Education 4.0, Industry 4.0, Lifelong Learning: A Descriptive Literature Review

Aidrina Sofiadin

aidrina@iium.edu.my
International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia

Abstract

A new transformation of industry known as Industry 4.0 has drawn much attention among researchers and entrepreneurs. From a higher education perspective, Industry 4.0 has grown concerned about how institutions can produce graduates that are compatible with Industry 4.0. Due to the high business operation migrated to the online platforms, there is a need for graduates that have Information Technology (IT) skills, thinking skills, critical skills, and communication skills. A lack of necessary skills and knowledge of the Fourth Industrial Revolution (4IR) will lead to high unemployment among graduates. This paper aims to assess the relationship between Education 4.0 and Industry 4.0. Also, how e-learning plays a role while promoting lifelong learning. Thus, this leads to the development of the Education-Industry 4.0 Framework. A descriptive literature review on Education 4.0 and Industry 4.0 intends to identify and improve the millennial skills and knowledge. The descriptive literature identified four elements of Education 4.0, six crucial skills of millennial graduates, and seven technologies of Industry 4.0. The interrelationship between Education 4.0, millennial graduates, and Industry 4.0 was identified. Furthermore, this paper identified e-learning as a component of closing the gap between Education 4.0 and Industry 4.0. Even though there has been a lot of research on Education 4.0 and Industry 4.0, this paper aims to provide descriptive literature that provides a guideline on how Education 4.0 can produce graduates that meet the industry 4.0 requirements through e-learning to promote sustainable education.

Keywords: Education 4.0; Industry 4.0; e-learning; lifelong learning.

1. Introduction

The transformation of the industry from mechanization, waterpower, and steam power to cyber-physical systems has led to high demand for skills such as critical and creative thinking, communication, self-learning, ICT and data analysis, and innovation among graduates. Due to the high technology environment of industrial 4.0, high education is needed to ensure individual qualifications and skills are practical in industry 4.0(Andre, 2019; Kaymaz et al., 2020). Nowadays, most machines are connected to a network that promotes information production and sharing. The fourth industrial revolution(4IR) or refer as Industry 4.0, allows smarter data access that leads to more efficient and productive. This leads to applications such as identifying new insights and opportunities for the manufacturer to optimize their operations, logistics, and supply chains(Marr, 2018). The use of the Internet of Things and the cloud have brought more devices connected online that are collecting, storing, and sharing data. Since technology continues to change, new challenges among learning organizations arise.

Nowadays, Education 4.0 has become the buzzword among learning organizations. The high unemployment rates caused by the COVID-19 pandemic are causing concern. Many business operations have moved to the online platform. Thus, the process of business online has led to a high need for Industry 4.0 skills and knowledge. Due to increasing online business operations, education 4.0 needs to equip leaners with IT skills, thinking skills, critical skills, communication skills, and human skills. What is Education 4.0? How industry 4.0 impacts education 4.0? According to the World Economic Forum (2017), Industry 4.0 is changing the world due to the impact of new technologies on economics, education, and industries. To manage these trends, learning organizations need to teach students the ability to manage new trends to ensure effective future professional development(González and Calderón, 2018). Education needs to be transformed to develop future-proof student skills and experiences. Education 4.0 responds to the innovative needs of industry 4.0 (Hussin, 2018) as it focuses on bringing an experienced workforce(Mourtzis et al., 2018) and improving life skills as part of preparing learners for future jobs(Ernst & Young LLP., 2017). Students need to continuously learn digital skills throughout lifelong learning to meet future job knowledge and skills requirements. Since education will have a significant influence on industry 4.0, learning organizations need to focus on the accessibility and quality of education(Ragulina, 2019). Thus, lifelong learning is important to ensure that future employees possess knowledge and skills that are required in industry 4.0 and later.

2. Industry 4.0, Education 4.0, and Lifelong Learning

2.1. The Fourth Industrial Revolution (Industry 4.0)

Today, the revolution of the industry has led to Industry 4.0, which has induced major changes in job skills and employment. The fourth industrial revolution is making a positive impact on digital transformation and integration of organizations (Catal and Tekinerdogan, 2019). IR 4.0 technologies such as Artificial Intelligence (AI), Augmented Reality (AR), Virtual Environment (VR), Mixed-reality (MR), Extended Reality (XR), Cyber-Physical Systems(CPS), and Internet of Things (IoT) intends to improve quality of life that promotes social wellbeing and environmental sustainability by providing greater convenience, security, and job transformation. These benefits required certain knowledge, technologies, and expertise, thus, educational curricula need to include and reflect on the latest technologies, concepts, and paradigms (Catal and Tekinerdogan, 2019).

Industry 4.0 has affected job structure and competitiveness, such as organizations, financial systems, health, innovation skills, and education variables. Due to these changes, learning organizations courses that meet the present and future jobs demand. Due to the technological changes in industry 4.0, it is crucial to ensure that future workers will be highly trained and equipped with interdisciplinary skills that enable them to perform reflective thinking(Almeida and Simoes, 2019). A study shows that there was a low efficiency of cooperation between universities and companies of industry 4.0(Fonina et al., 2019). Thus, there is a need for education 4.0 to meet industry 4.0 needs to achieve a balance and sustainable growth of a country.

2.2. Education 4.0

Nowadays, education 4.0 focuses on innovation-producing education, which intends to integrate advanced technologies into students' courses as preparation for industry 4.0. For instance, courses such as Autonomous Robotics, Programming of embedded systems, Network modelling, Internet of Things and Smart Cities, Distributed Systems, Automation Engineering, and Machine Learning are offered course at the University of Padova in Italy (Tosello et al., 2019) to train students on autonomous and industrial robotics in industry 4.0 milieu.

Technologies such as Artificial Intelligence (AI), Augmented Reality (AR), Virtual Environment (VR), Mixed-reality (MR), Extended Reality(XR), Cyber-Physical Systems(CPS), and Internet of Things (IoT) are the main technology's enabler for education 4.0 (Mourtzis et al., 2018; Popenici and Kerr, 2017; Shahroom and Hussin, 2018). It should be noted that Ellahi et al. (2019) indicates that universities should enhance their current curriculum in line with the latest technologies required by industry 4.0. These technologies are advanced technologies which intends to assist people task. However, according to Butler-Adam (2018), educators need to teach students to be able to make ethical and moral decisions since AI is not likely to perform successful decision-making

2.3. Lifelong learning and e-learning

Even after graduating from school or universities, learning is still too important in our daily life. Individuals should take responsibility for their learning throughout life. One of the Sustainable Development Goals, which is quality education, aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"(United Nations, 2015). The inclusion of lifelong learning has increased awareness among academicians and organizations as part of their education agendas and policies. Lifelong learning refers to continued education that enhances human brain active engagement, physical activity, and healthy social relationships(Nordstrom, 2006). The world of lifelong learning will be a major component of education 4.0 (Støckert et al., 2019). A good practice guideline was developed by Thayaparan et al. (2015) for lifelong learning allows higher education institutions to meet the industry requirements by providing lifelong learning through-life studentship, promote communication between higher education institutions and industries, and promote the new learning and teaching technologies. Lanz et al. (2018) added that the concept intends to enhance industry-academia collaboration to support learning in different career levels.

Based on a research result, learning management systems need to be more actively engage with the assessment and improvement of individual skills and behaviour (Osis et al., 2015). Thus, e-learning may play an important role as a tool for improving individuals education quality and satisfaction. E-learning offers personalization and flexibility that are also the two fundamental characteristics of education 4.0(Bartolomé et al., 2018). The flexibility of lifelong learning able to promotes more effective ways of further education (Meincke and Tavangarian, 2011). E-learning has been recommended as one of initiative towards engineering education. The digitalization of education is set to be the new destination of e-learning(Makarova et al., 2018). E-learning and lifelong learning are conditioned by the Internet as same as industry 4.0 (Huba and Kozák, 2016). The digital factory academy concept and cyber-physical systems laboratory are concepts that help to support lifelong learning for companies (Lanz et al., 2018).

3. Research Methods

3.1. A systematic and comprehensive literature review

An effective literature review leads to a firm foundation for knowledge advancement and theory development(Webster and Watson, 2002). A literature review was conducted in this study to present evidence on a meta-level study on the relationship between industry 4.0 and education 4.0. According to Synder (2019), this is a critical component of developing a theoretical framework. Proper steps on conducting a literature review need to be followed to ensure the review is accurate, precise, and reliable(Snyder, 2019). Since systematic literature review has been widely used in many disciplines, this study adopted this method. A systematic review aims to identify all empirical evidence that fits the inclusion criteria to answer the research question(Snyder,

2019). There are a few systematic review guidelines(Davis et al., 2014; Moher et al., 2009)were published. The systematic review methodology adopted a five-step process (Khan et al., 2003), which are 1) Identify the research questions; 2) Identify relevant study; 3) Evaluating the quality of the studies; 4) Summarizing the research evidence, and 5) Explain the findings. To provide a comprehensive literature review for this study, guidelines by Williams (2018) was adopted.

3.2. The exploratory phase

In this phase, the research topic and questions were identified. This step aimed to identify the most appropriate information sources for industry 4.0 and education 4.0. By conducting a systematic way of finding relevant literature, research ethics and objectivity can be obtained(Onwuegbuzie and Frels, 2015). Onwuegbuzie and Frels (2015) added that the information must be stored and managed in systematic to avoid plagiarism. For this, the author referred to publications from Emerald, IEEE Xplore, Scopus, SpringerLink, ScienceDirect, Taylor and Francis Online, and GoogleScholar. Also, the author expanded the search on other sources such as media, observations, documents, experts, and secondary data via social networking. For instance, the author used ResearchGate and LinkedIn to communicate with various experts.

3.3. Interpretive phase

The search strategy for the descriptive literature review includes a selection of range specification for year of publication, identifying specific terms, key topic, and searching through titles, abstracts, and keywords. The keywords used by the author fell into two categories, shown in Fig 1.

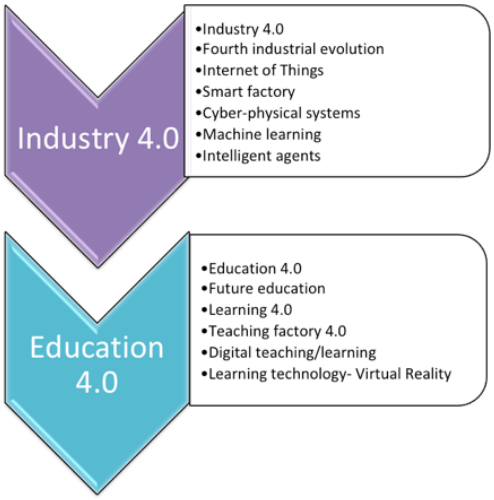

Fig. 1. Keywords used for this study

Mendeley and Readdle PDF Expert tools were used to store and manage the relevant database. The initial search queries resulted in a total of 388 articles. Then, these articles were filtered and analyzed at two levels using NVIVO. During the first level, the articles were analyzed by the topic, abstract, and keywords. The articles that focus on education 4.0 and industry 4.0in the education context was selected; all other articles related to industry 4.0 in other context were discarded. Then, the full text of the selected articles was reviewed. The outcome of this filtering process leads to 183 articles that are relevant to the research topic. Then, the 183articles

were then classified according to industry 4.0 and education 4.0.

3.4. Communication phase

Finally, this phase focused on developing the research framework and writing a comprehensive literature review. This phase involves a descriptive review of the selected literature. A descriptive analysis of topics such as trends of studies, a common outlet for topic and research method applied was conducted. Based on the pattern of the published articles, new insight on closing the gap between industry 4.0 and education 4.0 was discovered.

4. Descriptive Statistics

The 183 articles were coordinated systematically using a coding scheme and were analyzed based on the year of publication, title, and publication channels. Apart from these, research gaps were identified through the innovation of an Education-Industry 4.0 framework.

4.1. Distribution of articles by topics

Generally in most industry 4.0 papers, the word “Career” was mostly prompted in the publication topics (41%), followed by the phrase “Intelligent Agents” (17%) and “Internet of Things” (17%). Areas discussed on “Career” include to operational performance level(Tortorella et al., 2020), work skills(Moldovan, 2019), professional standards(Gorbunova et al., 2018), skills development(Lambrechts and Sinha, 2018), skills requirements(Lorenz et al., 2015; Maisiri et al., 2019; Siphamandla Mthembu and Ngong Ocholla, 2018), changing role(Trevelyan, 2019), career development(Hirschi, 2018; Whysall et al., 2019), graduates preparation(Winterton and Turner, 2019), and technological unemployment(Pinto et al., 2019). Overall, most researchers were concerned about the impact of industry 4.0 towards the present and future career. Nevertheless, researchers are also interested in areas such as Cyber-Physical systems, robots, machine learning, Internet of Systems (IoS), and autonomous equipment were also discussed in some articles.

Meanwhile, most education 4.0 articles concerned on producing human force that meet the industry 4.0 requirements. Most of these papers focused on redesigning education (19%), followed by education 4.0 transformation (15%) and contributions (14%) toward industry 4.0 that is attracting a number of a great deal of interest from researchers. Whereas industry 4.0 technologies (11%), higher education readiness (9%), and gearing for industry 4.0 (6%) are within the area of focus. Fig 2 below shows the keyword frequency among the selected articles.

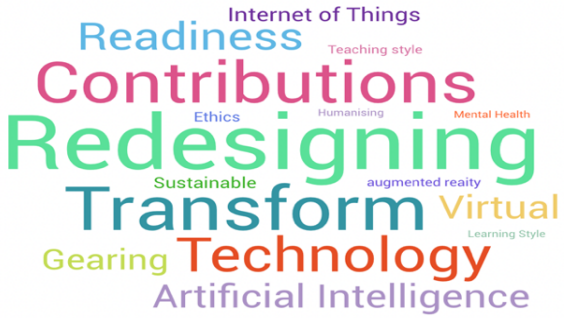

Fig. 2. Keyword frequency on education 4.0

In 2022, there is increase of publication on education 4.0 in terms of readiness, education transformation, implementation, designing education, and contribution. Since these articles are not as many as those with industry 4.0, this study intends to create awareness of the role of education in meeting Industry 4.0 requirements to ensure the future graduates and the human capital equipped with the knowledge and skills on Industry 4.0.

4.2. Distribution of articles by year

Since the term “Industry 4.0” was introduced in year 2011 as part of an initiative to improve German manufacturing(Rojko, 2017), this study selected articles from the year 2019 to 2022 which focused the connection between the Industry 4.0 with the education. In this study, the author also observes the development of publications since 2012. There is no or limited article was published in the year 2012, however, the four publications were identified in 2015. Since then, the journals, conference papers, and books publications started to grow until now, see Fig 3.

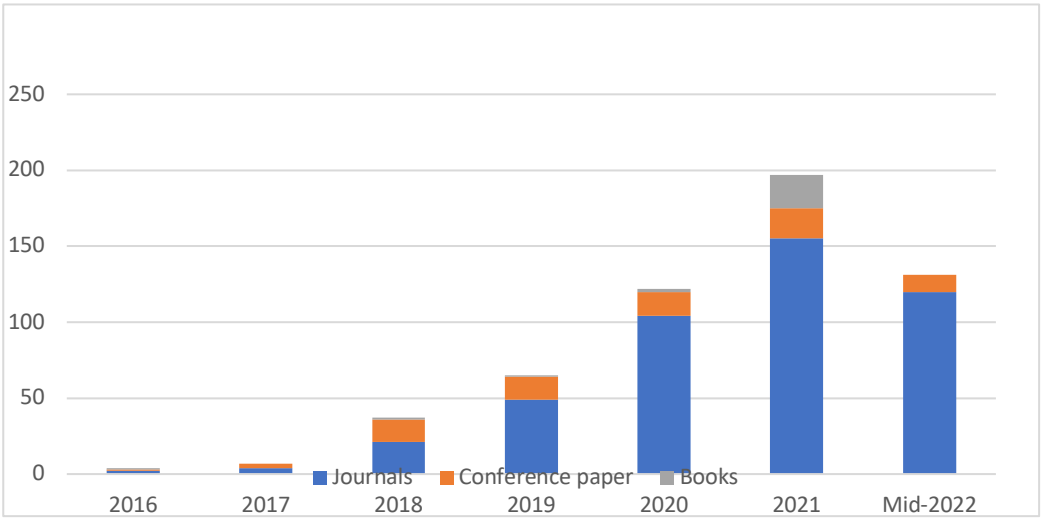

Fig. 3. Development of publications on Industry 4.0 in education context.

This indicates that the increasing number of publications related to industry 4.0 reflects the increasing awareness of the new technology advancement and job requirements in the industry. Moreover, due to the COVID-19 pandemic, the online platform has managed to support and sustain some economy activities which rise the attention towards the potential of Industry 4.0 and its technologies.

4.3. Publications outlets

In this study, most of the articles are from academic journals (83%), followed by conference paper (15%), e-books and books (2%). Journal from the "Sustainability" has the most publications of 13 journals. Secondly, Procedia Computer Science published 6 journals. While most of the conference publications are proceedings of the international conference on industrial engineering and operations management with 10 conference papers. This is because the conference focused on topics such as Internet of Things, Cyber-Physical systems, industrial digitalization, big data, and analytics. Yet, there is limited article that represents a framework that show how lifelong learning can be promoted through e-learning while play a role in improving knowledge and skills that meet industry 4.0 requirement.

4.4. Research gaps

Various articles explained the theories and concept of education 4.0 and industry 4.0. However, a few of articles discussed the relationship between education 4.0 and industry 4.0. most of industry 4.0 articles focus mainly on the concepts of industry 4.0 and education 4.0. Most of these articles discuss how Industry 4.0 improves manufacturing and continuous information exchange and interaction between humans and machines(Rojko, 2017). Due to industry 4.0 increased competitiveness through the use of smart machine, intelligent agents, and big data, most articles discussed the significant influences of industry 4.0 to the graduates with radical changes in the job requirements (Helmrich et al., 2019; Hirschi, 2018; Maisiri et al., 2019; Moldovan, 2019; Sallati et al., 2019; Starr-Glass, 2019; Whysall et al., 2019). However, most of these articles do not discuss the education 4.0 concept. Other articles on industry 4.0 focused on the technologies of industry 4.0 that can be used in education such as Internet of Things(Kazimirov, 2018; Sim and Choi, 2020; Wanyama, 2017), machine learning(Ciolacu, Tehrani, et al., 2017), intelligent agent (IA)(Bogoviz et al., 2019; Popenici and Kerr, 2017), and augment reality(Andrés et al., 2019; Mourtzis et al., 2019; Schuldt and Friedemann, 2017; Schuster et al., 2016). Furthermore, the contribution of these Industry 4.0 technologies towards education was discussed in some articles(Almeida and Simoes, 2019; Butler-Adam, 2018; Clavert, 2019; Shahroom and Hussin, 2018; Stankovski et al., 2019; Xing and Marwala, 2017). The use of IA, cloud computing, and machine learning leads to smart education(Assante et al., 2019; Zhu et al., 2016). Also, these technologies inspired the nine technological pillars higher education curriculum by Hernández-Muñoz et al. (2019).

Many articles on education 4.0 discussed on curriculum change(Ellahi et al., 2019; Jeganathan et al., 2018; Ramirez-Mendoza et al., 2018), training standard(Gerasimova et al., 2019), higher education policy(Vodenko et al., 2019), and innovative education(Harkins, 2008; Richert et al., 2015) in meeting industry 4.0 needs. Also, various articles on education discussed on technologies can be used in order to respond to industry 4.0 requirements. Technologies such as virtual reality(Barker and Gossman, 2013; Liagkou et al., 2019), intelligent robotics(Lanz et al., 2019; Sung et al., 2013; Verner et al., 2020), open-source tools(Dasgupta, 2020; Tosello et al., 2019), simulation games(Ab Rahman et al., 2019; Almeida and Simoes, 2019; Paravizo et al., 2018; Zarte and Pechmann, 2017), mobility(Huamani et al., 2019; Jaschke, 2014; Popov et al., 2019; Wilke and Magenheim, 2017), and digital technology(Grishina et al., 2019; Lambrechts and Sinha, 2018; Svoboda, 2020; Tirto et al., 2020) could enhance learning outcome. Some articles(Almeida and Simoes, 2019; Ciolacu, Svasta, et al., 2017; Golob and Bratina, 2019; Janssen et al., 2016; Miranda et al., 2019; Mourtzis et al., 2018; Prieto et al., 2019; Ramirez-Mendoza et al., 2018; Rodríguez et al., 2019) discuss the concept and technologies of industry 4.0 and education 4.0. This shows that there is a clear relationship between these two concepts.

There is a lack of articles on both education 4.0 and industry 4.0 that focus on lifelong learning and e-learning. Since the e-learning emerging technologies includes Intelligence Agent, Virtual Reality, Augmented reality, big data, and machine learning, cloud computing, and social network (Arshad and Saeed, 2015; Baskaran, 2018; Ashkay, 2019;), there is a gap identified during the analysis. There is no or limited number of publications that considered e-learning as a platform that supports industry 4.0 technologies that are also part of the e-learning emerging technologies. The use of e-learning emerging technologies could deliver assist education institutions to deliver education 4.0. Furthermore, e-learning could provide an open and lifetime access to promote equal learning opportunity to all toward education 4.0, Industry 4.0, and future industrial revolution. This indicate that e-learning has the potential to create future ready learners that will be remarkable in the future. Trevelyn (2019) indicates how changes of curriculum in meeting industry 4.0 requirements could achieve sustainable development goals through lifelong learning. While Jaschke (2014) suggested that the integration of mobile learning in education could promote lifelong learning. Together with e-learning as a learning platform, individual able to learn continuously to improve their skills and knowledge to meet their job requirements. Digital education(Makarova et al., 2018) and Web-based learning(Sommer et al., 2016) could be the new

purpose of e-learning.

5. Proposed education-industry 4.0 framework

The challenges in industry 4.0, education 4.0, and lifelong learning motivate this research, which aims to develop a new education-industry 4.0 framework, see Fig 5. Based on a comprehensive literature review, several criteria have been considered in developing the framework. The components of the proposed education-industry 4.0 framework are based on the literature review. The framework includes two key elements that are technology and skills development. In addition to these, e-learning concept was added to ensure that the education-industry 4.0 framework will promote lifelong learning.

The review identifies various technologies of education and industry 4.0 that are used to assist the development of education 4.0. The technology consists of Internet of Things (IoT), machine learning, intelligent agents, big data, robotics, virtual reality, mobility, and cloud computing. IoT could support communication, group analysis, and simulation activities (Kazimirov, 2018). The proposed education-industry 4.0 framework acknowledges the role of technologies of industry 4.0 and education to achieve education 4.0. Education 4.0 technologies such as virtual environment, intelligent robotics, gamification, mobile learning, and digital learning intend to improve the learning process. Since e-learning can deliver virtual learning environment, gamification, mobility, and digital learning, e-learning could be the best platform for education 4.0.

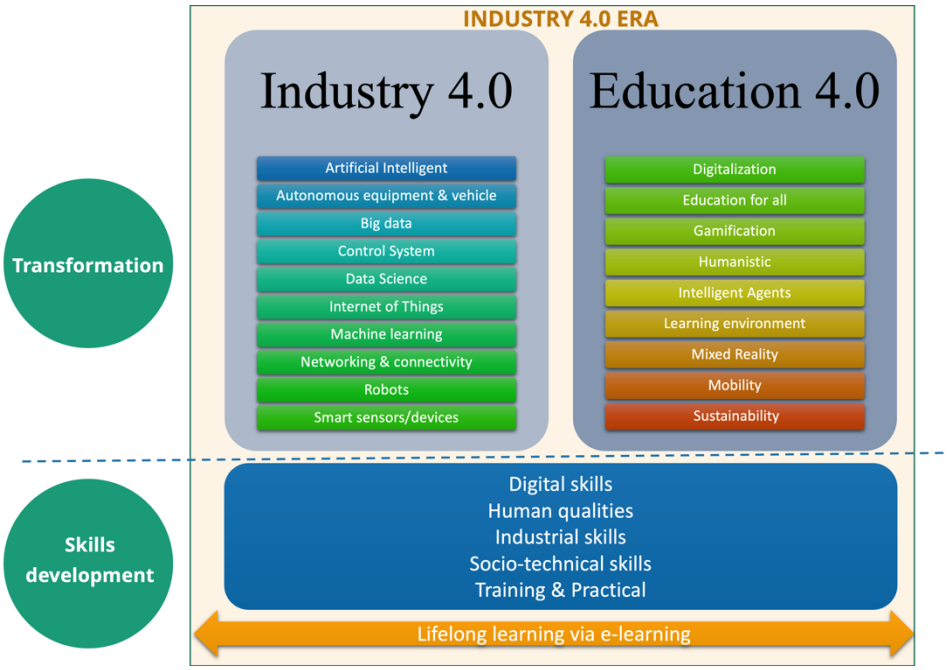

Fig. 5. Proposed Education-Industry 4.0 Framework

It is found from the literature review that Industry 4.0 has significantly impacted the job requirements. Based on a comprehensive literature review, learning organizations need to focus on the curriculum, pedagogy, training standard, and soft skills development. Learning organization needs to consider on redesigning the

curriculum(Ellahi et al., 2019) and pedagogy(Haseeb, 2018) to meet the industry 4.0 demand. Personalize learning ecosystem should be developed to allow learners to design their own educational pathways based on personal goals(Bartolomé et al., 2018). In order to embrace the new era of economy, graduates should have skills such as critical thinking, ICT literacy, technical skills, communication skills, multidisciplinary knowledge, learnability, problem-solving skills, and leadership skills(Monash University, 2018).

E-learning as a communication platform between education and the industry. The learning organization needs to cooperate with the industry to identify and meet industry needs(Fonina et al., 2019). While the industry needs to communicate with the learning organization to address the required knowledge and skills that they expected from graduates. In addition, individual able to continuously learn to improve their knowledge and skill, hence, implementing lifelong learning. As technology constantly changes, the pattern of industry 4.0 and education 4.0 will also change. Thus, this framework is adaptable to future elements in later industry evolutions.

6. Conclusion

The literature review of this research focused on studies that support education 4.0 and industry 4.0 through e-learning while promoting lifelong learning. This framework promotes collaboration between learning organizations and the industry to ensure a high number of qualified graduates for the present and future industry. Most of the articles focus on education 4.0 and industry 4.0 rather than how e-learning can play a role in enhancing collaboration between the learning organizations and the industries while promoting lifelong learning among society. Due to the lack of research has been conducted on lifelong learning and e-learning in education 4.0, this limits the literature available for this study. Nevertheless, most of the articles ignite some insight to close this research gap, which is e-learning and lifelong learning. The proposed framework was developed, which consist of necessary technologies and skills required in both education 4.0 and industry 4.0. The proposed framework intends to assist the learning organization to meet the students' needs in becoming qualified in future job. The role of e-learning as a platform for an individual to continuously learn new knowledge and skills is crucial in meeting the present and future industry expectations.

This research is aimed to discover the current state of research on the topic of industry 4.0 and education 4.0 by performing systematic literature. A total of 183 articles were analyzed for this research purpose. As a result, missing components were identified. An effective solution to bridge the gap between the traditional education model and new employment pattern is the education 4.0 concept. Furthermore, e-learning could act as a learning platform to deliver education 4.0 while promoting lifelong learning. Thus, the developed framework aims to support education 4.0 and industry 4.0 by identifying the necessary technology and skills required for a graduate to meet the industry needs, see Fig 4.

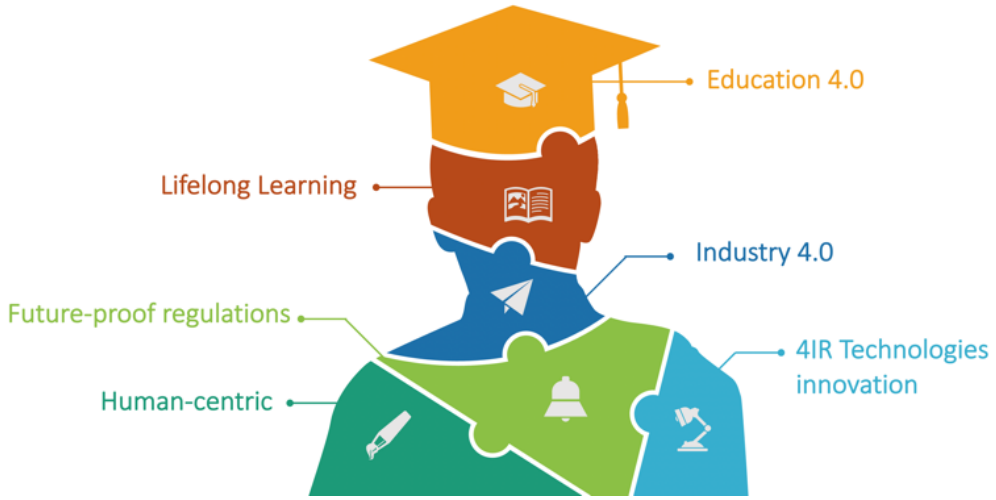

Fig. 4. Graduates attributes for education 4.0 and industry 4.0

The use of e-learning as a communication and educational platform. Since the collaboration between learning organizations and the industries is important, e-learning could play an important role as a communication platform. The relationship between education 4.0 and industry 4.0 is essential to boost students' knowledge and skills that are relevant to industry 4.0 needs. Learning organization should focus on prepare learners to function in the Fourth Industrial Revolution rather than focuses on the number of graduates produced. Since industry 4.0 has changed the pattern of job skills and employment, learning organization needs to provide courses that meet the industry needs. The learning organization should embrace the new education 4.0 to meet the requirements of industry 4.0. The learning organization, students, and industries should understand the principles and components of industry 4.0 to actively participate in the industrial revolution. The framework outlined the high-demand skills for industry 4.0 for the learners to actively learn. Additionally, the framework serves as an overview of the relationship between the industry, learning organization, and future employee to potentially unlocking new capabilities that meet future needs. The learning organizations need to adapt and change the course elements based on industry 4.0 to guarantee a sustainable learning.

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