

## Competences in digital servitization: a new framework

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### Abstract:

This paper contributes to the research on servitization in manufacturing companies. Its main purpose is to describe and explain how the evolving technological landscape is influencing the skills that companies seek for facilitating the service growth. Grounded on the actual knowledge on this topic, this study presents some preliminary findings from an on-going research, that focus on the impacts of digital transformation on competences and capabilities of manufacturers. To this concern, this paper is also part of the broader set of studies on the forth industrial revolution (I4.0), and on the changes to organization of manufacturing firms due to the raise of digital business and smart products, smart services, smart workplace, etc. The main contributions of this research are twofold: first we propose a theoretical framework that - based on the review of the existing literature – sheds lights on the trends of “digital servitization”. Second, we explore the competences that support the digital servitization (i.e. “digital competences”). To achieve this latter objective, we carried out interviews with CEOs, HR and service managers of companies undergoing servitization and digital transformation. This study also provides avenues for further research dealing with competences for the I4.0 revolution.

**Keywords:** Digital transformation, servitization, competences, I4.0, framework

### 1. Introduction

The introduction of digital technologies in manufacturing firms, and their integration with operational technologies, are core to the fourth industrial revolution (I4.0). This combination is expected to have far-reaching implications on competitive advantage and market pressures (McKinsey Company 2015; The Boston Consulting Group 2015), as well as on industries and supply chain organization (Porter and Heppelmann, 2015). This changing landscape requires workers with higher and diversified competences (Capgemini Consulting 2014). The transformation of workplaces is changing job profiles. Employees are required to outfit with skills ranging from data elaboration to communication, in order to face increasingly complex and interactive tasks, and take data-driven decisions (Carnevale and Smith, 2013). The shift to service business (i.e. servitization) in combination with the digital revolution amplifies these changes, in particular for individuals working in the service department of manufacturing companies. Training and recruiting people with this digital mindset is vital for keeping up with innovation and servitization. Although this subject has high-priority in many studies and research on I4.0, exploration remains rather abstract. Most papers are example-based and limited to a specific industry. Following this standpoint, this study aims to:

- (i) Create a theoretical framework that sums up the current body of knowledge on this topic, to sheds lights on the competences that should be developed by individuals for successfully facing the challenges related to I4.0 and digital servitization,
- (ii) Identify and set implications and opportunities for future research on digital competences.

In order to achieve these objectives, we made a systematic literature review, and carried out numerous interviews with C-level managers of large companies. Last, we organised a round table with experts of HR management, as part of a well-attended conference that yearly debates issues connected to the service transformation. This paper is structured as follows: section 2 provides a brief research background on digital servitization and competences, section 3 outlines the methodology we used in order to define our digital competences’ framework, whereas section 4 presents the research findings. Finally, section 5 discusses the theoretical and managerial implications and sets directions of future research.

### 2. Background

In this section, we describe what we call the “digital servitization” of manufacturing companies, and identify the main gaps which lead us to explore the competences and skills that are required by this transformation.

## 2.1 Digital servitization

Manufacturing companies are facing a continuously changing business environment. To differentiate themselves from fierce competition, react to product commoditization and increase profits, product-centric firms are complementing their offerings with more and more services. The effects of this strategy, which is termed with different names (e.g. servitization, service infusion, service transformation, etc.) have been explored since more than a decade (Neely, 2009; Baines et al., 2008). It is also known that digital technologies can facilitate this transformation (Lerch et al., 2015). In fact, technologies such as Cloud Computing, or Big Data and Predictive Analytics, are radically changing the way services are delivered to customers, and their adoption can be crucial to move towards more service-oriented business models (Ardolino et al., 2017). As a consequence, there is a growing strand of studies that focus on “digital servitization”, and explore how manufactures leverage digital technologies so to raise the value of their product-service offerings (Song, 2016), increase the service delivery process (Kwak et al., 2015), develop smart services (Wunderlich et al., 2013) and enable more service-oriented business models (Adrodegari et al., 2017). Among the biggest challenges there are the changes to the company culture (from product- to service-dominated), to organisation (from product-production to customer-centric), to leadership style and people competences (Demirkan et al., 2015). Specifically, people involved in the transformations connected to a digital servitization strategy need new competences and skills, in order to apply for new roles and jobs. The next section illustrates the current body of knowledge on this topic.

## 2.2 Digital competences

Numerous reports suggest that digital technologies are profoundly impacting on the future of jobs (World Economic Forum, 2016). In particular, simple, repetitive and standardized tasks will be more and more automated, and workers will be replaced by machines (Brynjolfsson and McAfee, 2012). Jobs lost is remarkably expected in both assembly and production task, due to robots and digital automation (The Boston Consulting Group, 2015). Despite the raise and progress of these technologies, some authors claim that humans will remain the core factor in manufacturing companies (Schirmer, 2013). However, they need to adapt and develop new knowledge and new ways of working (Bondarouk and Ruel, 2009). It is then crucial for companies to support their employees in developing the skills required by the digital workplace. In this avenue, a lot of work has still to be done: according to a recent survey (Europe’s Digital Progress Report, 2017), 37% of labor force in EU had insufficient digital competences, whereas 11% had none. It is worth noticing that “digital competences” entail a broader set of hard and soft skills, connected but not imperatively limited to the proficient use of ICTs (Bowles, 2014). For instance, the European Commission has defined

“digital competence” as those skills that allow a confident and critical use of the Information Age technologies (Punie and Cabrera, 2006). Despite their relevance, a specific definition is still missing, and there is paucity of studies that shed lights on this topic (van Deursen and Van Dijik, 2009). Various institutions, consortia and policy makers have issued projects aiming to define the proficiencies level of digital competences that are required to foster innovation in business firms (Ilomäki et al., 2011). A consistent framework is also needed to systemize, rationalize, describe and classify each digital competence that manufacturing companies are seeking for (Ras et al., 2017). Managers could exploit these frameworks to guide recruitment and requalification of employees. In the next section we illustrate the research strategy that we follow to contribute to this topic.

## 3. Research design

The research was carried out between June and December 2017. The process consisted of three main phases (i.e. conceptual development, application and preliminary validation) as illustrated in Figure 1 and described in the remaining of this section.

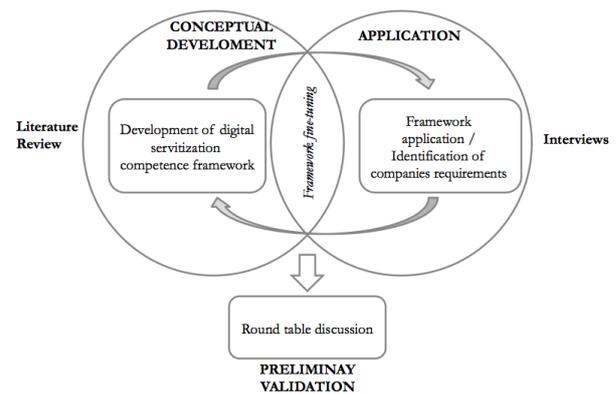


Figure 1: Research design

### 3.1 Conceptual development

Despite the fact that this research is in its early stage, we conducted a literature review (Voogt and Roblin, 2012) to explore existing theories and summarize the current body of knowledge, before gathering any further data about problems and practices. The main objective of this review was to identify and classify the competences requested for digital servitization. Our review encompassed English-speaking peer-reviewed papers, practical articles, reports and white papers, covering the period from 2000 to 2017. A keyword search was conducted in the Scopus database and Google Scholars, with keywords such as: “competences”, “skills”, “capabilities” combined with “digital”, “Industry4.0”, “servitization”, “digital technologies” and “framework”. We scrutinized the found articles based on their title and abstract, and excluded contributions not pertaining to theoretical models and classifications of digital competences. Finally, 28 papers that met the inclusion criteria were read in detail and scrutinized. To ease the

content analysis, we designed a structured database where each competence provided by the selected papers were listed. In particular, if the same competence was mentioned with a synonym in different papers e.g. “data analysis” and “big data analysis”, but clearly with similar meanings, we considered it as one entry of the database. In this way we also aim to contribute to the harmonization of the terminology, facilitating a common understanding of these competences, for both researchers and practitioners. Building on the analyzed body of literature, we developed a first version of the framework for digital servitization competence.

### 3.2 Application

Due to the exploratory intent of this research, we conducted interviews with companies aiming at identifying the competence requirements from a managerial point of view. We prepared an interview guideline, which included the developed competence framework, in order to collect primary qualitative data and to stimulate the discussion with the interviewees. This application helped us also to test its completeness, comprehensiveness and managerial applicability. The above interview guideline consists of twelve open questions on different areas such as trends, technologies, competences, roles, recruitment, training, and obstacles to digital servitization, that were all aspects emerged from the literature review. We use this script to interview numerous C-level managers working in different industries. This greatly enhanced the validity and reliability of the data collection method. The companies were selected according to the following criteria: a) they should be well acknowledged servitized firms; b) they should be large multinational companies; c) they should have shown interest to the research objectives, and trust towards the overall quality and expertise of the research team. We therefore conducted 22 in-depth interviews with managing directors, country managers, service directors and HR directors of 14 companies from different industries. These included industrial machinery, construction machinery, computer industry, consumer electronics, electrical equipment, automation, domestic and professional appliances. Interviews lasted around 60-90 minutes each and involved at least 2 researchers taking notes and posing follow-up questions regarding the interviewees’ perceptions and understandings. Moreover, all the interviews were recorded after asking permission, to facilitate the following analysis and elaboration. The interviews were conducted either in Italian or in English but the material was translated to English after transcribing the recordings. Due to anonymity requests, the participants of this research are numerically presented as “Interviewee #” throughout this work. Specific analysis was then conducted with coding and synthesis being aided by mind-mapping techniques (NVIVO), and this led to common themes being established as responses to the principal research questions.

### 3.3 Preliminary validation

Finally, to validate the framework derived from both the literature analysis and interviewed companies, we organized a final round table discussion with experts. This was held on 2017 November 7, in Milan (IT) at the XIV ASAP International Conference. Around 200 people from 132 companies attended the conference. Following the guideline of nominal expert technique (i.e. expert panel), the round table included participants that were selected on the basis of their company role and proven expertise on innovation and digital competences. We invited the Head of Education and Communication of TIM Academy (the biggest telco company of Italy), the CEO of Men at Work (a very large temporary work agency), the HR director of Canon Italy, the HR director of CGT (Italian dealer of Caterpillar), and the General Manager of Stilmas, a company producing clean water plants for pharmaceutical and bio-tech industries. A moderator led the discussion of the panelists, thus helping to keep focus on the debated topics. He looked particularly after to the fact that each participant had the same amount of time to discuss his/her views. Initially, a researcher presented the digital competence framework, then each panelist in turn was specifically asked to comment and reply. It was largely debated if they could find analogies in their organization. Each panelist agreed on the needs of developing the framework competences, and on the linkages with digital servitization. In addition, each expert was requested to communicate their own suggestions and conjectures on how their companies could have developed and procured the most relevant competences. In the following section we present the findings of this research, in the form of a preliminary attempt to develop a framework for digital competences.

## 4. Findings

The first version of the framework was created on the base of the reviewed literature. The most mentioned competence in the literature on digital servitization is data analysis (Prifti et al., 2017; van Laar et al., 2017; Kleindienst et al., 2016; Lenka, 2016; DigComp; Sjoedin et al., 2016; Schuh et al., 2017). Scholars firmly believe that the above-mentioned competence is necessary for succeeding in the transformation connected to the forth industrial revolution. It is also mentioned that effective communication, either related to technical or literacy issues, is key to service and digital innovation (Prifti, 2017; van Laar et al., 2017). Since I4.0 is all about digital technologies, the ability to apply expertise and use these technologies is vital. IT (cyber) security (Kleindienst, 2016, DigComp, 2016), process digitalization (Schuh et al., 2017; Lorenz et al., 2017), operation research (van Laar et al., 2017), software programming (Lorenz et al., 2016), awareness of the impacts and potentials of new technologies (DigComp, 2016), are some of the most significant competences. In addition to the technical competences and hard skills mentioned above, some soft skills and behavioral competences are also relevant for life-long

learning in the digital age (van Laar, 2017); for instance, self and time management (Cleary et al., 2017), collaboration, negotiating and emotional intelligence have an important role in teamworking and leadership for innovation projects. The majority of interviews strengthened these findings, and specifically stressed out the relevance of the following abilities: the capacity of creating digital content in technical or commercial form; the capacity of acting as a leader, the capacity of speaking in the customer’s language. Taking into account any results from both the literature and the case study research, we developed our digital competence framework that is presented in Table 1.

Table 1: Framework for digital servitization competences

DATA ANALYSIS & MANAGEMENT	DIGITAL CONTENT CREATION	SOFT SKILLS	INNOVATION APPETITE
Find, collect, elaborate & analyse data	Creation of digital content in technical & commercial form	Communication in customer’s and stakeholder’s language	Knowledge of impacts and risks of new technology, and of adoption approaches
Manage data security (cybersecurity) & protect digital assets	Problem-solving, creativity, logical thinking, design new solutions	Teamwork attitude	Management of projects for the introduction of new/digital technologies
	Design & development of software & hardware	Leadership	
		Results orientation, time & stress management	

We grouped the digital competences into four categories: a) data analysis and management, b) digital content creation, c) soft skills, and d) innovation appetite. In respect to the first group (i.e. data analysis and management), it is worthwhile noting that two different categories are considered: the first is related to the ability of finding, collecting, processing and analyzing data. The second to cybersecurity and digital assets protection. As confirmed by many interviewees, it is essential that employees can evaluate the most suitable sources, find the most appropriate data, and navigate among them. For example, Interviewee 3 said “The data scientist should be able to transform the information into something that is actionable for the business and for the managers”. Managers also expects that data scientists supporting the service transformation are highly skilled in advanced methods such as simulation modeling and analysis, statistical techniques, machine learning application. This is confirmed by the following sentence by Interviewee 14, that explained us how much crucial is the “Developing of data-driven

simulation tools, to study the accuracy of demand forecast using techniques like regression models”. As far as security issues are concerned, it is agreed that employees should be aware of the importance of technologies and practices for protecting sensitive data, as well as data that cannot be disclosed. Interviewee 7 claims that it is crucial that employees should act adequately to protect networks, computers, programs and data from attack, damage or unauthorized access. The second group (i.e. digital content creation) consists, firstly of being able to create digital contents in technical and commercial form. In this case, the focus is on creating contents such as presentation, articles, videos, podcasts, etc. in order to communicate and express oneself and the company thoughts through digital media. Many interviewees insisted about the relevance of the mentioned competence, otherwise abilities in data science are past time. Secondly, we found that creativity together with critical thinking and complex problem solving, are requested to facilitate the conception of solutions to ill-structured problems, that are typical of the shift to a service-based business. Another skills-set that we found remarkably appreciated concerns the capacity of writing codes and creating programs and user application, to support and automatize complex tasks such as data entry, data analysis, cost calculation, etc. Interviewer 18 claimed that “Developing digital applications is one of the most demanded competences nowadays”. The third group (“Soft skills”) encompasses those social skills that are fundamental to work and live in a complex social environment. For instance, effective communication abilities. This was considered a core - but not yet so well developed - competence, i.e. being able of speaking the language of every internal and external counterparts (e.g. colleagues of other departments, customers, suppliers, management board, etc.). In fact, it is agreed that the service transformation requires more integrated processes, in product/service development, planning, execution and control. People then need to adopt common ground, standard work processes and joint vocabulary, to establish effective collaboration among the different functions and departments. More than the half of the interviewees stressed out the importance that more communication skills are needed in this respect, towards internal and external stakeholders. As Interviewee 2 notifies, “the lack of communication between the employees could lead to an important reduction of efficacy of the innovation process”. The quest for “teamwork attitude” and leadership, the next two skills included in this category, is greatly connected to the previous concept. As said, in every social system, humans need to cooperate and collaborate, and any efforts lead towards common objectives. About 16 interviewees indicated that leading people towards innovation is essential in the current competitive arena. Emotional intelligence, empathy, and the ability of convincing and mobilizing people, strongly characterize the traits of the requested leaders and intrapreneurs. Last but not least, results orientation,

time and stress management, were also cited as important skills. For example, Interviewee 4 recognizes the great importance of being responsible of your own time, especially during the digital era, in respect also to the allocation of this time to learn new things that can be useful in the next future. The last group (“innovation appetite”), include a general knowledge about the impact and potentials of new technologies, as well as the capacity of evaluating costs, benefits and any risks related to their use for business purposes. About half of the interviewees suggested that it is key having in their team people that know the impact of new technologies. Additionally, it was said that the capacity of managing innovation projects, i.e. project connected to the adoption of these technologies, was relevant too. Being able to overcoming resistance and aversion to changes is acknowledged to be core for service innovation. Interview 8 indicated that the introduction of new technologies could be better achieved if people were experienced from previous participation to innovation projects. As said, the framework was presented to the panelists during the ASAP conference, as they agreed to join the roundtable. Generally speaking, all the experts agreed on the fact that all the competences included in the framework could be relevant for digital servitization. In certain cases, (i.e. Head of Education and Communication of TIM) it was said that the proposed framework complies with what they used for internal assessment and for designing training initiatives. This sentence will make more clear this concept: “The TIM Academy has the duty of training about fifty new profiles that have been identified and will be core to our digital transformation”. Furthermore, the manager said that in TIM about 200 people were hired to act as “innovation evangelists”, with the responsibility of getting knowledge over new technologies, participate to events, research collaborations, and providing support to pilot projects. This again fits well with the fourth pillar of the framework (i.e. “innovation appetite”). The managers participating to the round table stressed also the importance of adopting sophisticated talent management systems, that should be aligned with the company strategies and values. For instance, the HR director of Canon said that they are under a major transformation. They are working hard to define the digital competences that are requested to facilitate this innovation, putting humans and their well-being the center of the company’s values and objectives. In fact, each employee – in collaboration with his/her boss – has a certain freedom in deciding which skills should be developed in relation to the desired career paths. This way, self-interests can be matched with the company’s ones. Of course, this approach presupposes a certain extent of self-empowerment that is still missing in most employees. The HR Manager of CGT stressed out the importance of leveraging digital technologies to provide smart services. As said, “CGT has already launched a digital business unit. They are projecting an application which will indicate to the customer the availability of each machines. Carrying out these projects will help us

to understand which competences are missing in our department, and then we will work to develop or integrate them, also with the aid of our network partners”. The General Manager of Stilmas claimed that in his relatively small market niche, the creation of a digital business is more and more important. The company struggles to facilitate this transformation, and many “old traditions” are going to be broken. According to the same panelist, the challenge is changing the companies’ culture. In sum, all these companies are looking for a new kind of employee: CGT is looking for people with *passion*, Men At Work’s suggest that any manager should *surround himself/herself with fantastic people*. Motivation and quality of people and relationships in the workplace appear thus as crucial driver to support complex innovation processes.

## 5. Conclusions

### 5.1 Research and managerial implications

Despite the importance of the digital revolution and of the move of manufacturing companies to a service business, our research shows that the actual contributions on the digital competences that support these transformations are scarce. In addition, existing studies highlight the transformations in the workplace without a concrete view on the linkages and interplay between individual skills/competences and organizational capabilities. For that reason, building on the existing studies and empirical research, we developed a theoretical framework to identify and classify the digital competences requested by manufacturing companies undergoing digital servitization. We organize in four categories/pillars the different competences that have been identified, on the base of the capabilities they enable. Moreover, by grouping these aspects into a set of common dimensions, allows harmonizing the different terms used in literature. The combination of this framework with the innovation dynamics of manufacturing firms is entirely new to our best knowledge. Comprehensively, our work focuses on the competences that an employee should develop in order to contribute to the new transformations and to the social system in which she/he lives and works. Through a literature review, numerous interviews, and an expert panel, we brought up both skills related to behaviors and competences related to technologies and innovation attitude. This research has practical implications. The proposed framework can be used in practice both by researchers and managers. It can support firms in defining which skills are necessary to support complex transformation. Moreover, the results are useful for determining the needs of training/reskills employees, as well as the mechanisms for recruitment new talents.

### 5.2 Future research

As with any research, this study comes with limitations, some of which offer fruitful avenues for future research. Firstly, the extension of the research to different sectors

would support a greater generalization of the findings. For example, future research should perform explanatory surveys in order to test the significance of the competences in different industry sectors as well. Secondly, although the framework provides a detailed and structured description of the necessary digital competences, it adopts a static approach. Future studies could adopt this framework to develop assessment methods that aim to establish the skill proficiency that is needed, in a certain team/transformation. This way, the digital competence model can help elaborating the organizational strategies in terms of recruitment and requalification/reskilling of the existing workforce. Last but not least, future research may use the digital competence framework to identify a list of competences for every emerging professional role, e.g. which competences a data scientist should bring. This study is exploratory in nature and should be considered as a starting point.

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### References

- Adrodegari, F., Saccani, N., Kowalkowski, C., and Vilo, J. (2017). PSS business model conceptualization and application. *Production Planning and Control*, 28(15), 1251-1263.
- Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G. and C. Ruggeri (2017). The role of digital technologies for the service transformation of industrial companies, *International Journal of Production Research*, 83(10), pp. 1–17.
- Baines, T.S., Lightfoot, H.W., Benedettini, O. and J.M. Kay (2008). The servitization of manufacturing: A review of literature and reflection on future challenges, *Journal of Manufacturing Technology Management*, 20(5), pp. 547–567.
- Bechtold, J., Lauenstein, C., Kern, A. and Bernhofer, L. (2014). Industry 4.0 – The Capgemini Consulting View. Capgemini Consulting.
- Bondarouk, T., and Ruel, H. J. M. (2009). Electronic Human Resource Management: challenges in the digital era. Guest-editors' Introduction to a Special Issue. *International journal of human resource management*, 20(3), pp. 505-514.
- Bowles, J. (2014). The computerisation of European jobs. Blog post, Bruegel.
- Brynjolfsson, E. and McAfee, A. (2012). Race against the Machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy. The MIT Center for Digital Business.
- Carnevale, A., Smith, N. and Strohl, J. (2013). Job growth and education requirements through 2020. Recovery.
- Cleary, M., Escott, P., Lees, D., and Sayers, J. (2017). High Hopes and Expectations: Consumer Disappointment and Recovery. *Issues Ment Health Nurs*, 38 (3), pp. 280-282.
- Demirkan, H., Bess, C., Spohrer, J., Rayes, A., Allen, D. and Y. Moghaddam (2015). Innovations with smart service systems: Analytics, big data, cognitive assistance, and the internet of everything. *Communications of the Association for Information Systems*, 37(1), pp. 733–752.
- Europe’s Digital Progress Report (2017). European Commission. Brussels.
- Gebhardt, J., Grimm, A. and Neugebauer, L.M. (2015). Developments 4.0 Prospects on future requirements and impacts on work and vocational education. *Journal of Technical Education*, 3(2), pp. 117-133.
- Iloäki, L., Kantosalo, A., and Lakkala, M. (2011). What is digital competence? In Linked portal. Brussels: European Schoolnet.
- Kagermann, H., Wahlster, W. and Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Acatech.
- Kleindienst, M., Wolf, M., Ramsauer, C. and Pammer, V. (2016). What workers in Industry 4.0 need and what ICT can give – an analysis. 16th International Conference on Knowledge Technologies and Data-driven Business. October 19, 2016 Graz, Austria
- Kwak, J.-Y., Kim, S.-T., Lee, K.H. and Yang, S. (2015). Service-oriented networking platform on smart devices. *IET Communications*, 9(3), pp. 429-439.
- Lenka, S., Parida, V. and Wincent, J. (2016). Digitalization capabilities as enablers of value co-creation in servitizing firms. *Psychology and Marketing*, 34(1), pp. 92-100.
- Lerch, C. and M. Gotsch (2015). Digitalized Product-service Systems in Manufacturing Firms: A Case Study Analysis, *Research-Technology Management*, 58(5), pp. 45–50.
- Lorenz, M., Kupper, D., Russmann, M., Heidemann, A. and Bause, A. (2016). Time to accelerate in the race toward Industry 4.0. The Boston Consulting Group.
- Lorenz, M., Russmann, M., Strack, R., Lueth, K.N. and Bolle, M. (2015). Man and Machine in Industry 4.0, How will technology transform the Industrial workforce through 2025? The Boston Consulting Group.

- McKinsey Global Institute, Jobs Lost, Jobs Gains: Workforce Transitions in a time of Automation, December 2017.
- Meier, H., Völker, O. and Funke, B. (2011). Industrial Product-Service Systems (IPS2) : Paradigm shift by mutually determined products and services. *International Journal of Advanced Manufacturing Technology*, 52(9-12), pp. 1175-1191.
- Neely, A. (2009). Exploring the financial consequences of the servitization of manufacturing. *Operations Management Research*, 1(2), pp. 1–50.
- Porter, M. and Heppelmann, J. (2015). How smart, connected products are transforming companies. *Harvard Business Review*.
- Prifti, L.; Knigge, M.; Kienegger, H. and Krcmar, H. (2017): A Competency Model for "Industrie 4.0" Employees, in Leimeister, J.M.; Brenner, W. (Hrsg.): Proceedings der 13. *Internationalen Tagung Wirtschaftsinformatik*, St. Gallen, S. 46-60.
- Proposal for a council recommendation on Key Competences for LifeLong Learning (2018). European Commission. Brussels.
- Punie, Y., and Cabrera M. (2006). The Future of ICT and Learning in the Knowledge Society. Report on a Joint DG JRC-DG EAC Workshop. Seville: European Commission Joint Research Center.
- Ras, E., Wild, F., Stahl, C. and Baudet, A (2017). Bridging the Skills Gap of Workers in Industry 4.0 by Human Performance Augmentation Tools – Challenges and Roadmap. Proceedings 10th International Conference PErvasive Technologies, pp 428-432.
- Schirner, G, Erdogmus, D, Chowdhury, K. and Padir T. (2013). The future of human-in-the-loop cyber-physical systems *Computer*, 46(1), pp. 36-45.
- Schuh, G., Anderl, R., Gausemeier, J., Hompel, M. and WahlsterSjoedin, W. (2016). Industrie 4.0 Maturity Index, Managing the Digital Transformation of Companies. Acatech Study.
- Song, W. (2016). Requirement management for product-service systems: Status review and future trends. *Computers in Industry*, 85, pp. 11-22.
- van Deursen, A. and Van Dijk, J. (2009). Using the Internet: Skill related problems in users' online behavior. *Interacting with Computers*, 21 (5-6), pp. 393-402).
- van Laar, E., van Deursen, A., van Dijk, J. and de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, 72, pp. 577-588.
- Voogt, J., and Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, 44(3), pp. 299-321.
- Vuorikari, R., Punie, Y., Carretero Gomez, S. and Van den Brande, G. (2016). DigComp 2.0: The Digital Competence Framework for Citizens. Update Phase 1: The Conceptual Reference Model. JRC Science for Policy Report.
- World Economic Forum (2016). The Future of Jobs, Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.
- Wünderlich, N.V., Wangenheim, F.V. and Bitner, M.J. (2013). High Tech and High Touch: A Framework for Understanding User Attitudes and Behaviors Related to Smart Interactive Services. *Journal of Service Research*, 16(1), pp. 3-20.
- Yin, Robert, K. (1984). *Case study Research, Design and Methods. Applied Social Research Methods Series*. International Educational and Professional Publisher, 5, pp. 1-53.