Understanding knowledge management and upskilling in Fourth Industrial Revolution: transformational shift and SECI model

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Abstract

Purpose – The adoption of knowledge management (KM) to steer new skills and capabilities among people provides evidence that KM not only offers competitive advantages but also provides a means for organisational survival, by improvising core capabilities or generate new ones that can drive people in the Fourth Industrial Revolution (4IR) era. This paperaim to identify critical new skills and capabilities among people within an organisation to stay competitive, innovative and relevant.

Design/methodology/approach – The paper presents the findings on new skills assessment for Fourth Industrial Revolution. The study was carried out through an interview with a focus group discussion technique to gather data on the role of KM in creating new set of skills or capabilities in Fourth Industrial Revolution's landscape. The study also reports a bibliographic study of critical skills based on more than a decade of related academic and industry publications to portray research trends and future directions.

Findings – There is a demand in "must-have" skills related to Industry 4.0 such as capability for complex decision-making, complex problem-solving, collaborative innovation, project management, creativity and critical thinking, social skill and social responsibility. While these skills are critical enablers to aiding individuals in the scenarios of plausible 4IR futures, several important new research trends that emerge have also not been adequately explored including KM and Industry 4.0 skill gap, skill evolution, machine knowledge, intuitive decision-making, rational decision-making, technostress, digital fluency, collaborative innovation, industrial policies, human–machine interaction and societal systems.

Research limitations/implications – This research provides a roadmap for the next research trends and topics in the area of Fourth Industrial Revolution and new skills requirements. The study discusses some of the essential issues and challenges with upskilling required for Industry 4.0. It also focuses on how upskilling learning initiatives influence new knowledge creation. This primarily contributes to the educational field in deciding how and when to adopt appropriate strategies and identify which initiatives to best meet the needs of its community.

Practical implications – KM enables individuals to utilise their existing core capabilities or generate new ones for immediate investment in upskilling to meet current and future skills needs required by an organisation. Simply put, KM will improve the organisation's talent-driven learning strategy and increase individuals' ability to learn faster and attain sustainable competitive advantage in a fast-paced ever changing environment.

Originality/value – This paper is useful to academics, practitioners and policymakers in the fields of KM. The research provides initial insight into new skills mapping in the context of Fourth Industrial Revolution and the needs for researchers to understand the recent research trends in KM.

Keywords Skills, Knowledge creation, Knowledge management, SECI, Fourth Industrial Revolution, KM research trends

Paper type Research paper

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Introduction

It is more apparent now than ever that global issues such as the COVID-19 crisis require global solutions and that digitalisation of all activities and remote operations and digital readiness need to be part of this. Digital readiness refers to innovative workplaces with digital-ready workforce, and the emergence of Fourth Industrial Revolution (4IR) that is driven by the rapid technological advancements and has somewhat disrupted the existing environment for various industries. Fourth Industrial Revolution, or commonly known as IR 4.0 or Industry 4.0, is a term often used to refer to the developmental process in the management of manufacturing and chain production. Industry 4.0 offers speed of innovation to enable the rapid deployment of digital technologies, shorten product life cycles, expand business through developing new products and services and improve product development processes (Anshari and Almunawar, 2021).

Innovation has become the essential component of an organisation to improve performance and solve problems especially under the uncertain conditions of the real world by noticing relevant problem features in existing knowledge (McAdam, 2000). The process of innovation is heavily reliant on knowledge management (KM). KM is a process toward creating and using knowledge in an organisation (Rosenthal-Sabroux and Grundstein, 2008), to foster innovation, develop new skills and capabilities and create a positive work environment (Temel *et al.*, 2021a). López-Nicolás and Meroño-Cerdán (2011) highlighted that the creation of new and valuable knowledge can be converted into products, services and processes by transforming general knowledge into specific knowledge. The ability to capitalise on gains resulting from the use of competitive advantage through the fourth industrial revolution technology can further stimulate the organisational interest in KM (Darroch, 2005).

KM has several values in the innovation process. According to du Plessis (2007), KM helps to develop platforms and processes to share tacit knowledge. It helps in conversion process from tacit to explicit knowledge and facilitating collaborative work to spark innovation in the workplace. It allows knowledge to flow freely in the organisation to increase information accessibility in the innovation process (Temel *et al.*, 2021b). KM also provides high level, specialist assistance in targeted areas such as identifying the knowledge and skills gaps to build competencies for developing human resource professionals and establishing a knowledge-driven culture to facilitate the innovation framework or process for success.

The focus of this research is to fill a gap in knowledge concerning skills identification trends in the context of Industry 4.0 so that organisations can adapt their KM strategies. Academics, practitioners and policymakers engaged in KM will benefit from this research. The research presents exploratory insight on skill mapping in the context of the Fourth Industrial Revolution, as well as the necessity for researchers to be aware of current KM research trends. To sustain KM practices in the long run, a comprehensive understanding on a set of new skills and capabilities is of the utmost importance. It is a determining factor as to how an organisation responds to disruptive innovation technologies of 4IR.

Hence, this study provides an overview of KM, an exciting and high impact field, highlighting new research trends relating to upskilling and KM in the context of 4IR comprising skills evolution, applications and emerging research opportunities. The study deployed a focus group discussion (FGD) and secondary sources of data through bibliometric study of critical skills publications conducted by past researchers and literature based on topics pertinent to the evolution of skills and 4IR. Finally, this study provides directions for future research in the field of KM in the era of Industry 4.0.

Literature review

This section identifies three themes relevant to the study: Fourth Industrial Revolution, KM and the relation between KM and Fourth Industrial Revolution. Reviews on each theme is presented as follows.

Fourth Industrial Revolution

Built upon the existing foundation of the Third Industrial Revolution, Industry 4.0 has revolutionised the current global landscape (Anshari, 2020). Vertical integration of smart production systems and horizontal integration of global value chain networks are all part of Industry 4.0, as is through-engineering across the entire value chain and manufacturing acceleration (Gilchrist, 2016). It is thus recognised for its exponential growth of technological advancements and breakthroughs that shifts existing systems and operations to redefine the physical, digital and biological boundaries (Schwab, 2016), which ultimately altering existing business conduct and practices. With the rise of efficiency resulting from Industry 4.0, Rüßmann *et al.* (2015) identifies nine technological trends that function as the building blocks that drives Industry 4.0, namely, autonomous robots, simulation, horizontal and vertical system integration, Internet of Things (IoT), Cybersecurity, Cloud Computing, Additive Manufacturing, Augmented Reality and Big Data and Analytics. Throughout history, mankind has gone through four industrial revolutions in which the first one occurred in the late 1700 s where production was mechanised through the use of water and steam. The Second Industrial Revolution happened in the late 1800 s in which mass production was facilitated by electricity. The Third Industrial Revolution came about in 1969 where information technology and electronics served to automate production. Finally, the Fourth Industrial Revolution (also known as Industry 4.0) brought upon a much more sophisticated and advanced new technology beyond those of which exist during the Third Industrial Revolution and has blurred the lines between digital, physical and biological fields.

Due to the rapid technological advancements, there has not been any official record that marked the start of Industry 4.0. Technologies of Industry 4.0 (also known as disruptive technologies) include the IoTs, bio and nanotechnology, artificial intelligence (AI), autonomous vehicles, robotics, quantum computing, 3D printing, energy storage and material science (Diwan, 2017; Anshari, 2020). Many of these Industry 4.0 key technologies have been ill-defined by previous researchers, which raises the importance to enumerate the required skills of industry 4.0 (Bongomin *et al.*, 2020). Knowledge and skills constraints are a key challenge for the implementation of the Industry 4.0, and this questions or reflects the ability of an organisation to efficiently manage their knowledge as well as collect new knowledge so-called KM.

Knowledge management

KM can be described as a vital component for all organisations to achieve sustainability and maintain a long-term strategic competitive advantage. The idea of establishing KM in an organisation is to assist employees in using the resources and information available effectively to complete tasks more efficiently. KM is a strategic move for putting the right information to the right people at the right time and assisting people in sharing and using the information into actions that can improve organisational performance. Rosenthal-Sabroux and Grundstein (2008) defined KM as a process towards creating and using knowledge in an organisation. There are also various definitions of KM in the literature that have different applications in different fields. Girard and Girard (2015) provides a comprehensive definition whereby they define KM as process and technologies used in

knowledge creation, dissemination and utilisation within an organisation. KM allows individual employees and managers to create, share, capture and retain knowledge from within and outside of the organisation, and thus creates opportunities for all individuals in the organisation to innovate (Temel and Durst, 2020).

The roles and benefits of KM can be summarised in three points. KM as an aid to making well-informed decisions, a catalyst for innovation and a driver of organisational performance. Firstly, knowledge is an integral part of a company's strategy because it helps the management to make the right decisions that breed the best results. With knowledge, a company is able to extract data to understand the problem better and decide on a solution that aids in the increase of the company's profitability.

Secondly, KM improves the efficiency of expertise and promotes innovation. KM encourages open innovation through gathering, sharing and storing of internal and external data, information and knowledge as well as collaboration of talented individuals. Talent management maximizes the potential of individual employees and underpins education to maintain or stretch performance. It also turns employees into competitive advantage (Grimsdottir and Edvardsson, 2018; Rahimi *et al.*, 2017). Innovation is crucial for companies to gain competitive advantage and increase profitability. Therefore, a company that effectively manages knowledge can build on existing ones, which may in turn inspire new branches in knowledge and produce outcomes better than competitors. As knowledge is imprinted in people's minds, it therefore should be shared to help an organisation build new routines and mental processes to change or perform the tasks more efficiently (Al-Husseini *et al.*, 2015). It is only when knowledge-sharing is encouraged, the synthesis of old and new ideas can avoid or reduce the "me-too" syndrome. "Me-too" syndrome is one of the most disturbing trends among innovative thinkers and it occurs when businesses copy or agree with each other which in turn will hinder them to grow in an oversaturated market (Byukusenge and Munene, 2017).

Thirdly, when companies have a healthy management of knowledge acquisition, knowledge sharing and knowledge storage, their organisational performance increases as they are intrinsically linked. Every company consists of teams of employees, and each team is assigned with specific tasks in order to achieve optimal outcome. The teams need to work together and are expected to be well-versed in the necessary work skills. To facilitate growth, knowledge sharing is vital since the teams are able to learn from each other and grow together, ensuring a smooth workflow and meeting the goals of the company. Therefore, when knowledge is shared, employees not only become innovative but also efficient problem-solvers, thereby ultimately guaranteeing organisational performance.

Manfredi Latilla *et al.* (2019) found that knowledge sharing among small and medium enterprise (SME)communities has shown great potential in improving their business performances and achieving goals. In the arts and creative industry, knowledge can be systemized and transferred to become a source of competitive advantage. Specialised craftsmen are expected to create specific or unique items. Hence, there is a need to have a constant flow of knowledge transfer from the current generation to the next generation of skilled craftsmen (Manfredi Latilla *et al.*, 2019). Manfredi Latilla *et al.* (2019) further described for organisations that put greater emphasis on KM, their brand's high value would generally derive from specific intimate, human qualities of personal handicrafts that are not found in automated or delocalised production processes of other similarly priced brands. In the craft industry, different organisations have different ways of practising knowledge transfer. Some prefer to teach others directly. Some assign tutors (who are often retired craftsmen) for newer generation of craftsmen to seek guidance and input from them, and some prefer to document by filming and afterward archiving the method for future

viewing by generations across time and place. Knowledge transfer is even more essential because handmade products require a personal "trademark" that differentiates them from mass-produced and automated brands.

The reasons for KM at organisational level include but may not be limited to globalisation, the growth of leaner organisations and competitive advantage (Dalkir, 2005; Akhavan *et al.*, 2014). According to Kör and Maden (2013), knowledge is both an intellectual asset and a beneficial tool for organisations to compete in today's ever-increasing market competition (Carneiro, 2000; Alavi and Leidner, 2001), whereas KM practices are directly related to organisational performance, which affects financial performance (Zack *et al.*, 2009). For this reason, there is a growing number of organisations undertaking KM initiatives and investing in them (Choi and Jong, 2010).

KM has offered a lot of benefits for individual employees, business communities and industries. This includes the effectiveness in gaining or retrieving and recreating information and in providing better services to employees and customers due to the standardised processes and enhanced decision-making, thus reducing the chances of making errors in the organisation. All new knowledge generally comes from people as they have the information and ability to utilise them based on their experience, expertise and judgment (Gottschalk, 2007). Dave and Koskela (2009) believe that by leveraging past knowledge and experiences, the capability and productivity of a company can be improved significantly. In the study of Yap and Lock (2017) on Malaysian-based construction SMEs, they view the KM practices as pertinent and fundamental because if one is lacking in them, the effects can be detrimental and may cause delays in project delivery.

In the construction industry, time is seen as valuable, hence improved efficiency, delivery reduction time and decision-making are considered highly significant. Yap and Lock (2017) further suggested that knowledge should be effectively exploited to achieve growth sustainability and stay ahead of the competition. Dalkir (2005) echoes a similar sentiment for one to fully utilise the organisation's knowledge base, paired with "the potential of individual skills, competencies, thoughts, innovations, and ideas (pp. 79–80)", as this will allow a company to compete more effectively in the future.

Tacit vs explicit

As the studies on KM become more prominent in today's world, various definitions of KM have emerged from a multidisciplinary field of study. Dalkir (2005) identified, two forms of knowledge: tacit and explicit. Tacit knowledge is an individual knowledge that exists in a person's mind (Duffy, 2000). It is difficult to teach this tacit knowledge to another person due to its difficulty in articulation. For example, tacit knowledge can be a specific way a person has learned to operate a machine. This is difficult to explain on words as another person has to learn the process him/herself. Tacit knowledge can be experience or job based. This knowledge is used by organization members to perform their daily tasks. However, there is a process where it can be externalized and turned into explicit. For example, in Japanese companies, there is a four-step process for this. Workers sit in a group and through shared experiences they bring tacit knowledge to people through metaphors and analogies which is easier to understand for others. Then, it becomes explicit and internalized by other group members. This tactic is used to help share knowledge in Japanese companies (Haghirian, 2010).

Furthermore, Polanyi (1958) defined tacit knowledge as the "know-how, know-why and know-what" that resides within an individual, while explicit knowledge is already presented in a tangible form which enables one to teach or train. While the latter can be easily

captured, the former is the opposite, and this can only be properly articulated by someone who has a better understanding of certain things. KM also has a three-stage cycle:

(1) knowledge capture and/or creation;

(2) knowledge sharing and dissemination; and

(3) knowledge acquisition and application (Dalkir, 2005).

All these are captured by the socialisation, externalisation, combination and internalisation (SECI) model.

The SECI model proposes a workflow by which organisations spiral their knowledge within and outside their organisations, with the goal of optimising and creating value to the knowledge that already exists in the organisation. SECI model was introduced by Nonaka and Takeuchi in 1996 as a cornerstone of knowledge creation and transfer theory in KM. The model is highly linked with culture. SECI model was used in the study to describe knowledge creation and present the challenges of new upskilling development opportunities with some recommendations. The model emphasizes on knowledge sharing and proposes four quadrants of knowledge transfer, which derive from tacit and explicit knowledge that can be shared, combined, created and converted in the organisation. There are *socialisation, externalisation, combination* and *internalisation* (shown in Figure 1).

According to Nonaka *et al.* (1996), *socialisation* involves knowledge in a face-to-face interaction. E*xternalisation* happens when tacit knowledge is converted to implicit knowledge. Tacit knowledge is "what people carry in their minds and are difficult to access", while explicit knowledge is "what is documented and codified", and therefore, easily transferred. C*ombination* involves tacit knowledge transferred into explicit knowledge, while internalisation is converted from explicit to tacit (Faith and Seeam, 2018). Overall, the SECI model explains how knowledge sharing can be relayed to knowledge transfer and hence, developing know-how skills.

Despite the benefits of KM, having to implement them can be quite complex, as it requires well-thought-out strategies and appropriate tools and processes for use. The implementation of KM requires a step-by-step process where an organisation must begin with an understanding of their strategy and vision and how KM can contribute to their achievements (Pasher and Ronen (2011). However, this does come with a price. There are issues of records and information overload affecting searching and finding the most relevant

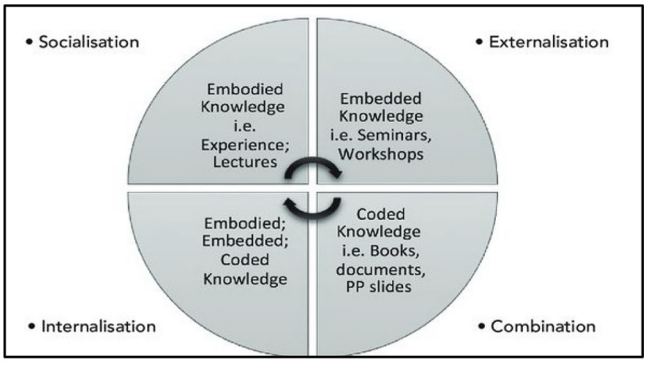


Figure 1.
Knowledge Quadrants Using the SECI Model

Source: Faith and Seeam (2018)

information in a timely and easy manner, the inability to explain why certain decisions are agreed upon and why things are done the way they are, the loss of intellectual assets due to employee turnover or retirement and issues with knowledge presentation, communication and maintenance. Dalkir (2005) suggests that one way to retain valuable knowledge (i.e. tacit knowledge) is to identify intellectual assets and ensure that legacy materials are produced and stored for future reference. Additionally, holding educational programmes and seminars may also be beneficial for the employees to share and develop their knowledge (Akhavan *et al.*, 2014).

Yap and Lock (2017) have also identified three critical challenges to KM practices which can hamper down the KM initiatives, stemming from organisational, cultural and people issues. The issues include lack of motivation that affects knowledge sharing behaviour, rigid organisational practices such as bureaucracy and hierarchy where one relies too much on a particular manager to circulate the knowledge and lastly, lack of trust that arises from a tightly controlled culture. To reduce these barriers, Akhavan *et al.* (2014) propose an organisation to consider revising the hierarchical structure and expanding the communication system to speed up the process of knowledge transfer. Not to mention, the cooperation of team members is also crucial in ensuring the effectiveness and productivity of an organisation, thus creating a culture of trust and sense of belonging that may be able to increase the ability to execute KM activities.

Knowledge management and Industry 4.0

Given how Industry 4.0 had transformed the world through its advanced technologies, it has brought upon changes to major industries, including the way how jobs and education are performed and prepared for example transforming the nature of manually performed jobs by replacing it with machine-handled tasks. Zhao *et al.* (2012) asserted that "the one who owns the latest knowledge, acquires more knowledge, creates the updated knowledge, and produces the use-value containing more knowledge will be able to achieve a superior position in the future position (p. 1)". Thus, the education system must prepare its current students with the necessary and relevant skills and knowledge to produce a workforce that are inherently capable and competent to work in the present technologically driven era. This prompted a revolution in education which has transformed the KM process towards personalised and peer-supported learning and the creation of a continuous learning culture in the workplace. The learning process involves the alignment of both technology and humans which enable new opportunities and possibilities (Fisk, 2017). Moreover, it enables efficiencies through the deployment of AI, future open-source content, digital technologies and personalised data, as well as the creation of blueprints for future learning processes from initial school-based learning to workplace learning.

Do businesses automatically fail due to the absence of KM? To survive and succeed in 4IR's era, an organisation needs to innovate. Whether it is product innovation, market innovation, business model innovation or other types of innovation, as long as they are able to captivate customers and distinguish themselves amongst the numerous organisations in this fast-changing world. For example, Kodak was a highly successful company. However, the company ultimately failed as they did not innovate and focussed solely on selling film cameras. After the emergence of digital cameras, companies such as Nikon and Sony were thriving, while Kodak moment had gone disappearing from the market. Kodak's management made a wrong decision for refusing to follow the trends at the time when customers were increasingly attracted to digital cameras, its features and capabilities in comparison to film cameras. Kodak that acquired good and strong reputation in the market for years and had a large customer base, might have been able to survive the transition from

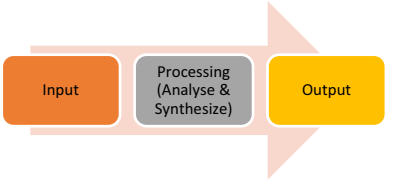
film to digital cameras production if only the company implemented KM including knowledge gathered from the market, competitors' technologies and customer feedback.

KM in the perspective of Industry 4.0's focusses on achieving strategic balance premised on three interlocking factors: people, process and technology. The perspective of *Human (people) factor* is central in KM process, as KM is based on human activities, interactions and interpretations on information. KM should be built in understanding perspective of soft and hard skills required in Industry 4.0's context. Knowledge audit is a critical task for KM department to assess the need for future skills. Future skills identification can speed up knowledge flow within the organisation by doing less trial and error. KM enables businesses to learn from their past successes and failures. It is preferable for an organisation to capitalise on existing knowledge assets by redeploying or upskilling in areas where the organisation stands to benefit (such as using knowledge from one department to improve or create a product in another) and modify knowledge from previous processes to create new solutions. KM also encourages long-term focus to develop the necessary competencies and skills, eliminate obsolete knowledge and strengthen company's ability to restore key knowledge and competencies from being lost or copied (Hajric, 2018). Dimitrova and Scarso (2017) discussed how BT, a world-leading provider of rail equipment and solutions, used crowdsourcing internally. BT believes that each employee is a "hidden innovator" who may have "hidden knowledge" and such knowledge can be accessed using crowdsourcing, regardless of employees' status within the company, expertise or physical location. While much of the information is from individual employees, crowdsourced input from around the world can also be used to make informed decisions for the organisation's strategy and raising overall unity.

Another important factor of KM is the process component (procedures/business processes). Business processes are ways that guide how work is conducted in an organisation. KM requires organisations to understand and map their future work processes of Industry 4.0 to demonstrate how tasks are performed and compile knowledge that is critically needed for completing the tasks as this will help to increase the efficiency and effectiveness of the organisation. The last factor is derivative technologies of Industry 4.0, which enables to translate and convert KM plan into action. Technology (*machine centric*) can facilitate interactions between people to share knowledge (Omotayo, 2015).

Methodology

The paper presents a framework for the Fourth Industrial Revolution called Upskilling. The framework is constructed using carefully selected theories and concepts from the literature on the Fourth Industrial Revolution, KM and skill development. This literature review enables validation of the original theory proposed, ensuring the study's validity and the results' reliability (Bauer *et al.*, 2005). The framework proposed in this research is the result of three stages of framework development, summarized in Figure 2 (Levy and Ellis, 2006).



Source: Levy and Ellis (2006)

Figure 2.
Three Stages of Framework Development

The inputs address challenges associated with finding relevant literature. This approach begins with the gathering of relevant literature, such as that on Industry 4.0, KM and skill development. Processing involves qualifying the literature (i.e. validating its quality, various quality levels of peer-reviewed work, etc.), as well as learning how to read research literature (i.e. cognitive/construct-level, literature streams, theories), and combining concepts from multiple areas. Data visualization from bibliometric analysis is presented to obtain an overview diverse information on in the field of KM and Industry 4.0. The connectivity is displayed in the form of a graph to demonstrate the correlations and patterns generated from previous research on this subject. The outputs stage of the process covers concerns connected to the actual writing of the literature review and description of the body of knowledge's impact, as well as the development of the suggested framework. To highlight how the framework is implemented in practice, a FGD on an important concept is used to identify potential theoretical foundations (Webster and Watson, 2002). FGD with 35 respondents was also conducted to gather data on the new skills and capacities among people in facing challenges of Industry 4.0. A focus group is an interview or interview with a moderator in which the number of respondents is homogeneous, unstructured and done in an unstructured manner (Byers and Wilcox, 1991). The goal of a focus group is to encourage participants to express their thoughts and ability to communicate with one another. Participants in the study were asked questions about their thoughts, opinions, beliefs and attitudes toward the types of talents and skills required to deal with Industry 4.0 and the role of KM in achieving these skills. When examining and testing the validity of research data, researchers use triangulation procedures. The term triangulation of sources refers to comparing the results of interviews with other sources of information (Putra and Sahla, 2018). This study analysed the collected data in the following steps:

- conduct FGD to gather data;
- make transcripts of all interviews and discussions from focus groups;
- data cleaning, which includes identifying data that is relevant to the topic and research problem;
- coding by categorisation that is grouping the data into categories. Each group is assigned with different colours;
- making synthesis is the process of determining the link between two categories; and
- finally, identify signs that arise and can be used as a guide when drawing conclusions.

Data gathered from the discussion along with the key findings from the literature analysis were then used to develop skills mapping for meeting demands of Industry 4.0.

Findings

KM is the process of accumulating, disseminating and effectively using knowledge (Davenport, 1996). It appears to be straightforward, but it is critical to the success of any organisation. Concerns about knowledge sharing continue to dominate organizations, and on top of that, today's organisations must immediately address the widening skills gap caused by new technology, which demands highly skilled training that new hires simply do not possess. Furthermore, a Deloitte analysis estimates that between 2018 and 2028, the skills gap will leave an estimated 2.4 million jobs unfilled, with a potential economic effect of $2.5tn (Accruent, 2020). This research is essential in determining the publication trends of peer-reviewed journals indexed on Scopus. Trends can be identified using the keywords

Industry 4.0 AND Knowledge Management AND Skills. In an effort to better understand the current state of skills and capabilities in the context 4IR, the relation between KM and skills, identifying the future sources of knowledge and a bibliometric study were analysed with reference to relevant literature, major scholars, disciplines and publications and key research topics. Data was gathered from a number of large-scale and well-known digital libraries, primarily the Scopus index database and Science Direct. The choice of these three keywords was intended to narrow down our search and analyses on publications of direct relevance to our interest. This kind of limitation is common in bibliometric studies. The collected data was exported as XML records and parsed into a relational database for analysis. The initial number of records retrieved was 169 papers, and after removing duplicates, the number of unique records totalled 72.

Figure 2 shows the overlay visualisation and growth trends of publications relating to the three search keywords. Overall, industrial research, automation, computer-aided instruction, complex adaptive management had the largest coverage and the longest history. This is consistent with the evolution of skill set and Industry 4.0 as the term appeared first in the early 2017 in the research publications. According to the findings of this bibliographic analysis, the combination of KM, skills and Industry 4.0 produces several notable skills, as shown in Figure 3. The analytics highlight some major soft skills set related to Industry 4.0 capability namely complex decision-making, complex problem solving, collaborative innovation, project management, creativity and critical thinking, social skill and social responsibility. This is critical for KM as a tool and as an organisational strategy for identifying the skills requirements of current and previous research findings in the context of Industry 4.0.

Furthermore, Figure 4 shows research density from KM bibliographic analysis. The strong color indicates that the research in KM has a high density and saturation, while low color density indicates that there are not many research yet conducted on these topics. In our collection, the publication rate on knowledge transfer, technology transfer, AI, industrial research, digital technologies and aging workface has increased in recent years. Overall, the topics extracted were highly relevant to new skills in facing 4IR, especially for its managerial and application values, although there was lack of description on most of the detailed technical terms, this could be attributed to the tendency of authors using broad terminologies in article titles and abstracts.

It is also observed that topics pertinent to KM, Industry 4.0 and skill are slow density research area and not yet heavily discussed for further exploration. Specifically, the topics

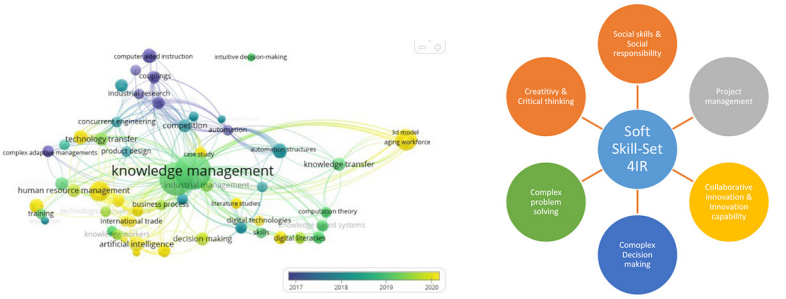


Figure 3.
Research Visualisation and Trends for KM, Industry 4.0 and Skill Set

Source: Authors' Compilation (2021)

Source: Authors' compilation (2021)

Figure 4.
Density Visualisation for KM and Industry 4.0 Research Trends

covering skill gap, skill evolution, machine knowledge, intuitive decision-making, rational decision-making, technostress, Management 3.0, digital fluency, collaborative innovation, industrial policies, human–machine interaction and societal systems (Figure 5).

While, from the FGD, the study reveals some important facts about KM strategies for organisation in preparing new skills and capabilities in response to Industry 4.0. First, a significant portion of academia raised concerns of how Industry 4.0 would cause a further amplification of unemployment among labour force to stay relevant. Second, the main driver behind the emergence of Industry 4.0 is the vast advancement of global technologies that

Source: Authors' compilation (2021)

Figure 5.
Research Trends for KM, Industry 4.0 and Skill

compliments the shift of modernisation towards Industry 4.0. These said technologies include cloud computing, big data, IoT, AI, Expert systems and Augmented Reality that would potentially cause a significant shift in the new knowledge creation. Third, advancement of technologies would create new business models that would result in managing new knowledge and the changing demand for skills and talents. Finally, organisation must adapt to KM and changes in the competencies required in Industry 4.0. Following are the arguments for underlying changes in knowledge requirements.

Knowledge management for routine and structured decision

Several respondents highlighted a job that can be done by robot, automation or machines are usually *routine tasks*, for examples factory/production workers and bookkeepers. These jobs are normally structured – specific, clear, expected to be done in certain order and at a certain time and do not require compassion (Workfront, 2020). Static knowledge, which deals with routine and automated operations, demands a low-complexity skill set and an automated or structured decision-making process, as displayed in Figure 6 (Cluster 1). It is a skill set that machine operations can easily replace. This includes telemarketing, bookkeeping clerks, receptionists, computer support specialists, market research analysts, proof readers and taxi drivers. For example, taxi drivers' routine is quite simple and straightforward where they only need to pick up a passenger and send to the desired location. Nonetheless, there has been several automated self-driving cars invented which can be a threat to the taxi industry. Also, clerks' tasks are now programmable and can be automated using software such as bookkeeping software. They do not require heavy decision making. The derivatives of 4IR technologies such as AI, robotics and expert systems further enable them to exercise skill set that commonly associated with routine and structured tasks, and these technologies can produce data for use by organisations effectively and efficiently and be accessed anytime. Jobs in this nature of task also require less human interaction and attention. Therefore, people in this job category require new skills and capabilities to stay relevant and competitive in facing 4IR. The role of KM is to

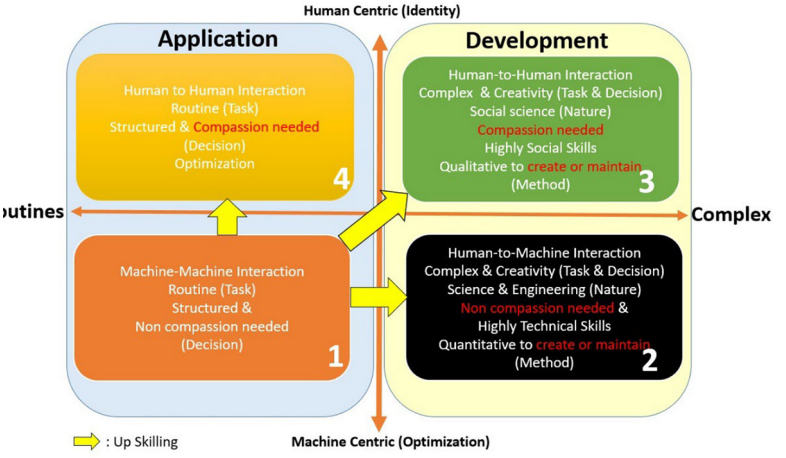


Figure 6.
New Upskilling Model for Industry 4.0

Source: Authors' compilation (2021)

ensure that knowledge transfer occurs from workers in this cluster to other clusters such as Clusters 2, 3 or 4 (Figure 6).

Knowledge management for routine decision and compassion

KM defines a continuous process of developing and sharing innovative ideas through social interactions, collaboration, education and practice. Information and data interchange are widely utilised to improve knowledge creation and problem-solving building blocks. Respondents identified there are jobs that involve making routine decisions but also require compassion, trust and empathy due to dealing with social activities such as tour guides, care takers, elderly companions, event organisers and social workers. They asserted that the jobs involve human-to-human interaction, highly require social skills as well as compassion and the combination of AI and compassion human skills for this kind of jobs. In general, these jobs are high in human interactions (human centric) but low in complexity. These jobs require individuals to apply their prior knowledge to perform tasks or jobs and exercise compassion in their interaction with others (human touch and social interactions). Cluster 5 in Figure 6 depicts the role of knowledge creation for this type of work.

Knowledge management for high creativity with technical skills

The new KM strategy for organisations is to ensure that the organisation is ready to transform skills with high creative and technical capabilities. Respondents in FGD identified jobs that do not only require or demand high creativity and technical skills but also involving interaction between humans and machines particularly in science and engineering fields. As stated by respondents, this is where humans need machines to get the job done for a task that is high in complexity and requires creativity and specificity from a human's decision (Cluster 2 in Figure 6). Jobs that fall into this cluster include scientists, engineers and pilots. They require machines to help them perform and still need to make complex decisions in order to get the job or task done. Automated decision-making is very highly and unlikely practiced because it is risky and could harm other people, for example, the job of drone operator. In the military industry, the use of drones has been widely implemented by countries to combat terrorism. Its usage minimizes the number of soldiers going to the war zone and reduces the number of deaths during a war. Drone can be seen as a means of weapon to attack enemies precisely and effectively. However, should the drone be automated by an AI, there is still an operator behind it to prevent unnecessary attacks on civilians. Drones can also be seen as a means of commercial video where individuals use KM process to leverage existing core capabilities or generate new ones in order to invest in fast-growing products, services and solutions required by the market (Pasher and Ronen, 2011). Simply said, good KM will transform any businesses into a fast-learning, competitive advantage-oriented organisation.

Knowledge management for complex decision but compassion

KM plays a major role in managing human assets in the organisation simply because there are tasks that demand complex decision making but also require compassion, empathy, trust, leadership and social skills in social interactivity. It represents jobs that involve human-to-human interaction, with tasks that are typically complex and require humans to determine and complete tasks from beginning to end. Jobs included in this cluster (Cluster 3 in Figure 6) are generally related to professions in social science such as psychologists, educators, managers and social scientist. General Managers, politicians, commanders, economists and diplomats who are regarded as strategic decision makers also fall under this cluster. They are least likely to be replaced by machines or robots as they require high social

skills, creativity, complex-problem solving and human skills. Also, these skills cannot be programmed into machines or robots (Anshari *et al.*, 2021; Görmüş, 2019; Hussin, 2018; Kergroach, 2017). Respondents viewed that tasks performed in such jobs are not just complex but individuals are expected to make complex decisions and apply their social skills where compassion is needed. Complex decision making does not involve repetitive tasks and the tasks are changing daily, and thus it requires the use of technologies merely as a support system in in the process of accomplishing the jobs or tasks.

Discussion

This section discusses the results of the study derived from the bibliographic analysis and FGD. The findings provide opportunities not only for the research community in understanding the new skills set for 4IR, but also KM research direction especially for educational development programmes in the context of knowledge creation and dissemination. While there is an increasing demand for individuals' social skills, with deep knowledge and soft skills needed to solve complex people's problems, there is a clear shortage of some skills with technical and complex decision making capabilities. The discussion is divided into three parts: new upskilling model for Industry 4.0, understanding KM using SECI model and the significance of knowledge creation and transfer.

New upskilling model for Industry 4.0

With reference to Figure 5, the aforementioned framework could be utilised by organisations in developing strategies to cope with and meet new skill sets that are in demand in Industry 4.0. The framework classifies four different job clusters, and each cluster is represented with different types of jobs and skill requirements. It exhibits types of jobs that can be automated and replaced by machines and that will not be able to be replaced and automated using machines or robots. The x-axis determines the nature or character of jobs from 'routine' to 'complex'. The y-axis demonstrates whether the jobs or skills are centred towards machines or humans. On the y-axis, human centric means a job that requires identity while machine centric means a job that requires optimisation. Clusters 1 and 4 are "application" type of jobs towards routine tasks, and Clusters 2 and 3 are "development" type of jobs towards complex tasks. Generally, the left part of the matrix in the framework characterizes routine jobs. The right part of the matrix characterizes jobs that require complex skills and creativity skills. The upper part of the matrix characterizes human-centric jobs that mostly involves human to human interaction and requires compassion, and lastly, the lower part of the matrix characterizes machine centric jobs that heavily rely on machines and hence does not require compassion.

Based on the framework, four further essential qualities of skills or jobs can be distinguished:

(1) machine to machine interaction;

(2) human to machine interaction;

(3) complex human to human interaction; and

(4) routine human to human interaction.

Explanation on each of these quality dimension is entailed. First is machine to machine interaction dimension. This refers to the nature of skills that require structured decision making and routines tasks, but no compassion. An example of such tasks is the assembly line involved in lean industrial manufacturing processes. Given that these tasks do not require expert skills, they can easily be replaced with machines, robots, or technologies by performing repetitive, dull and simple tasks simultaneously to help organisations increasing

their production consistency, speed and save operating costs. Considering intensive human labours are highly affected by Industry 4.0, this dimension proposes upskilling and creation of new knowledge for the people to undergo translation shift into Clusters 2, 3 or 4.

Second dimension is human to machine interaction. This is concerned with tasks that require creativity and involves complexity. Such tasks do not require compassion but highly technical, complex problem solving and quantitative-oriented skills. In this dimension, technical and engineering knowledge are advanced to fulfil the needs for tasks in Cluster 1. Any problems or improvements and people required in Clusters 1 and 2, respectively, can be considered as human-to-machine interaction.

Third dimension is the complex human-to-human interaction dimension. Other than requiring compassion and complex decision making to accomplish the jobs, tasks in such jobs are impossible for machines and technology to carry out. For example, general managers, social scientists, psychologists and educators largely deal with human interaction and organisational conflict whereby reasoning and non-cognitive skills can be of help to mitigate risk through conflict management. Jobs that are complex and require creativity, compassion, decision-making skills and innovation, including those that are related to the two aforementioned dimensions nonetheless, would still need to be performed by humans throughout the fourth industrial revolution (Anshari, 2020).

Finally, the routine human to human interaction dimension. This is primarily related to jobs or tasks that require high degree of compassionate engagement and action as they are dealing with fellow human beings. Jobs that exist in this dimension are caretakers, social workers, tourist guides and event organisers. These jobs are generally high in human interactions (human centric) and low in terms of complexity, and individuals are expected to apply their prior knowledge to execute the jobs or tasks in a proper and successful way.

Socialisation, externalisation, combination and internalisation model and new upskilling in Industry 4.0

On the skills mapping, this was then analysed with reference to KM strategies for possible knowledge transfer and sharing by using SECI model. SECI model has become the cornerstone of KM's theory, especially in the context of Organisation Learning (OL), and this study uses the model to examine topic on OL. The theory, concept and findings in the study present the basis for understanding the phenomenon, and constructing a proposed model followed by several recommendations.

When applying SECI model for understanding KM, Figure 5 can be interpreted as to which job clusters are susceptible for replacement and each job cluster can be ranked from most to least susceptible for replacement. Cluster 1 is the most susceptible for replacement in comparison with other clusters. This is because 4IR is related with the advancement of technologies and the jobs require interaction between machines, and only involve the *combination* quadrant of SECI model that has already been codified. Cluster 2 involves interaction with machine whereby the *externalisation* quadrant of knowledge transfer can easily be codified to a machine/instrument or a technological innovation. In addition, jobs in Cluster 2 are the ones that most familiar with the digital world. This is due to the nature of the jobs which largely related to science and engineering and requires high technical skills. Using the SECI model, jobs in Cluster 2 are mostly likely in need of combination, externalisation and internalisation of knowledge creation and transfer for individuals to perform the jobs or tasks effectively and efficiently. Cluster 3 which does not involve interaction with machines and is solely human to human interaction, would require complex interaction of *socialisation* quadrant to create new knowledge. Jobs in this cluster will be hard to replace with technologies although it is possible. Finally, although jobs in Cluster 4

do not involve complex interactions, they perform routine tasks and require compassion that involves knowledge *internalisation* quadrant. Similar to Cluster 3, jobs in Cluster 4 will also be difficult to replace with technologies of 4IR. Nevertheless, individuals who are skilled in human to human interactions such as those in Cluster 4 are often acquainted with the IoT such as developing user-friendly apps in smartphones and creating digital platforms that benefit a lot of people.

The utilisation of technologies and smartphones (not only as a communication device but also as a payment provider) encourages organisations to develop new businesses and create job opportunities. Inevitably, with such a competitive tech hiring landscape for the best tech talent, today's employees must therefore be capable and comfortable to navigate their work in the digital world successfully.

Knowledge management and organisation learning

The relationship between KM and OL can be seen in a variety of ways. While, Industry 4.0 focuses on smart technology, AI and robotics, impacting the daily lives of humans. The integration of humans and machines creates new innovation, opportunities and possibilities. New knowledge creation in OL must align with the emerging IR 4.0. According to Easterby-Smith and Lyles (2003), OL focusses on the process, whereas KM focusses on the content and information that an organisation collects, generates, processes and, eventually, uses. The implementation of KM in OL comes with several challenges such as slow in adapting to advanced technologies, lack of facilities and infrastructure and scarcity of talent. These affect both research and innovation processes especially in jobs defined in Clusters 1 and 2 that involve machines in their interaction. With limited research facilities, it can be difficult for an organisation to strive to be innovative especially in the technological aspects. Due to the lack of experience in handling advanced technologies, it becomes even harder for the organisation to acquire *internalisation* and e*xternalisation* quadrants of knowledge transfer. For these reasons, the possibility to have and implement smart factories in Job clusters 1 and 2 can be extremely challenging, as this requires highly skilled workers to innovate, operate and maintain the technologies needed for the jobs.

Moreover, overwhelming information can make OL process difficult and becomes uninteresting for fostering talents within an organisation, which in turn affecting their performance and level of knowledge gained (Durst and Zieba, 2020). Staff are no longer needed to be taught but trained, and they need to rethink and realign their learning approaches with unique needs in IR 4.0 beyond the anticipated skills. Intellectual and analytical skills are the prerequisite skills for academics and how effective and exciting their interactions with students is dependent on the learning environment which they operate in, that is irreplaceable by robots. Implementing and incorporating smart technologies into the learning environment will prepare skilling for adapting new business models and processes in organisations as Industry 4.0 evolves. Developing OL in the context of Industry 4.0 enables use of digital technology, customised data and open source content to its full potential. In the case of analysing knowledge creation as part of the initiative in introducing new skills, the SECI model can be applied in many ways. For example, in the current setting amidst the COVID-19 global pandemic, OL activities have now globally conducted via online to promote social distancing and avoid virus transmission (Durst and Henschel, 2021).

Overall, this study suggests that the implementation of OL in 4IR requires facility management involving people, technology, process and strategy. Organisations must consider and plan each of the facilitating factors carefully to ensure the acceleration of digitalisation in all industries including the educational field yielded results in terms of increased performance, productivity and competitive advantage. Identifying skills set for

future jobs requires a collaborative effort across organisations and greater understanding on different types of job cluster. The new upskilling model developed in the study provides information about the job skills requirements with reference to the nature of decision making (routine or complex) and interactions (human or machine-centric) involved in each job cluster. Lastly, transparency in KM process (knowledge creation and transfer) must be continually embraced by organisations throughout all levels of stakeholders to smooth out operations for long-term success and ensure the translation or transformation shift of individuals across the four job clusters can be successfully achieved.

Limitations and future direction

This research does have limitations. The design of the study focuses on bibliographic analysis, with a FGD as a preliminary study to better understand upskilling trends in the context of Industry 4.0 and KM has been used as a keyword search from Scopus published papers exclusively. As a result, larger journal databases are needed to extract more thorough patterns. For future research, the proposed models can be utilised as a test platform for developing KM strategies in mapping current skill scenarios within an organisation. A case study-based method can be used to equip organisations with comprehensive procedures for examining KM from the perspective of Industry 4.0 readiness. Finally, the applicability of this research is expected to provide a pathway for organisations to develop better KM strategies as part of developing Industry 4.0 competencies.

Conclusion

This study highlighted the importance of upskilling and KM in the context of 4IR. Digitalisation, as key to industry 4.0, not only has the potential to affect the sustainable development of organisations or companies in the long run but also their competitive advantages particularly with respect to people and other resource capabilities. Digitalisation affects future jobs and skills in which many researchers deem that this can only be resolved through the implementation of KM process. KM helps to mitigate risks resulting from the loss of knowledge sharing and transfer and skills depletion. While identifying new skills set and creating new knowledge in KM receives greater attention in the current workforce, the culture of innovation that promotes creativity, discipline and management remains essential for knowledge sharing and transfer. Innovation culture is expected to make room for compassion, empathy, leadership and freedom (Durst *et al.*, 2021). Hence, skills set in 4IR which are largely determined by the degree of routinisation or complexity in decision making process and types and levels of interactions for performing and completing the jobs or tasks, also pointed out the roles of education, technology preparedness and readiness at individual, organisational and societal levels.

The study further shows there is a growing need to step up to the challenges and develop long-term solutions that combine technology, intelligence, experiences and operational perspectives through integrating KM strategies into OL. Given the fact that today, we are at the critical point of the Fourth Industrial Revolution, organisations are pressured to shift their mindsets from social norms ("Me too" syndrome) that were once acceptable and admirable to alternate choices. Digital transformation that relies on the human–machine interface has also made people more agile in the workplace rather than limiting them. Finally, despite the increased challenges in responding to the requirements of upskilling and creation of new knowledge and transfer, evolving in Industry 4.0 and the application of KM continues to be critical amid COVID-19 pandemic.

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