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Operator 4.0: What to Know to Share Knowledge?

Francesca Collevecchio*, Elisa Barbizzi†, Michele Rivetti‡

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Abstract

The Industry 4.0 paradigm represents a significant transformation for organizations that become increasingly automated through the implementation of new disruptive technologies. In this context, knowledge is the primary strategic asset underpinning competitive advantage; therefore, knowledge sharing (KS) is vital for business success as it increases the company knowledge base. Since KS requires the active involvement of the workforce, the paper explores what skills the operator 4.0 must have to facilitate and enhance the KS process through interaction with the workplace and technology infrastructure. Specifically, we argue that operator 4.0 needs a pool of knowledge, i.e., T-shaped skills, to optimally participate and facilitate knowledge transfer within the organization.

Keywords: Knowledge Sharing; Operator 4.0; Skills and competences.

* **Francesca Collevecchio**, Dottoranda di ricerca di Management and Law (Economia e gestione delle imprese, SECS-P/08) presso il Dipartimento di Management dell'Università Politecnica delle Marche; e-mail: f.collevecchio@pm.univpm.it.

† **Elisa Barbizzi,** Dottoranda di ricerca di Management and Law (Economia e gestione delle imprese, SECS-P/08) presso il Dipartimento di Management dell'Università Politecnica delle Marche; e-mail: e.barbizzi@pm.univpm.it.

‡ **Michele Rivetti**, Dottorando di ricerca di Management and Law (Organizzazione aziendale, SECS-P/10) presso il Dipartimento di Management dell'Università Politecnica delle Marche; e-mail: m.rivetti@pm.univpm.it.

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1. Introduction

The contemporary economic landscape is characterized by a high level of dynamism due, first and foremost, to the multiple challenges that digitization is posing in recent decades. Among these, the affirmation of the Industry 4.0 paradigm (I4.0) is crucial in the global business environment since it strongly affects both processes and the working environment within the organizations.

The increasingly dynamic background requires higher flexibility, agility, and attitude for changes, thus requiring new resources. According to the resource-based perspective (Penrose, 1959), the organization is a "knowledge system" (Pentland, 2013). In this context, the famous ancient phrase "knowledge is power" (attributed to Francis Bacon, 1597) is more true than ever since it is necessary to recognize knowledge as the leading strategic resource to develop new ideas, innovate and gain a competitive advantage (Du Plessis, 2007). Knowledge represents the central element in Organization 4.0, where the production or procurement process evolution – which is the main focus in the literature on the topic of I4.0 (Ivanov et al., 2019; Koh et al., 2019) – is the result, among others, of the contextual evolution of knowledge management (KM). KM is particularly crucial to allow the company to operate and compete in the modern knowledge-intensive economy (Abubakar et al., 2019). Indeed, I4.0 enables technologies that facilitate knowledge storage and transfer, such as data mining, cloud computing, artificial intelligence, and Internet of Things (IoT), moving knowledge management forward to the so-called Knowledge Management 4.0 (Ansari, 2019). Such evolution is radically reshaping the labor market, generating a profound transformation in the role of the worker, who operates in a working environment that requires continuous development of new knowledge, skills, and abilities (Ras et al., 2017). The human-centric approach to KM 4.0 underlines the human relevance, which remains a key actor in organization 4.0 as a primary source of knowledge and, more precisely, of tacit knowledge (Nonaka, 1994). However, for this to be true, the shop floor worker must evolve to meet the so-called Operator 4.0 (Romero, Stahre, et al., 2016; Romero et al., 2020), namely a highly skilled worker who is able to interact with technologies characterizing the more complex work environment to promote a continuous flow of knowledge (Kaasinen et al., 2020; Longo et al., 2017; Romero et al., 2020).

Because of the importance of the issue in managerial practice, in recent years, some scholars have begun to focus on the relevance of the new skills required by the I4.0 paradigm. Several studies have been developed to identify and classify the competences needed in the new, increasingly dynamic, flexible, and digital work contexts (Buenechea-Elberdin et al., 2017; Cotet et al., 2017; D'Antonio & Chiabert, 2018; Kaasinen et al., 2020; Pinzone et al., 2017; Whysall et al., 2019). In this perspective, some competence models were developed (e.g. Erol et al., 2016; Hecklau et al., 2016; Simic & Nedelko, 2019) aimed at determining the core skills that can facilitate the complete transition to the new I4.0 paradigm. Previous research emphasized that new skills are needed to take advantage of the multiple opportunities of I4.0 (Zhou et al., 2016) and, at the same time, to face the significant challenges which it entails (Hecklau et al., 2016; Horváth & Szabó, 2019; Olsen &

Tomlin, 2020; Simic & Nedelko, 2019). So far, the main objective of researchers has been to understand what are the critical skills that allow the transformation of operators into operator 4.0 to best fit the I4.0 paradigm (Dworschak & Zaiser, 2014; Flores et al., 2020; Kaasinen et al., 2020; Romero, Stahre, et al., 2016), without considering the impact of those skills and competences that foster knowledge sharing.

Knowledge sharing is widely recognized as one of the main enablers of KM in organizations, especially in the era of I4.0 (Abubakar et al., 2019; Alavi & Leidner, 2001; Farooq, 2018). It enables knowledge to be transformed into economic value and competitive advantage by linking individual knowledge with the broader organizational level of knowledge (Farooq, 2018).

Thus, although I4.0 competences are certainly a sine qua non for working in a modern and successful company, they are not in themselves sufficient to maximize company value. Firms, which are increasingly digital, automated, and interconnected, need an ever-increasing knowledge base to remain competitive in the marketplace (Du Plessis, 2007; Nonaka, 1991). Therefore, knowledge sharing becomes a vital process to increase the knowledge base and make it available so that it can be translated into innovations meeting market demands and, thus, into economic value and growth (Kang & Lee, 2017). Since it is not in-depth analyzed the role of operator 4.0 in enhancing knowledge sharing, neither the competences nor skills he must hold for this specific purpose, the paper aims to shed light on this topic.

Several studies have focused on the knowledge sharing process, analyzing the main drivers and enablers (Alavi & Leidner, 2001; Bock et al., 2005; Gupta & Govindarajan, 2000; Wu & Zhu, 2012). Similarly, in recent years, considerable literature has developed to examine the new skills and competences required by the I.40 paradigm (Chumnumporn et al., 2020; Kaasinen et al., 2020; Li et al., 2019; Szalavetz, 2019). Nevertheless, the academic literature regarding skills for the I4.0 paradigm does not consider the determinants affecting knowledge sharing processes comprehensively, and the two perspectives have been studied while keeping different research streams. To date, no one has integrated the two issues to analyze which specific skills are particularly significant to facilitate the transfer of knowledge between the various KM 4.0 factors. Therefore, we examine what basic preliminary knowledge is necessary for operator 4.0 to enable the various interactions within the organization, facilitating the knowledge sharing process. In greater detail, we address the following research question: what are the main skills that operator 4.0 needs for enabling the knowledge sharing process in the Industry 4.0 paradigm? The paper is organized as follows: In the next paragraph, the theme of knowledge management is presented, underlining the importance of knowledge in the context of Industry 4.0 through a human-centered approach. The third paragraph focuses on the relevance of the knowledge sharing process, arguing that it involves several factors in organization 4.0. In the fourth paragraph, the most relevant I4.0 skills that the operator must hold are discussed. Starting from those, in the fifth paragraph we develop a conceptual model to outline the main skill categories needed to facilitate knowledge transfer in organization 4.0.

2. Knowledge management in the era of Industry 4.0

Knowledge Management (KM) raised as a specific study discipline since the Nineties when the rapid technological transformations led researchers to recognize knowledge as key for value creation. KM is a vast concept that includes multiple actors, practices, and processes. It can be defined as the process of "capturing, distributing, and effectively using knowledge" (Davenport & Prusak, 1998). KM has been considered for some time now as one of the most important leverages to achieve sustainable competitive advantage and to make the company ready and proactive towards the evolution of the markets. As Nonaka argued, "in an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge" (Nonaka, 1991). The debate about knowledge is very ancient and goes back to the Greek philosophers' time, namely Plato and Aristotle; nevertheless, there is no univocal meaning of knowledge so far, and the theme is largely discussed in managerial literature. According to the empiricism perspective of knowledge theory (Bolisani & Bratianu, 2018), knowledge is the outcome of human experience and sensory perception, and it is not created a priori. The well-known Nonaka definition of knowledge as "justified true belief" (Nonaka, 1994) highlights the relevance of human in the knowledge creation process, which makes knowledge created by individuals available throughout the organization[1].

The last decades have been characterized by several industrial disruptions due to the technological evolution that are completely changing industrial paradigms, shifting many organizational activities towards more digitalized ones – i.e. production processes and supply chain management (Ivanov et al., 2019; Koh et al., 2019). Industry 4.0 (I4.0), the so-called fourth industrial revolution[2], strongly affects companies, shifting towards the so-called smart factories – i.e., companies ideally suited for innovation implementation and more heterogeneous workers – enabling a new level of interaction between actors. The prominent I4.0 disruption lies in the automation through the introduction and integration of a multitude of new technologies within the company, i.e. Internet of Things (IoT), Artificial Intelligence (AI), blockchain technology, robotics, Cyber-Physical Systems (CPS), and cloud computing (Roblek et al., 2016; Xu et al., 2018). The new digital systems must be implemented contextually within a new concept of the organization, i.e. Organization 4.0 (Li et al., 2019), where the adoption of the I4.0 paradigm drives a significant change in the nature of work, resulting in increased automation of

[1] More precisely, Nonaka argues that individuals are at the centre of the process of knowledge creation at a fundamental level, although the organization, including all systems that characterise it, is fundamental to articulate and amplify the elementary unit of knowledge generated by each individual (Nonaka, 1994).

[2] Many authors agree that the current technological evolution is a real revolution leading the main challenges and opportunities for companies. However, the debate is open in literature, and some scholars argue that we cannot speak about "technological revolution", because history is not dictated by technology, but by the human who drives its evolution (Salento, 2018).

processes and tasks within the organization that has somehow shifted the focus from human to machine. Henceforth, this latter becomes a central player in organizational processes, and it is no longer a simple tool to support humans. To the extent to which the term "machine" is understood as also referring to advanced technologies like machine learning, AI, cloud computing, etc., it is clear how machines could replace humans not only in terms of performing tasks but also in terms of creating and managing knowledge. From this viewpoint, the increasing hybridization of KM actors due to the recognition of the machine as a knowledge actor (Ansari, 2019) raises a human-machine relationship dilemma, which triggers the crucial question "who does what" within the organization.

Whereas, on the one hand, the transformation of work concerns greater autonomy due to the automation of processes and the consequent risk of substitutability (Ansari, 2019; Ansari et al., 2018); on the other hand, it emphasizes the concept of human-centricity, that means that "humans should never be subservient to machines and automation, but machines and automation should be subservient to humans" (Rosenbrock, 1990). It entails the evolution of the worker towards the so-called operator 4.0 (Kaasinen et al., 2020; Romero et al., 2020), i.e. a smarter operator who cooperates not only with people working within the organization, establishing a partnership with them based on continuous giving and receiving, but also with machines that aid him/her in his work, thus achieving a human-automation symbiosis work system (Romero, Stahre, et al., 2016) and enhancing a mutual learning process (Ansari et al., 2018). In this respect, it is clear how the role of the individual in the organization evolves, requiring strong and more difficult to imitate competences and capabilities (Agostini & Filippini, 2019; Ras et al., 2017) that enable the company to develop and consolidate tacit knowledge, which has been recognized as the main source of competitive advantage since the pioneering works of the late 1990s (Nonaka, 1994; Nonaka & Takeuchi, 1995; Winter, 1987). Operator 4.0 must interface with more complex daily tasks in the digitalized environment, showing more than ever the importance of soft skills that allow greater flexibility and adaptability in an extremely dynamic work context. Indeed, operator 4.0 is a highly skilled worker equipped with the necessary skills to manage the digital disruption forced by I4.0 and to interact with machines fostering a continuous flow of knowledge.

While, as discussed above, the technology-driven development of I4.0 brings new challenges companies need to face to survive, from KM perspective it seems to offer multiple tools to create, manage and share knowledge. Indeed, the disruptive times we are currently living are emphasizing the importance of KM to face the numerous challenges the digitization poses. Knowledge is, indeed, the primary crucial element for developing and adopting innovations (Du Plessis, 2007), which are in turn the lifeblood to disrupt traditional business models and survive the highly dynamic context. The shift from traditional companies to organization 4.0 characterized by autonomous and learnable systems significantly affects KM, by moving it towards the so-called Knowledge Management 4.0 (KM 4.0) (Ansari, 2019), i.e. KM architecture ready for the current digital age. I4.0 paradigm influences the method

to both access and share knowledge, thus constantly influencing the human and machine interaction with knowledge, which is becoming more and more interconnected. In this landscape, the concept of knowledge as an exclusive human product may be questionable since the development of AI, machine learning, deep learning, and data science play a critical role in the creation and dissemination of knowledge (Peinl, 2017). Indeed, according to Nonaka (Nonaka, 1994), knowledge creation derives from a continuous conversation between tacit and explicit knowledge, and advanced technologies contribute considerably in terms of explicit knowledge, i.e. purely theoretical knowledge that is easily stored and transferable. On the contrary, tacit knowledge, which derives from experience and practice, is hardly separable from the individual. In agreement with Einstein's famous quote according to which "knowledge is experience. Everything else is just information", human centricity remains a fundamental concept in KM 4.0. As highlighted by Smith (2001), about 90 percent of the organization's overall knowledge is synthesized in people heads, and it can be difficult to transfer as it is often created unconsciously by humans through their personal experiences. Indeed, the smart operator owns a superior knowledge of the working environment (Longo et al., 2017) that comes from the continuous interactions with procedures and contents that contribute to increasing his skills in the workplace as well as in everyday life.

KM 4.0 opens multiple questions about the role of the individual, i.e. operator 4.0, in knowledge management processes. Nonetheless, the managerial literature on KM has paid little attention to this aspect, focusing mainly on the technological infrastructure supporting the knowledge processes (Fakhar Manesh et al., 2020). The following paragraph focuses on a particular KM process: knowledge sharing within the organization, between individuals as well as between humans and machines, and externally, between different organizations.

3. Knowledge sharing in organization 4.0

The organization is a "knowledge system" in which phenomena of creation, storage, transfer, and application occur (Pentland, 2013) and within which the organizational learning process takes place, i.e., a "systematic behavior to acquire capacities for dealing with the needs and challenges of organizations in competitive environments" (Kumaraswamy & Chitale, 2012). Nonaka pointed out knowledge sharing as an extremely important part of generating knowledge (Nonaka, 1994), outlining the knowledge creation process as a virtual cycle in which sharing tacit knowledge is key. Although new technologies enhanced by I4.0 may potentially automate knowledge sharing, a fully automated knowledge sharing process would lack the creative reworking of information by actors, which is a key component for creating new knowledge. In this sense, therefore, the fully automated knowledge sharing process would make the company lose opportunities for development and innovation. However, it cannot be ignored the support of digital tools, without which the company would not be able to manage a significantly higher flow of knowledge than in the past (Fakhar Manesh et al., 2020). Workers must, therefore, possess and

be able to develop new skills that enable them to interact with highly interconnected digital systems (paragraphs 4 and 5).

Knowledge sharing plays a crucial and tangible role in organizations, as it can reduce costs and production time in developing new projects and increasing company performance and innovativeness (Z. Wang & Wang, 2012). There is not a unique definition of knowledge sharing in literature. It has been defined as an essential component and 'key enabler' of knowledge management (Alavi & Leidner, 2001), and it concerns the exchange of both tacit and explicit knowledge among members within the organization. Knowledge sharing has not to be intended as a static asset, but as a dynamic resource, since knowledge generates new knowledge that can be converted into economic value benefiting the organization (Farooq, 2018; Hendriks, 1999). Indeed, knowledge sharing is widely recognized as an indicator of business performance, and several scholars evidenced the significant positive impact of knowledge sharing on competitive advantage (Farooq, 2018; Oyemomi et al., 2016; Z. Wang & Wang, 2012).

Van den Hooff and de Leeuw van Weenen (2004) distinguished between two forms of knowledge sharing, i.e. knowledge donating and knowledge collecting, arguing that both are active processes. Indeed, donating entails the active communication of personal knowledge, while collecting results from the active consulting of colleagues (van den Hooff & de Leeuw van Weenen, 2004). According to previous literature, knowledge sharing is a bidirectional process which occurs between at least two actors, the source and the receiver (H. F. Lin, 2007; Syed-Ikhsan & Rowland, 2004; Tangaraja et al., 2016; van den Hooff & de Leeuw van Weenen, 2004; D. Wang, 2015). Considering only the active process of KS assumes that knowledge transfer occurs exclusively between individuals. However, the technological transformations and the increasing digitalization are broadening the scope of KM analysis, including not only the individual but also focusing on technological factors, which deserve an in-depth analysis (Zhao et al., 2020). In organization 4.0, KS occurs at various levels: from individual to the organization, between individuals, as well as between individuals and processes and infrastructures. As argued in the previous paragraph, in organization 4.0 a growing hybridization of KM actors is observed, where technologies become important players (Ansari, 2019). Indeed, Industry 4.0 leads to forms of human-machine mutual learning, which "involv[e] reciprocal exchange, dependence, action or influence within human and machine collaboration, which results in creating new meaning or concept, enriching the existing ones or improving skills and abilities in association with each group of learners" (Ansari et al., 2018, p. 119). The introduction of IT infrastructures makes the workplace increasingly interconnected and open, thus providing new sources of knowledge. Based on this, technological infrastructures and the interconnected workplace may be considered themselves sources of knowledge that should be transferred to workers (Ansari, 2019; Peinl, 2017) and, therefore, key "actors" in the KS process that interact with operator 4.0. Indeed, by interacting with the digitized work environment, the individual receives continuous information not only through active communication with other individuals, but also by computerized systems, through which he or she can absorb

new knowledge. Although the concept of absorptive capacity was initially introduced at the firm level (W. M. Cohen & Levinthal, 1990), several scholars pointed out the crucial role of the individual level of absorptive capacity (e.g. Kang & Lee, 2017; Volberda et al., 2010).

Knowledge sharing behavior is influenced by contextual forces (Bock et al., 2005), which concern psychological, organizational and technological factors (Wu & Zhu, 2012). Among these, technological factors play a key role in facilitating collaboration among workers and transforming individual learning into organizational learning by providing a dynamic flow of information through IT systems (Brahma et al., 2020). Therefore, technological factors are valuable opportunities for KS. Industry 4.0 creates new networks and allows individuals to be more exposed to connections through an increasing number of digital channels, which extend the possibilities for operator 4.0 to learn, thus boosting KS (Brahma et al., 2020). Indeed, KS is driven by communication and information flows that reach operator 4.0 through different channels, and IT supports allow a more extensive knowledge network gathering a wider number of individuals, as well as a larger number of available communication channels and faster access to knowledge sources through technological systems (Alavi & Leidner, 2001).

Although technologies automate the process of knowledge sharing, facilitating the transformation of knowledge into capital for the company (Z. Wang & Wang, 2012), a high-tech environment means that the operator 4.0 deals with greater complexity, so the potential benefits may be limited if a supportive organizational culture is lacking (S. Wang & Noe, 2010). Furthermore, machines cannot replace all human activities, such as creative, innovative and communication activities that become the main focus of human work (Agostini & Filippini, 2019),. Indeed, knowledge remains closely linked to the individual, i.e. operator 4.0, who plays a crucial role in terms of knowledge sharing. As Shariq et al. (2019) argued, a "knowledge-related phenomenon" must be studied considering the human being and his nature. The process of knowledge sharing is considered, in fact, a human tendency, which may vary according to individual behavior (Bock et al., 2005). Motivation and commitment to the organization are the most examined individual-related antecedents of KS (van den Hooff & de Leeuw van Weenen, 2004) and previous literature showed that both significantly influence KS dynamics (Book et al., 2005; Hsu, 2006; C. P. Lin, 2007; Taylor, 2006; van den Hooff & de Leeuw van Weenen, 2004; Witherspoon et al., 2013). Following the ability-motivation-opportunity framework (Blumberg & Pringle, 1982), we argue that in addition to motivation and opportunities (i.e. the workplace resources that enable KS), knowledge sharing is strongly influenced by abilities, i.e. experience, knowledge, and skills (Chang et al., 2012), especially in the organization 4.0 environment. Indeed, I4.0 technologies require new skills (Ras et al., 2017; Wei et al., 2017) as the real-time connection of physical and digital systems profoundly change the way work is done and, thus, the processes and interactions among players (Olsen & Tomlin, 2020). Therefore, the operator 4.0 needs specific skills, both hard and soft (i.e., T-shaped skills), allowing him/her to better interact with technologies and people, respectively, in order to foster KS.

Table n. 1 – Synoptic table of the most relevant papers explaining the evolution of KM processes.

Author	Results and relevant contributions
(Nonaka, 1994)	The author developed a theory of organizational knowledge creation, explaining how knowledge held by individuals, organizations, and societies can be simultaneously enlarged and enriched through the continuous dialogue between tacit and explicit knowledge. Special attention was given to individuals, without whom no knowledge could be generated.
(Alavi & Leidner, 2001)	Authors state that the knowledge management systems are supported by various and flexible forms of IT, facilitating the transfer of knowledge.
(Smith, 2001)	The author summarizes key factors for using and improving knowledge in a worker-centered environment.
(van den Hooff & de Leeuw van Weenen, 2004)	Authors outlined two forms of knowledge sharing, donating and collecting knowledge, arguing that both require the active involvement of the individual.
(Bock et al., 2005)	Authors focuses on the individuals' intention to share knowledge, asserting that it is associated with socio-psychological and organizational factors.
(Du Plessis, 2007)	The author clarifies the role of knowledge management in innovation and to identify the drivers for its application. Findings show that KS is a driver of innovation.
(Pinho et al., 2012)	The study aims to identify and discuss about barriers and facilitators to four processes implied in knowledge management: acquisition, creation, sharing, and transfer.
(Wu & Zhu, 2012)	Authors developed an integrated theoretical model including streams of research from social psychology, organizational learning, knowledge management, information systems contribute.
(Witherspoon et al., 2013)	Authors analyzed why knowledge is the most important component of sustainable organizational growth and economic performance. This analysis aims to summarize the determinants of individuals' knowledge sharing (KS) in the organization.
(Romero, Stahre, et al., 2016)	Authors introduced Operator 4.0 by exploring a set of key enabling technologies that can support the development of human-automation symbiosis work systems within the Industry 4.0 framework.
(Tangaraja et al., 2016)	Authors reviewed the existing literature on knowledge sharing and knowledge transfer, founding that the former is a subset of KT, which is a broader concept.
(Farooq, 2018)	Authors found knowledge sharing as a predictor of business performance.
(Abubakar et al., 2019)	Authors proposed a framework supporting relationships between knowledge management enabling factors, organizational performance, and the mediating effect of the knowledge creation process
(Ansari, 2019)	The author discussed the theoretical foundation of KM 4.0 and related practical aspects in dynamic, data-driven, and hybrid human-machine working environments in smart factories.
(Brahma et al., 2020)	The article shows that digital workplaces present challenges that can be mitigated by the knowledge sharing process.

4. Skills and competences for the Operator 4.0

As illustrated above, the rapid technological developments underlined by the Industry 4.0 paradigm are changing the working environment, facing workers with multiple challenges, first of all, the increased level of automation, which potentially leads to the need for fewer workers. Therefore, for the traditional shop floor worker to remain a central player in the organization, he or she must be better qualified, moving forward operator 4.0 (Kaasinen et al., 2020; Li et al., 2019; Romero, Stahre, et al., 2016; Romero et al., 2020). Hence, having high and relevant skills is increasingly important, and in a context where machines could take the place of humans in performing multiple tasks, soft skills are vital (Flores et al., 2020). Indeed, the human-centric perspective of KM 4.0 focuses on aspects and peculiarities of human that are difficult to replicate by machines. From this viewpoint, it is imperative to consider soft skills, i.e., personal skills and abilities derived from the conjunction between professional and social skills. Cotet et al. (2017) describe soft skills as "the attitude of each of us, our compatibility with others and how we manage social interactions mostly in professional environment." Soft skills and knowledge background are essential for business sustainability (Bawden, 2008; Sofo et al., 2013), especially in the context of Industry 4.0 as it blurs the boundaries between the various roles and duties within the organization, which is characterized by a higher degree of interdisciplinarity between the multiple tasks (Ras et al., 2017).
In addition to soft skills, such as creativity, social intelligence, innovation competence, and problem-solving, human-machinery interactions require domain competences, e.g., the configuration of cyber-physical systems, maintenance of sensor networks, or knowledge about Internet of Things (Ras et al., 2017). In this context, the so-called T-shaped skills emerge as a fundamental resource for operator 4.0, who must use their skills across several areas in order to develop a systemic thinking ability (Lee & Choi, 2003). Managerial literature highlighted the relevance of T-shaped skills in terms of knowledge creation and, consequently, for their impact on value creation (Abubakar et al., 2019; Hamdi et al., 2016; Hansen & Von Oetinger, 2001; Tomenendal et al., 2018). T-shaped skills are so named to emphasize the dual dimension's importance, horizontal and vertical (described by the letter 'T'). The vertical axis refers to the experts' knowledge and experience in a specific field; on the contrary, the horizontal axis refers to broad general skills (Abubakar et al., 2019). Employees holding T-shaped skills play an essential role in the organization since they have adequate knowledge of the discipline and specific know-how necessary to cooperate with others as a team (Hamdi et al., 2016) as well as with the new automatized systems of Industry 4.0. Their contribution in terms of knowledge creation makes employees having T-shaped skills valuable actors within the organization 4.0. Indeed, they can operate in various fields (Leonard-Barton, 1995) and are able to combine both theoretical and practical knowledge, thus understanding how different forms of knowledge can be fused through the use of I4.0 technologies (Madhavan & Grover, 1998). As argued by Hansen and Oetinger (2001), T-shaped skills allow operator 4.0 to engage simultaneously in his specific

work or a specific area of expertise (the vertical dimension), as well as in other organizational areas (the horizontal dimension). In this way, operators can extend their skills to various operational fields in order to create new knowledge through constant interaction with new technologies. According to Johannessen et al. (1999), employees fitting these skills can help their teams to efficiently and systematically coordinate knowledge, facilitating the development and integration between workers. This means that individuals with T-shaped skills are able to process and understand different types of information, which is the key aspect in KM 4.0 (Ansari, 2019), leading to the evolution and development of a new way of interacting and working with new I4.0 operating systems that could have a significant impact on organizational performance (Abubakar et al., 2019).

Several scholars argued that T-shaped skills is a valuable facilitator of KM processes (Alavi & Leidner, 2001; Huang & Chin, 2018; Lee & Choi, 2003; Pinho et al., 2012). Indeed, according to Huang and Chin (2018, p. 1248), "the core ability most associated with knowledge transfer is T-shaped skills" as they involve extensive enough knowledge to engage in synergistic interactions with people operating in other fields (Madhavan & Grover, 1998), thus fostering knowledge sharing.

Although the debate about the relevance of skills within I4.0 is widening, it does not yet focus in-depth on key skills to facilitate the knowledge sharing process within the organization. Moving the focus to this specific element of KM 4.0 requires a new key to reading the T-shaped skills described above in order to outline a specific skills model for enhancing knowledge sharing. Indeed, the knowledge sharing process involves converting personal knowledge into a form that can be easily intelligible to be absorbed by other players operating in the company and enable organizational learning (Ipe, 2003). We believe that to making knowledge available, it is fundamental that the individual (operator 4.0 in the specific context of the organization 4.0) has specific skills, outlined in the following paragraph, that allow him to interact with the more complex digitalized system.

5. A skill model for Operator 4.0 to facilitate knowledge sharing

The literature review has highlighted the relevance of interactions between the organization' actors for generating and sharing knowledge (Bock et al., 2005; Gupta & Govindarajan, 2000; Shariq et al., 2019; Wu & Zhu, 2012). The organization's shift towards organization 4.0 due to adopting the industry 4.0 paradigm outlines a new working environment, where new technological systems become key elements contributing to KM processes (Ansari, 2019). Indeed, in digitized companies, technologies such as ICT and cloud computing are crucial to store and disseminate information, significantly influencing KM processes. At the same time, the human operator assumes a central role as an enabler of these technologies (Prezioso et al., 2020; Romero, Stahre, et al., 2016). As anticipated above, the worker in organization 4.0 must possess specific skills, i.e. T-shaped skills, which allow him to daily interface with advanced technologies and complex systems; in this sense, he

becomes operator 4.0, also called augmented operator (Romero, Stahre, et al., 2016; Segura et al., 2020).

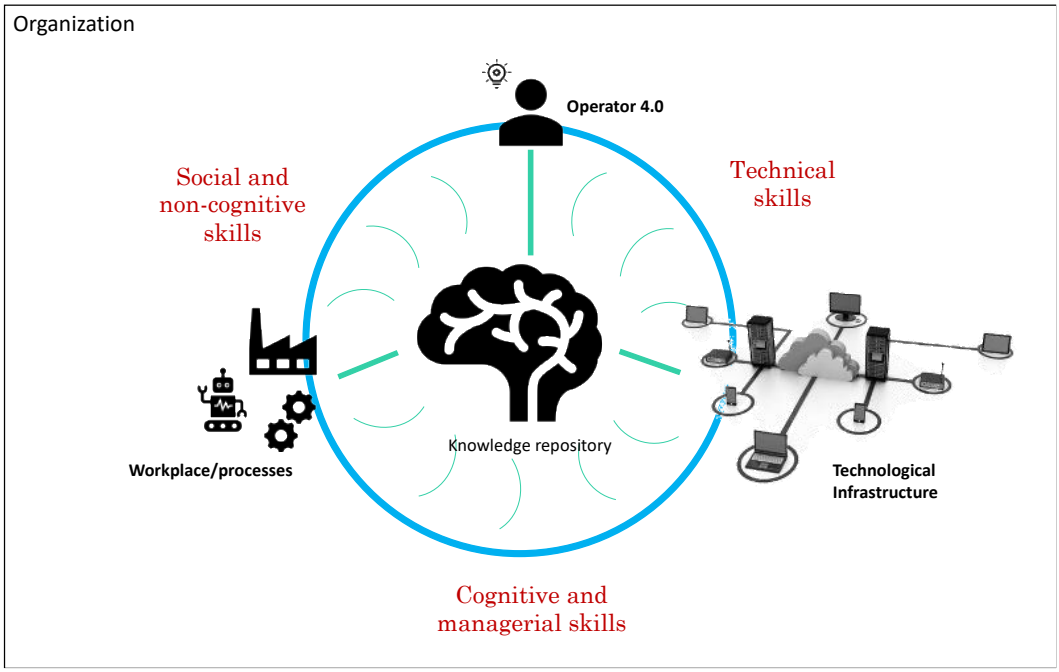
Therefore, three main hubs of KS could be identified in the organization 4.0: 1) the operator 4.0, i.e. each worker in organization 4.0, who must be highly skilled, smarter and able to interface with advanced technologies (Romero, Stahre, et al., 2016); 2) the workplace, where operators meet each other physically or virtually, and the organizational processes, characterized by high automation due to the implementation of the I4.0 paradigm; 3) the fundamental technological infrastructure, which includes ICT, cloud computing, data mining, AI and IoT. These three elements represent the cornerstones of the knowledge sharing process in the I4.0 context: the operator holds the basic knowledge and the skills that trigger the KS process (Nonaka, 1994); the workplace is the environment where the process unfold and it embeds the collective knowledge (Lam, 2000); the technological infrastructure emerging in the I4.0 context has a facilitator role.

Starting from this, we analyzed the interactions between the three hubs and, consequently, how knowledge is transferred between them. As already said, following the mainstream perspective (Nonaka, 1994), we believe that human being is the heart of knowledge management processes, as he holds the primary and original organizational knowledge. Indeed, human interaction with the workplace and technologies allow the transfer of knowledge within the organization. Nevertheless, besides residing in the individual, new knowledge derives from the underlying technological structure. Indeed, advanced technologies are able to replicate reality by providing new meanings and interpretations, thus playing a crucial role in creating and sharing knowledge (Peinl, 2017).

Figure 1 illustrates the framework of KS in organization 4.0, outlining three categories of skills that can facilitate and foster the process. We argue that knowledge sharing carries out between three main hubs of the process: 1) the individual, which becomes operator 4.0 in the context of I4.0; 2) the workplace and organizational processes; and 3) the fundamental technological infrastructure. They represent the three key elements characterizing a company fitting the I4.0 paradigm, strongly interconnected due to the continuous flow of knowledge (the blue circle in figure 1) that is constantly exchanged and transferred between them. This virtuous circle is the core of KM 4.0 and leads to creating new knowledge, thus expanding the company's knowledge repository, which can then be transformed into economic value (Hendriks, 1999). Indeed, the interaction between the various actors of the organization is key to expanding corporate knowledge. In this perspective, it is extremely important that operator 4.0 hold T-shaped skills, having not only the specific skills needed to be able to perform his tasks (the vertical axis of "T") – which, in a highly digitized environment, are less and less mechanical (Prezioso et al., 2020) – in the best possible way, but first and foremost those skills that allow him/her to better interact with the workplace as well as with the technological infrastructure in order to be able to transfer and, at the same time, absorb knowledge (the horizontal axis of "T"). In so doing, operator 4.0 contributes to generate new knowledge and increase the knowledge base available in the organizational knowledge repository. Although knowledge transfer is an

inseparable process that takes place in a continuum of interactions between the various actors, we believe that an analysis of the various interactions taken independently, extrapolating them from the whole, can help to understand in more detail which skills are particularly relevant.

Figure n. 1. – Key skills for enabling knowledge sharing



5.1. Operator 4.0 – Workplace

Digital transformation and I4.0 are transforming the organization into a real ecosystem understood as a set of individuals, processes, and machines, where operator 4.0 must interact and cooperate with multiple actors in a highly dynamic workplace. In this context, operator 4.0 is not only the one who holds and shares knowledge but is also the receiver of the collective knowledge that is embedded in other individuals, practices, procedures, routines, norms, and all activities of the organization (Cook & Brown, 1999; Lam, 2000). Thus, he or she not only actively donates and collects knowledge (van den Hooff & de Leeuw van Weenen, 2004), but also passively absorbs it in daily interaction with the work context. According to Cook and Brown (1999, p. 386), "the body of (collective) knowledge is possessed by the group as a whole and is drawn on in its actions, just as knowledge possessed by an individual is drawn on in his or her actions". Therefore, social and non-cognitive skills are crucial in the interaction between operator 4.0 and the workplace in order to contribute to KS.

Social capital is a concept that gained particular importance in the KM literature (Huysman & Wulf, 2006), focusing on the collective abilities formed from social interactions. Social capital is a strategic asset for knowledge sharing (Yen et al., 2015). The process of KS requires various types of skills, both individual and social, which, through interaction, enable communication, coordination, and collaboration among operators 4.0 (Kao & Wu, 2016). First, acting as a team member is a crucial skill for operator 4.0 to exploit, exchange, and absorb knowledge with other individuals. It requires the development of interpersonal skills that underpin the participatory climate within Organization 4.0, which is key to stimulating learning capacity (Abubakar et al., 2019) and relies on trust as a key element of team performance (De Jong et al., 2016).

With globalization underway, working environments have become increasingly multicultural and multiethnic worldwide. In these new contexts, intercultural skills are undoubtedly crucial to interface and collaborate with other organization members (Hecklau et al., 2016). KM 4.0 highlights the value of collaboration and cooperativeness as key factors in sharing and creating knowledge. Indeed, by sharing goals, activities, and information, a flexible intellectual capital can be developed, which is the main feature that fosters the acquisition of skills, and especially soft skills, that would be difficult to acquire externally to support an inadequate learning organization (Abubakar et al., 2019).

Collaboration cannot be defined a priori as the ties' quality influences it, and many scholars pointed out a positive relationship between strong ties and knowledge transfer (e.g. Hansen, 1999; Reagans & McEvily, 2003). Since the interpersonal ties between the various operators can be very different, in a recent research, Wang (2016) distinguished between weak and strong ties, arguing that they depend on cognitive and relational capital that individuals are able to absorb. Relational capital, which includes trust, norms, and obligations, entails a common knowledge base that facilitates collaboration, thus favoring knowledge transfer (J. Wang, 2016); otherwise, a mere sharing of ideas and information would be involved in the process. Cognitive capital refers to those resources – i.e. cognitive and non-cognitive skills – providing shared representation, interpretation, and meaning (Nahapiet & Ghoshal, 1998). According to Yang and Chen (Yang & Chen, 2007), higher cognitive barriers are linked to lower team involvement, thus negatively affecting KS. Previous literature examined the role of non-cognitive skills in human capital (Alva, 2019), pointing out that those are very valuable. Non-cognitive skills refer to personality trait, such as proactivity, openness or autonomy, and socio-emotional skills, that affect cognitive performance (Brixiová et al., 2020). Therefore, those skills are particularly relevant in operator-workplace interaction, as they influence the way people interact and their attitude towards KS.

Proposition 1: Social and non-cognitive skills help operator 4.0 to better interact with organization's actors, thus fostering the transfer of knowledge.

5.2. Operator 4.0 – Technological infrastructure

In the organization 4.0, the operator works in an automated environment where technological infrastructure is a pivotal element. ICT and IoT can boost knowledge sharing by taking away barriers (Hendriks, 1999; Huff et al., 1989). However, interacting with technologies requires specific skills and knowledge that enable the individual to use the infrastructure and know how to read the information contained therein, i.e., technical skills. According to Hendriks (1999), besides motivation, the technical skills are recognized as the link between the individual and the information systems to be used to their full potential.

Although the management of technological systems is the responsibility of specialized employees, i.e., computer engineers and programmers, technical skills are no longer exclusive to the latter, and it is necessary for all operators to hold the basic technical skills to interact with technologies, exchange information flows with them, and extrapolate and read the information processed by the machines. In other words, technical skills are needed to observe and interact with the technological infrastructure within the organization, in order to transfer individual tacit knowledge which can then be stored in the corporate knowledge cloud, becoming explicit knowledge available to the entire organization. At the same time, technical skills are crucial for allowing individuals to extrapolate the implicit knowledge stored in systems (D'Antonio & Chiabert, 2018).

Since the technological infrastructures can vary considerably depending on the job, these skills refer to the so-called domain-related skills (Erol et al., 2016) as they relate to the ability to access and use the knowledge required for a specific job. Thereby, technical skills refer to the vertical dimension of T-shaped skills. Among these, the following hard skills are certainly relevant: programming, data analysis, and, more generally, the ability to scale IT infrastructure.

Proposition 2: Technical skills facilitate knowledge sharing by allowing operator 4.0 to better interact with technological infrastructures.

5.3. Technological infrastructure – workplace

The connection between the technological infrastructure and the automated workplace raises the so-called augmented and virtual reality that operator 4.0 should face. Indeed, organization 4.0 is characterized by new interactions not only between man and machine but also between the digital and physical worlds thanks to implementing advances such as the IoT and digital twins. Cyber-physical systems (CPS) create a virtual copy of the physical reality and communicate and cooperate with other systems as well as with humans, making decentralized decisions (Lu, 2017). In the workplace-technology infrastructure relationship, the 'passive' contribution of operator 4.0 to knowledge transfer is particularly relevant, as he should firstly absorb knowledge. The flow of knowledge between technologies and automated processes is somewhat cryptic due to the high underlying technicality.

Therefore, cognitive skills – namely those skills directly linked to the information processing – are particularly relevant for the operator 4.0 (Zolotová et al., 2020) and can empower him/her to capture and absorb the knowledge flow exchanged. Moreover, analytical skills may help employees to synthesize and assess information received.

To be able to contemporary interact with both technological infrastructure and automated workplace, operator 4.0 needs to be able to rapidly shift between different fields of knowledge, thus requiring higher flexibility. In this sense, the horizontal dimension of the above-mentioned T-shaped skills is crucial. Equally important is the so-called intellectual curiosity (Cotet et al., 2017) that allows employees to develop new general knowledge by constantly increasing personal desire to know something new. It can concern several elements of organization 4.0, such as the functioning mechanisms of complex systems, new technologies and devices, analytical and mathematical relations as well as relational aspects between individuals.

According to the human-centric perspective, in order for human-automation symbiosis work systems (Romero, Stahre, et al., 2016) to work well and efficiently, these should be managed and controlled by humans. Social capital, i.e. operator skills, is vital as it allows to fix distortions that might occur in the technological and managerial assets of the Organization 4.0. IT systems are the tools that enhance and facilitate the network of relationships and communication among employees. Nonetheless, technology cannot bring people together, thus facilitating KS, if there is no social capital existing in Organization 4.0 (D. J. Cohen & Prusak, 2001). Therefore, the social network remains the core of the exchange and precedes the IT network (Huysman & Wulf, 2006), being the condition for the development of continuous exchanges between networks and the interdependencies that led to the dominance of the "socio-technical network" (Kao & Wu, 2016).

The role of the operator is in a certain sense elevated, as he/she no longer simply has to perform his/her tasks but be also able to manage the complexity of a system characterized by multiple and continuous interactions between technologies and processes. Indeed, several scholars talk about the importance of ICT governance in order to manage the higher complex and fast-changing activities (Amidei, 2009). Therefore, managerial skills are also quite important.

Proposition 3: Cognitive and managerial skills make the operator 4.0 able to deal with technological complexity and absorb knowledge embedded in the IT networks.

6. Discussion and conclusions

This paper provides first insights on the role of operator 4.0 in knowledge sharing within the organization 4.0. The managerial literature underlines knowledge sharing as the crucial KM process (Alavi & Leidner, 2001), which becomes even more relevant in KM 4.0 since the higher complexity and dynamism brought about by I4.0 demand for an even broader knowledge base (Levitt & March,

1988). In this context, the worker needs to evolve towards operator 4.0 (Kaasinen et al., 2020; Romero, Stahre, et al., 2016), developing T-shaped skills to operate in the dynamic context of organization 4.0. We argued that, besides empowering operators to perform their tasks, T-shaped skills are crucial enablers of knowledge sharing. Indeed, the operator who holds both specialized (vertical axis) and broad skills (horizontal axis) is more flexible and is able to operate across multiple domains, integrating different knowledge types (Hamdi et al., 2016; Lee & Choi, 2003; Leonard-Barton, 1995; Madhavan & Grover, 1998). T-shaped competencies are fundamental in the organizational context 4.0, as they provide the operator with operational flexibility interacting not only with people dealing with different activities, but also with increasingly advanced information and technological systems (Ansari, 2019; Longo et al., 2017; Rana & Sharma, 2019; Romero, Bernus, et al., 2016; Romero, Stahre, et al., 2016).

We developed a framework to pinpoint the main interactions through which the flow of knowledge sharing takes place within organization 4.0 as well as the main skills and abilities that may help operator 4.0 in exchange, absorb and generate knowledge. More in details, we argued that in the organization 4.0 the KS process flows through the interaction of three key factors: the operator 4.0, the interconnected workplace, and the technological infrastructures. Each of these interactions represents an important source of knowledge exchange, which can be amplified or resisted by the operator's ability to interface with the other factors. We argued that different categories of skills enable KS depending on the specific interaction. First, in the interaction with the workplace – i.e., the set of people, processes, machines, procedures, and norms where the collective knowledge is embedded (Cook & Brown, 1999; Lam, 2000) – social and non-cognitive skills are key in helping operator 4.0 to better interact with organization's actors, thus fostering the transfer of knowledge. Second, concerning the operator 4.0-technological infrastructure interaction, technical skills enable knowledge sharing by allowing operator 4.0 to better interact with technological infrastructures. Finally, cognitive and managerial skills make the operator 4.0 capable of dealing with technological complexity arising from the interaction between technological infrastructures and the workplace and of absorbing the knowledge embedded in the IT networks.

Nevertheless, the three macro-categories of skills identified cannot be separated so clearly in reality, since they are part of the same bundle of T-shaped skills that the worker must hold to enhance knowledge sharing and organizational learning, broadening the company knowledge base. Considering the framework as a whole, further fundamental aspects, both intrinsic and extrinsic to the worker, cannot be overlooked. First of all, the motivation to share knowledge: it focuses on the role of management, whose skills are anyhow crucial for conveying the value of knowledge sharing and motivating operators, which, otherwise may lead to the failure of KM initiative due to the existence of social barriers in the organization (Huysman & Wulf, 2006). Equally important are explicit channels for knowledge dissemination, such as training programs (Prezioso et al., 2020). In this sense, the capabilities of HR function also play a key role in the process, as it should implement policies aimed at

favoring the development of each operator. Indeed, while the context of organization 4.0 is extremely dynamic and constantly evolves, requiring workers to be highly flexible and adaptable, it is also true that HR management should support and assist them in continuous transformations, providing all useful tools to promote the transition.

This paper contributes both to academic research and practice. Regarding the former, starting from a review of the existing literature, the article contributes to broadening the analysis on KM 4.0 through the lens of human-centered approach and highlights the main issues related to knowledge in the context of Industry 4.0. More in details, we identified the main sources of knowledge within organization 4.0, shedding light on the dynamics that occur between the various "actors" that contribute to knowledge transfer within the organization 4.0. According to previous literature (e.g. Peinl, 2017), we pointed out that, besides the individual, advanced technologies play a critical role in the creation and dissemination of knowledge. Furthermore, our research helps to bridge the existing gap between two issues, skills for I4.0 and knowledge transfer processes, so far analyzed separately. Indeed, it provides first insights into the main skills required to facilitate the interaction between various organization 4.0's actors.

Moreover, by delineating the skills that best fit with the organization 4.0 to facilitate knowledge transfer, the paper provides useful guidance to HR managers not only during the recruiting process but also for an optimal human resources allocation. Indeed, the proposed model provides a general picture of the potential contribution of the single operator in terms of knowledge sharing within the organization. However, while knowledge sharing is extremely important, it does not in itself suffice to guarantee the suitability of an individual to work in an organization 4.0. Therefore, the model should be used to support and complement an assessment model of the I4.0 competences that are needed to fill a specific role (e.g. Erol et al., 2016; Hecklau et al., 2016; Simic & Nedelko, 2019). The integration of models can allow the company to develop a highly qualified workforce, assisting HRM as well as all operators in coping with the challenges presented by the increasingly digitized I4.0 scenario and, consequently, achieving strategic results (Armstrong & Taylor, 2020).

This study is far from claiming to be exhaustive. It is intended to be a preliminary analysis to a more in-depth empirical study that would allow to verify, deepen, and improve the scheme described, through the direct contact with companies. In addition, further research would be needed to broaden the analysis by including further significant elements; i.e. it could be integrated a deepening analysis of different types of knowledge, as well as the intrinsic and extrinsic motivations (Ipe, 2003), or even a more technical reflection on digital tools that can enable knowledge sharing. Moreover, this article does not focus in-depth on the underlying dynamics of interpersonal relationships; however, understanding how groups, operators 4.0, and organizations interact could be useful for improving our framework.

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