and assessing the students should be adapted to Industry 4.0. Hence, it is important that technical and vocational institutions should be familiarised with the attributes of Industry 4.0 before starting their journey with Industry 4.0.

Transformation in Industrial Revolution 4.0. Higher Education leaders should exploit the potential opportunities brought by the Industrial Revolution 4.0 with much responsibility and wisdom, by providing digital leadership for their institutions. Technologies brought forth in the Industrial Revolution 4.0 if wrongly used could easily lead them astray from the culture, core values and identity that Malaysia is proud of. Thus, it is important

Besides that, education and training for productive employment is vital for economic and social development in Asia and the Pacific country. Therefore, TVET is viewed as a tool for productivity enhancement and poverty reduction in the region. TVET plays important roles in implementing and promoting sustainable development. For that reason, industry can play a critical role in developing a TVET ecosystem. By giving their need for graduates, industry players can provide input on their requirements for TVET graduates, including specific skill and labour demand needs in the short and long terms. It is foreseen that TVET curricula, based on qualified, innovative, and competitive foundations, contribute not only to the countries that applies them, but also to the development of the countries on a global scale. Thus, one of most important challenges for government, policy makers and society is how to shift the culture of the industry and society to tackle the set of technology disruptions associated with this new industrial era.

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