

Digital Intelligence as Prerequisite of Artificial Intelligence's Integration in the Clothing Industry 4.0

Evangelia Kampakaki
Creative Design and Clothing Department
IHU International Hellenic University
Kilkis Greece
evakampakaki@gmail.com

Evridiki Papahristou
Creative Design and Clothing Department
IHU International Hellenic University
Kilkis Greece
evridikipapa@ihu.gr

ABSTRACT

Technological progress has been continuously changing the fashion industry and the way our society works, produces and consumes. Industry 4.0 focuses on cyber-physical systems, the Internet of Things and cloud computing and is extended to the entire supply chain beyond manufacturing, to all textile and apparel supply chain functions, including forecasting, consumer research, design, product development, merchandising, sourcing, production, retailing and distribution. The rise of robotics and Artificial Intelligence calls for new skills and competencies. Fashion industry employees are expected to have appropriate competency. The new age employees need to be equipped with a new set of skills in order to master technology, explore new possibilities, convert the new ideas into actions, communicate and collaborate with other people and with machines. In addition, a new way of thinking is developing in the digital environment, called Digital Intelligence. It could be considered as the outcome of people's need and their effort to adapt themselves to the continuously expanding digital environment. On top of that, as more complicated digital technologies will appear in the future, digital intelligence could probably evolve into the most necessary type of intelligence for success in the digital era. Despite the great importance of the subject, there is a gap in research that examines the required digital competency and intelligence of the future workforce in the apparel industry especially in our country. Such research will provide academic programs with an up-to-date assessment of potential industry workforce needs, allowing educators to make necessary changes to their curricula to better prepare students with the required skillsets.

KEYWORDS

Digital Intelligence, Artificial Intelligence, Clothing Industry 4.0, workforce digital competence

1 Introduction

Continuous technological progress undoubtedly affects and changes, in addition to our daily lives, every industrial activity. Smart devices, wearables, the Internet of things, Big data, smart industries, cloud computing, Artificial Intelligence (AI) and machine learning, robotics, human-machine interaction, social media and digital integration in all areas have changed the way we work, communicate, travel, being educated, consume, produce, live and form our lives.

From all these changes, the apparel industry could not be an exception. Although at a slower pace than other industries, the fashion industry was not unaffected by the technological revolution, the so-called 4th Industrial Revolution or Industry 4.0. New ways of production, new ways of communication, transactions, distribution, suppliers and customers approaches, run through the entire clothing chain. Workers in the clothing industry could not be unaffected by the new reality. Different ways of working and working environments, new tools, different working conditions, creation of new jobs and elimination of others, teleworking, different qualifications of the workforce, advanced requirements that an employee has to master in order to meet the new conditions in Industry 4.0, constitute the new reality.

In this reality some questions need to be answered. What are the characteristics of the new digital environment and what is the position of the clothing industry in the age of industry 4.0? How does artificial intelligence affect the environment of modern industry and in particular the clothing sector and what impact does this have on those employed in it? Are the employees and the future employees equipped with the appropriate qualifications of the new era? What are these qualifications? As the clothing industry incorporates more and more digital tools, what knowledge, skills and attitudes should the workforce need in order to make the most of the potential of "digital fashion"?

Future employees must possess digital competency in the Industry 4.0. But how can we define a framework for the digital

competency of employees as required by the modern fashion industry? Or do we now have to talk about a new way of thinking, the so-called digital intelligence in order to respond to a more conscious effort of people to adapt to a constantly changing environment?

Our literature review shows the lack of research data on the digital qualifications that people in the modern clothing industry have and should have. We aim to highlight the importance of exploring the digital competence of workers in the modern apparel industry. It is becoming clear that this will help to carry out appropriate training programs but also to cultivate a more general philosophy of lifelong learning of the workforce, in order to adapt and meet current and future requirements.

2 New Digital Environment

The world is constantly changing and evolving at a rapid rate, this has affected many companies and the entirety of their supply chain including all of its actors. This dynamic nature has put pressure on companies to innovate, collaborate and redesign business processes that best fit their business; hence, this calls for incorporation of various technologies and integrated enterprise solutions to manage complex and intricate processes [17]. Digital technologies bring both opportunities and challenges for the sustainable development of manufacturing companies [16].

With the development and industry revolution taking place production will take place much more differently. Physical beings and machines will be more connected and will communicate with each other. In future factories humans will have to work with a complex world of processes, networks of processes, machines, sensors, robotics and devices. This system will require different operating concepts for a better human-machine relation operation. In the future quick, intelligent and self-adoptive manufacturing processes will be the measurement of success and a competitive advantage [17].

The increasing digitalization of all manufacturing and manufacturing-supporting tools is resulting in the registration of an increasing amount of actor-and sensor-data which can support functions of control and analysis. Digital processes evolve as a result of the likewise increased networking of technical components and, in conjunction with the increase of the digitalization of produced goods and services, they lead to completely digitalized environments. Those are in turn driving forces for new technologies such as simulation, digital protection or virtual responsibility and augmented reality [12].

With the deep integration of intelligent technologies in the manufacturing industry, there has been a digital transformation that has changed the traditional production and operations management methods and offers the potential for the improvement of product development, production efficiency and customer service [16].

Digital technologies such as artificial intelligence, robotics and automation are transforming the world of work. Developing the

appropriate digital skills in the workforce is an important component in order to compete in this rapidly emerging global digital economy [5].

3 Industry 4.0 – Apparel Industry 4.0

The increasing fusion of Industrial production and Information and Communication Technologies (ICT) has brought the so-called Industry 4.0 into the manufacturing world. This phenomenon is making possible to connect information, objects and people due to the convergence of the physical and the virtual worlds and is enabling the transformation of factories into smart environments [1].

In the new era of Industry 4.0, the development and adoption of digital technologies has become one of the most frequently trending topics in both academic and professional areas. The term “digital technologies” refers to a collection and a paradigm of various intelligent and innovative technologies in the era of Industry 4.0, such as big data analytics, the Internet of Things and cloud computing, which realize connectivity, communication and automation [16].

The economic impact of this industrial revolution is supposed to be huge, as Industry 4.0 promises substantially increased operational effectiveness as well as the development of entirely new business models, services and products. Enabled through the communication between people, machines and resources the fourth industrial revolution is characterized by the integration of the Internet of Things (IoT) into the manufacturing process, the fusion of the physical and the virtual world and smart factories connecting people, machines, products and data. These connections lead to new ways of organizing and conducting industrial processes [8].

More recently, scholars suggest that the concept of Industry 4.0 could be extended beyond manufacturing or factories to the entire supply chain. With the help of information technology, data from each supply chain member can be shared with the whole supply chain instantly. Logistics and finance departments would also get instantly updated in order to prepare shipping and distribution needs. Simultaneously, the feedback of production information could guide marketing and sales teams to help develop timely retail and promotion strategies, ultimately responding to end-users’ behavior [24].

Connecting people, objects and systems leads to the creation of dynamic, self-organized, cross-organizational, real-time optimized value networks, which can be optimized according to a range of criteria such as costs, availability and consumption of resources [19]. Digital technologies create opportunities to develop new business models, serve customers in innovative ways, and run organizations more efficiently and profitably.

The new challenge of the apparel industry is the digital approach. Digital fashion is the interplay between digital technology and couture. ICTs have been deeply integrated both into the fashion industry as well as within the experience of clients and prospects.

In the production cycle, digital technologies are being used in the fabrics manufacturing. Digital tools support creativity of the fashion designers, as well as make it easier for them to develop a large variety of products. At the same time, digital fashion includes also digital practices in the physical shops as well as eCommerce or the online sales of the fashion items [9].

Fashion Apparel Industry 4.0, called a “smart apparel factory,” is the current trend of automation and data exchange in apparel manufacturing technologies. As a combination of several major innovations in digital technology, it includes the Internet of things, cloud computing, and cyber-physical systems that communicate and cooperate with each other in real time, used by participants of the value chain driving a new shift of change across the economy, with major implications for the fashion market – including RFID, sophisticated sensors, digital printing and fabrication, 3D product development, and more [2].

The growing popularity of social media and the prosperity of e-commerce has produced massive amounts of cross-media fashion data, such as street data shared by users, runway show data released by fashion brands and product data provided by e-commerce sites, displaying a rich and complex set of multimedia contents. Therefore, understanding and analyzing the semantics of large-scale cross-media fashion data through machine learning and computer vision techniques is one of the essential business analytics and technology tools for revolutionizing the industry and reshaping the mechanics of fashion. For instance, an increasing number of popular designers and brands are leveraging leading social networks to survey customer preferences, such as opinions, ideas, feedback, and trends [7].

The consequences for fashion industry leaders are clear: more than ever before, they need to refocus on a few truly distinguishing core capabilities to create sustainable value in the future. Digital capabilities are vital for moving forward with Industry 4.0. Apparel industry businesses must be proactive and adopt and adapt to new mindsets and management tools and digital culture to take full advantage of information technologies [2].

4 Artificial Intelligence in Fashion industry

Integration of Artificial Intelligence (AI) with recent emerging technologies such as Industrial Internet of Things (IIoT), big data analytics, cloud computing and cyber physical systems will enable operation of industries in a flexible, efficient, and green way [13].

With the current popularization of the Internet, the universal existence of sensors, the emergence of big data, development of e-commerce, rise of the information community, and the interconnection and fusion of data and knowledge with society, physical space, and cyberspace, the information environment for AI development has been changed profoundly. AI technology facilitates the development of new models, means, and forms, system architecture, and technology systems in the domain of intelligent manufacturing [14].

With the emergence of the big data era, companies, and more especially fashion companies, are faced with a new relationship between consumers, suppliers, and competitors. Fashion companies have also to manage different data with many and complex correlations and dependencies between them and uncertainties related to human factors. It is crucial for companies to master these data flows to optimize their decision making. In such situations, artificial intelligent techniques are particularly efficient. The potential applications of artificial intelligence in fashion industry cover a wide scope from design support systems to fashion recommendation systems through sensory evaluation, intelligent tracking systems, textile quality control, fashion forecasting, decision making in supply chain management or social networks and fashion e-marketing [22].

AI is constantly integrating with industry. AI can improve the efficiency and quality of integrated innovation, enhance the flexibility of production, enrich the channels and forms of communication, stimulate the satisfaction and promotion of consumer demand, and deeply affect the development of fashion industry [14]. AI also has the potential to completely disrupt the fashion industry, not only because of new business models, new ways of production but also on account of the impact on the people employed in the fashion industry and on their jobs [20].

The application of AI has been recognized in the Fashion and Apparel (F&A) industry at various stages such as apparel design, pattern making, forecasting sales production, supply chain management. With the emergence of globalization and digitalization, AI has gained attention to connect businesses globally. In the last decade, the F&A industry has utilized AI to a certain extent for improving supply chain processes like apparel production, fabric inspection, distribution. This was important as the F&A industry is volatile and it is always challenging to quickly respond to change in trends and continuously evolving consumer’s demands. An additional impact of digitalization is noticed in consumer behavior in the F&A industry. The increase in awareness and advent of new offline and online mediums has changed the contemporary consumer’s decision-making pattern, influenced by the various online and offline mediums. It is, therefore, important to create digital platforms for efficient requirements elicitation and collection. This can be attained by utilizing the benefits accompanied by Information technology (IT), Artificial intelligence (AI) techniques, big data analytical tools and other current technologies [6].

5 Digital Intelligence-Digital competencies

Rapid changes in the nature of work, influenced by the adoption of new technologies across all sectors, have stimulated an ever-increasing debate in industry, as well as in policy and academic writing in recent years. At the heart of the debate are questions about the nature and impact of the changes, and the specific character of the skills that are and will be required by the workforce [5].

Industry 4.0 will lead to dynamic, international and interdisciplinary work environments. For being able to always adapt the latest technologies and make the most out of them, fashion schools graduates should apply life-long learning. Apart from behavioral competencies, graduates must also bring domain related competencies as well as the ability to apply expertise and use technology. In this area all graduates need to bring IT and technology affinity [18].

It is expected that future workers must possess digital ability and skills, or competency, to efficiently deal with digital resources and environments. Particularly, to address digital competency, researchers argue that future professionals must possess digital intelligence, which indicates the ability to adjust in the digital environment, and information, media, and technology skills [24].

'Digital competence' has become a key concept in the discussion of what kind of skills and understanding citizens must have in the knowledge society. Digital competence covers information management, collaboration, communication and sharing, creation of content and knowledge, ethics and responsibility, evaluation and problem solving and technical operations [10]

Digital competency is considered as the abilities and skills that future employees must possess, to successfully understand, apply, analyze, and create digital resources and environments in the Industry 4.0. This implies that a new way of thinking is developing in the digital environment, i.e. digital intelligence. It could be considered as the outcome of people's need and their effort to adapt themselves to the continuously expanding digital environment. And, as more complicated digital technologies will appear in the future, digital intelligence could probably evolve into the most necessary type of intelligence for success in the digital era [21].

According to DQ Institute [25], Digital Intelligence (DQ) is a comprehensive set of technical, cognitive, meta-cognitive, and socio-emotional competencies that are grounded in universal moral values and that enable individuals to face the challenges and harness the opportunities of digital life. DQ has three levels, eight areas, and 24 competencies composed of knowledge, skills, attitudes, and values [25].

One of the Digital Intelligence competencies is Data and AI Literacy, that is part of Digital Competitiveness ability. Digital Competitiveness is the ability to solve global challenges, to innovate, and to create new opportunities in the digital economy by driving entrepreneurship, jobs, growth and impact. According to DQ Institute [25], Data and AI Literacy is the ability to generate, process, analyze, present meaningful information from data and develop, use, and apply artificial intelligence (AI) and related algorithmic tools and strategies in order to guide informed, optimized, and contextually relevant decision-making processes [25].

More specifically, in terms of knowledge, Data and AI Literacy, means that individuals understand the theory of data analysis, statistics, and AI-related mathematical concepts and computer programming. They understand how data is generated, how to

process data based on statistical understanding, and know how to create and/or use AI algorithms (e.g., machine learning, neural networks, deep learning) to recognize significant patterns and to improve decision-making processes. They understand concepts across multiple disciplines and identify the benefits, limits, and risks brought about through big data, AI, and related technology [25].

In terms of skills, individuals develop efficient and stable processes to collect, store, extract, transform, load, and integrate data at various stages in the data pipeline. They read, manage, analyze, and process data from a variety of sources, and prepare data in a structure that is easily accessed and analyzed according to specific requirements. They create and build knowledge by analyzing data and communicate its meaning to others with various data visualization tools. With understanding of AI, they develop, select, and apply relevant algorithms and advanced computational methods to enable systems or software agents to learn, improve, adapt, and produce desired outcomes or tasks [25].

They understand how data and AI may affect one's perception and reasoning. Individuals are also able to leverage AI to augment their own intelligence while remaining aware of how human value judgements play into the applications of big data and AI in society. Finally, in terms of Attitudes and Values, Individuals are confident in pursuing innovative and analytical careers. They are also proactive in applying their knowledge of data and AI into evaluating whether broader systems are acting in ways aligned with community values that promote well-being [25].

Another approach [23] refers that Digital intelligence has four key elements. The first is to understand why we would want to use technology, its strengths and the opportunities to apply it to our advantage. The second is knowing our options, what technology is out there and the ability to choose the right tool for the job. The third is understanding how it works and having the ability to apply our digital tools in an effective way. Finally, we need to develop the judgement to know when technology should be used, when it is going to benefit what we are doing and when it is going to subtract. Out of the above four, it is perhaps the fourth, judgement, which is the most important. [23].

Researchers in their study [18] proposed a Digital intelligence quotient (DIQ), that encompasses a comprehensive set of technical, cognitive and socio-emotional competencies which enable an individual to face challenges and adjust to the digital era. Recently, great leaps in technology have profoundly influenced everyday living with significant changes for both daily and working life. In their research they proposed a comprehensive questionnaire encompassing eight DIQ dimensions as digital identity, digital use, digital safety, digital security, digital emotional intelligence, digital communication, digital literacy and digital rights [18].

The European Commission's science and knowledge service defines The Digital Competence Framework 2.0 and identifies the key components of digital competence in 5 areas: Information and data literacy, Communication and collaboration, Digital content

creation, Safety and Problem solving [4]. The digital competency that would be required in the Industry 4.0 could be constructed from both Digital Intelligence and Information, media and technology skills. [24].

6 The need to define skills

The current workplace requires highly skilled workers faced with increasingly complex and interactive tasks. Such workers are expected to efficiently select knowledge from the amount of available information and effectively apply such knowledge, both in their professional and personal lives. Employees not only need excellent technical preparation; they also need sufficient skills to adapt to the changing requirements of the job. Such skills are critical for both people and organizations for keeping up with developments and innovating products and processes. The growing impact of globalization and the knowledge society have led many to argue that 21st century skills are essential to be successful in the workplace and that ICT is central to their development. Importantly, these skills go beyond the mere technical annotation. How someone thinks, solves problems, and learns, has a greater impact on a person's ability to function in a technologically rich society than just being knowledgeable about specific software [10].

Technology has supported changes that have reshaped workplaces and the nature of work, which include flatter management structures, task teams, and cross-organizational networking. Since employees' skills drive organizations' competitiveness and innovation capacity, the rapid integration of new information communication technologies results in continuously evolving digital skills necessary for employment and participation in society. In an age where ICTs predominate, people need the capabilities to thrive in and beyond education. The current workplace requires employees who can find, process and structure information; who can solve problems; who are creative innovators and who exhibit effective communication and cooperation abilities [11].

A significant conclusion is that there has to be a transformation of job processes as well as position redesigns for the purpose of ushering in this new era of employees plus technologies for more effectual outcomes as collaborative units in this industrial revolution encompassing artificial revolution. Artificial intelligence's influence on the workplace is expected to be profound. Certain jobs, professions, plus definite skills will wane; conversely others will increase and change as people complete job tasks while working beside consistently changing and progressively adept machines. The major task is to preserve the flexibility to improve through people, processes, and technology, while splintering blockades that obstruct harmonious change through knowledge growth and collaboration [2].

Particularly in smart manufacturing and factories, computer controls, modelling, big data and other automation technologies will be heavily utilized to improve product development, manufacturing, and distribution efficiencies; employees are asked

to not only manipulate all the tools or technologies but also possess the abilities and skills to analyze the digital data created by the digital terminals, and to make optimized working decisions. These supply chain functions may need additional training or development to be efficient with digital resources [24].

Given that digital fashion domain might see further significant growth and advances, which will be affecting the entire fashion industry, fashion educators need to make sure that the ICTs-related skills needed by the job market are duly covered by the overall curriculum and courses' syllabus. Thus, digital fashion education and training must aim to enhance the ability of their students to use a wide range of tools to increase their efficiency and responsiveness to a very dynamic market's need [9]. It is important for educational institutions to understand their contribution to a stronger economy by bridging the gap between subject matter taught in the classroom and real-world practices and relevance [3].

While digital fashion is a reality, and there is a strong industry interest in the domain of digital fashion communication, the academic research and the educational offer in the related field are on their initial stages. Based on the changes happening in the fashion industry, the specific skills that are required by the employees of the industry are also changing. Currently employers in the fashion industry tend to choose new employees that are skillful in information technology, being innovative and creative. Unfortunately, the exact set of skills and competences that are on demand today in the digital fashion domain is still unclear and under-researched [9].

It is not enough to accept that digital skills are essential for the workforce in the fashion industry. It is imperative that we define a framework for defining and evaluating them, so that employees have the opportunity to know how they can become more competent and effective in their work.

Conclusion

Especially in the apparel industry the field of workforce qualifications remains quite unexplored. In addition to exploring the required qualifications, it is necessary to develop a framework as well as their evaluation procedures. Apart from formulating a broader qualification framework for the industry as a whole, unfortunately very few studies examine the digital skills held by employees as well as what digital skills and to what extent are required by the modern apparel industry.

The current education systems need to be examined given the arrival of the AI-based wave of technological change. The education system with its current structure may no longer be sufficient when it comes to educating future workers or retraining workers who expect to have an increasingly lengthy work career in a world that continuously changes. To better prepare future employees in the apparel industry, training programs need to be updated and modernized to meet the new data. Students in fashion schools cannot be left behind. It is imperative that they acquire the qualifications to claim all the opportunities for professional

development but also to give, in turn, a new impetus to the fashion chain, which is so in need.

We believe that Artificial Intelligence and new technologies could not replace humans. Without human intelligence no technology is enough. We argue that man and technology can only function effectively as a whole and in collaboration. To do this effectively the workforce must be equipped with all the necessary knowledge, skills and attitudes to contribute to the production of better products and services and to a better quality of life.

REFERENCES

- [1] Paulo Afonso, A Santana, P Afonso, A Zanin, and R Wernke. 2017. ScienceDirect ScienceDirect Costing models for capacity optimization in Industry 4.0: Trade-off between used capacity and operational efficiency. (2017). DOI:https://doi.org/10.1016/j.promfg.2018.03.002
- [2] Sharon L Burton. 2019. International Journal of Economics, Commerce and Management United Kingdom, Grasping The Cyber-World: Artificial Intelligence and Human Capital Meet to Inform Leadership. Retrieved from <http://ijecm.co.uk/>
- [3] Meriem Chida and Gary Brown. 2011. Evaluating the gap between industry assessment of job readiness and graduation standards in higher education institutions: the case of fashion studies. *Int. J. Fash. Des. Technol. Educ.* 4, 2 (July 2011), 71–82. DOI:https://doi.org/10.1080/17543266.2010.525533
- [4] EU Science Hub. 2019. The Digital Competence Framework 2.0. Retrieved August 8, 2020 from <https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework>
- [5] Victor Gekara, Darryn Snell, Alemayehu Molla, Stan Karanasios, and Amanda Thomas. 2019. Skilling the Australian workforce for the digital economy. Retrieved from <https://www.linkedin.com/company/nvcr>
- [6] Chandadevi Giri, Sheenam Jain, Xianyi Zeng, and Pascal Bruniaux. 2019. A Detailed Review of Artificial Intelligence Applied in the Fashion and Apparel Industry. *IEEE Access* 7, (2019), 95376–95396. DOI:https://doi.org/10.1109/ACCESS.2019.2928979
- [7] Xiaoling Gu, Fei Gao, Min Tan, and Pai Peng. 2020. Fashion analysis and understanding with artificial intelligence. *Inf. Process. Manag.* 57, 5 (September 2020), 102276. DOI:https://doi.org/10.1016/j.ipm.2020.102276
- [8] Mario Hermann, Tobias Pentek, and Boris Otto. 2016. Design principles for industrie 4.0 scenarios. In *Proceedings of the Annual Hawaii International Conference on System Sciences*, IEEE Computer Society, 3928–3937. DOI:https://doi.org/10.1109/HICSS.2016.488
- [9] Nadzeya Kalbaska and Lorenzo Cantoni. 2019. Digital fashion competences: Market practices and needs. In *Lecture Notes in Electrical Engineering*, Springer Verlag, 125–135. DOI:https://doi.org/10.1007/978-3-319-98038-6_10
- [10] Ester van Laar, Alexander J.A.M. van Deursen, Jan A.G.M. van Dijk, and Jos de Haan. 2017. The relation between 21st-century skills and digital skills: A systematic literature review. *Comput. Human Behav.* 72, (July 2017), 577–588. DOI:https://doi.org/10.1016/j.chb.2017.03.010
- [11] Ester van Laar, Alexander J.A.M. van Deursen, Jan A.G.M. van Dijk, and Jos de Haan. 2018. 21st-century digital skills instrument aimed at working professionals: Conceptual development and empirical validation. *Telemat. Informatics* 35, 8 (December 2018), 2184–2200. DOI:https://doi.org/10.1016/j.tele.2018.08.006
- [12] Heiner Lasi, Peter Fettke, Hans Georg Kemper, Thomas Feld, and Michael Hoffmann. 2014. Industry 4.0. *Bus. Inf. Syst. Eng.* 6, 4 (August 2014), 239–242. DOI:https://doi.org/10.1007/s12599-014-0334-4
- [13] Jay Lee, Hossein Davari, Jaskaran Singh, and Vibhor Pandhare. 2018. Industrial Artificial Intelligence for industry 4.0-based manufacturing systems. *Manuf. Lett.* 18, (October 2018), 20–23. DOI:https://doi.org/10.1016/j.mfglet.2018.09.002
- [14] Bo-Hu Li, Bao-Cun Hou, Wen-Tao Yu, Xiao-Bing Lu, and Chun-Wei Yang. 2017. Applications of artificial intelligence in intelligent manufacturing: a review *. *Front Inf. Technol Electron Eng* 18, 1 (2017), 86–96. DOI:https://doi.org/10.1631/FITEE.1601885
- [15] Chenggang Li. 2020. Research on Artificial Intelligence for the Development of Fashion Industry. 2 (2020). DOI:https://doi.org/10.1145/3404663.3406873
- [16] Ying Li, Jing Dai, and Li Cui. 2020. The impact of digital technologies on economic and environmental performance in the context of industry 4.0: A moderated mediation model. *Int. J. Prod. Econ.* 229, (November 2020), 107777. DOI:https://doi.org/10.1016/j.ijpe.2020.107777
- [17] D Rupasinghe M. Aabid, A Majeed; Thashika. 2017. Internet of Things (IoT) Embedded Future Supply Chains for Industry 4.0: An Assessment from an ERP-based Fashion Apparel and Footwear Industry Safety Stock Optimization Models View project Supply Chain Network Design Optimization Models View project. *J. Supply Chain Manag.* 6, 1 (2017), 25–39. Retrieved from <https://www.researchgate.net/publication/317041889>
- [18] Khahan Na-Nan, Theerawat Roopleam, and Natthaya Wongsuwan. 2019. Validation of a digital intelligence quotient questionnaire for employee of small and medium-sized Thai enterprises using exploratory and confirmatory factor analysis. *Kybernetes* 49, 5 (August 2019), 1465–1483. DOI:https://doi.org/10.1108/K-01-2019-0053
- [19] Loina Prifti, Marlene Knigge, Harald Kienegger, and Helmut Krcmar. 2017. A Competency Model for “Industrie 4.0” Employees. *Wirtschaftsinformatik 2017 Proc.* (January 2017). Retrieved April 14, 2020 from <https://aisel.aisnet.org/wi2017/track01/paper/4>
- [20] Marianna Pupillo. 2019. Artificial Intelligence and the Fashion Industry. Luiss Department of Economics and Finance.
- [21] E Stiakakis, Y Liapis, and M Vlachopoulou. 2019. Developing an understanding of Digital Intelligence as a prerequisite of digital competence. Retrieved April 16, 2020 from http://www.itais.org/IT AIS-MCIS2019_pub/IT AISandMCIS2019-pages/pdf/94.pdf
- [22] Sébastien Thomassey and Xianyi Zeng. 2018. Springer Series in Fashion Business Artificial Intelligence for Fashion Industry in the Big Data Era. Retrieved from <http://www.springer.com/series/15202>
- [23] Simon Waller. 2015. The Four Elements of Digital Intelligence (DQ) | Simon Waller. Retrieved August 7, 2020 from <https://www.simonwaller.com.au/the-four-elements-of-digital-intelligence-dq/>
- [24] Baolu Wang and Jung E. Ha-Brookshire. 2018. Exploration of Digital Competency Requirements within the Fashion Supply Chain with an Anticipation of Industry 4.0. *Int. J. Fash. Des. Technol. Educ.* 11, 3 (September 2018), 333–342. DOI:https://doi.org/10.1080/17543266.2018.1448459
- [25] 2020. DQ Framework | DQ Institute. Retrieved August 6, 2020 from https://www.dqinstitute.org/dq-framework/#digital_intelligence