Competence management in Industry 4.0: An innovative concept to support a Skill@Mgmt 4.0 tool

Tiago Bastos
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT)
University of Aveiro
Aveiro, Portugal
bastostiago99@ua.pt

Juliana Salvadorinho
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT)
University of Aveiro
Aveiro, Portugal
juliana.salvadorinho@ua.pt

Andreia Vitória
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT)
Research unit in Governance, Competitiveness and Public Policies (GOVCOPP)
University of Aveiro
Aveiro, Portugal
atvitoria@ua.pt

Leonor Teixeira
Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT)
Institute of Electronics and Informatics Engineering of Aveiro (IEETA)
University of Aveiro
Aveiro, Portugal
lteixeira@ua.pt

Abstract

Industry 4.0 has started to radically disrupt the business environment and is likely to expand worldwide in the coming decades. This transformation has an impact not only on production processes, but also on the structure of work. The human factor has been one of the topics focused on in this paradigm, due to the volatility of role profiles that is closely linked to skills challenges. The main objective of this paper is to display the conceptualization of a technological tool capable of enabling greater ease and agility in the management of human resource competencies, while promoting an increase in workforce engagement. The study followed the triangulation methods methodology, where three sources of information were crossed: HRM documents (from consulting firms), scientific articles, and a focus group with experts in the areas of HR management and information systems, from academia and industry. Through this, it was possible to create a set of requirements for the tool that preserves what companies already have, i.e. the Lean philosophy. To this end, a competence matrix is digitally incorporated, transporting Lean to a higher level of excellence. In addition to the concept display, some interfaces of a low fidelity prototype are presented to facilitate the interpretation of the requirements. Hence, this tool promises a more agile management of competencies, with the possibility of future career prospects for the employee (through the comparison of what is required in other functions). In addition, it will provide the manager with a more agile allocation of people (through talent reviews) to functions, reducing labor turnover.

Keywords
Industry 4.0; Digitalization; Operator 4.0; Human Resource Management; Lean 4.0

1. Introduction
Price and customization have always been two important pillars for the market. Nowadays the customer wants specific products, with high customization, which culminates with short lifecycles (Nagy et al., 2018). The new industrial paradigm, known as Industry 4.0 (I4.0), launches the incorporation of digital technologies into the manufacturing process to improve productivity and efficiency (Leesakul et al., 2022). This digital transformation can potentiate benefits for the industry in terms of customized products in short time intervals (Silva et al., 2021), thus bringing together the ability to personalize products with the characteristics of mass production (Wang et al., 2017). But all paradigm shifts bring challenges and sometimes barriers and trade-offs. Vuksanović Herceg et al. (2020) points out as one of the main barriers is the lack of competencies that affect the organizations that want to migrate to the industry 4.0 paradigm. Also, Manda & Ben Dhaou (2019) refers to four potential challenges associated with this new paradigm: (i) potential job losses, meanwhile repetitive tasks could be performed by robots, even if in collaboration with humans; (ii) skills challenges, since the technology requires new capacities, both in programming and in the manipulation and analysis of the data generated; (iii) infrastructure challenges, closely related to the integration of components at the level of industrial processes that cyber-physical systems require; and (iv) security and privacy, focusing on the proper management of the massive amount of data generated, putting it to proper use. The challenges suggested refer a lot to the future of the human factor, as they are shown to be vital in future production systems, as they are able to coordinate and solve problems, make choices, cope with increasing complexity, and adapt flexibly to difficult working conditions (Li et al., 2019).

Although many studies are focusing on technology implementations, most of them have ignored the role of the human being (Neumann et al., 2021). Human-centered technologies, which put the human capital at the heart of the creative process, can be used to efficiently create value in industry 4.0. This vision is in accordance with the European Commission's policy, which emphasizes the need of having a skilled workforce to enable European business to be competitive and develop (Caldarola et al., 2018).

In this way, to have a better understanding of industry 4.0, it is important to know the human factor, as well as all the issues they face with the advance of technology (Mikulić & Štefanić, 2018). Therefore, careful management of the human resource is crucial to promote higher satisfaction of the workforce, ensuring an increase of quality, efficiency, and well-being of collaborators (Ciccarelli et al., 2022), as well as an alignment of their competences and interests (Scheffer et al., 2021).

In general, an I4.0 project should be implemented by phases, with current production methods being retained and considered from a socio-technical standpoint. The wave of Lean production and management that swept western industrial production in recent decades has given rise to the notion that the I4.0 environment to thrive may need to be incorporated into current lean production systems (Salvadorinho & Teixeira, 2021). Lean is a low-tech strategy, but outcomes were better than expected, so there is a strong need to preserve what is currently in place and, if feasible, improve it (Salvadorinho & Teixeira, 2021).

Within this context, the present study aims to create a concept to conceptualize a technological tool that can contribute to /help to fulfil the gap between the workforce competences and the function needs, by proposing a module for competency management, using a digitized Lean tool – i.e., the skills matrix – to facilitate the human resource management and foster the workforce engagement. To design the solution and elicit its requirements, a study based on a literature review was conducted, followed by a focus group with four organizations – three companies and one University.

2. Literature Review
2.1 Industry 4.0 and Lean 4.0
The first industrial revolution, which took place in the mid-18th century, was fundamentally characterized by the transition from human and animal labor to the use of machines powered by the steam engine and coal (Mohajan, 2019). Towards the end of the 19th century, the second industrial revolution emerged and was marked by an increase in quality and productivity, thanks to the technological developments that occurred due to the usage of electricity (Atkeson & Kehoe, 2001). The third revolution emerged from the appeal of personal computers and internet (Tang &

Veelenturf, 2019). This took to an automation and computerization of the work (Thorvald et al., 2021). The merge of barriers between physical and virtual worlds took to the Fourth Industrial Revolution also known as Industry 4.0.

The concept of Industry 4.0 was proposed as a result of a German government project that aimed to develop the economy through using high technology and can promote a transformation of conventional industries into computerized manufacturing (Tang & Veelenturf, 2019). The term Industry 4.0 has associated the digital transformation of industries, gaining force by the emergence of technologies such as artificial intelligence (AI), Cyber-Physical Systems (CPS), Internet of Things (IoT), or Big Data (BD) (Pattanapairoj et al., 2021). Briefly, AI is a technology that allows computers to process information in a way that is like human intellect (Chen et al., 2021). CPS is a new breed of systems with integrated computational and physical capabilities that may interact with people in a variety of ways (Rogall et al., 2022). IoT allows items to communicate and interact with one another (for example, machines, automobiles, goods, and other gadgets), empowering not only the connectivity between devices but also data sharing (Benotsmane et al., 2019). BD is the tool that emerges from the need to process huge amounts of data generated at high speed and with enormous diversity (Jagtap et al., 2020). There are nine pillars of technologies which are the support of Industry 4.0, they are big data, autonomous robots, simulation, horizontal and vertical system integration, IoT, cyber security, cloud computing, additive manufacturing and augmented and virtual reality (Alcácer & Cruz-Machado, 2019; Michael et al., 2015).

There has been a wave of Lean production and management that swept through western industrial production in the last few decades and so there was a need to digitize what there is of traditional Lean giving rise to the concept of Lean 4.0. The concept of Lean 4.0 emerges as the combination of lean philosophy and industry 4.0 technologies. These two approaches are complementary and Lean principles function as a prerequisite for digitalization (Gil-Vilda et al., 2021).

The new technologies coming from industry 4.0 tend to find visions of greater flexibility and automation, to enable higher quality, with a view to defect-free production to maximize efficiency. Lean Manufacturing has proven its effectiveness in environments of high demand variability, short new product development cycles, and highly competitive, customer-centric environments. So, in that way, that's possible to see the common points between the topics (Miqueo et al., 2021). An adjacent and distinctive characteristic of Lean production systems is respect for people and consideration of them in the journey of continuous improvement (Miqueo et al., 2021).

Valamede et al. (2020) gave the synergies between industry 4.0 technologies and lean principles (JIT, Kanban, Poke Yoke, VSM, Kaizen, TPM). For instance, in the case of VSM, the connection between all machines allows monitoring the value chain in real-time to act in an easy way to eliminate wastes and control lead times and machine costs. For example, in an assembly station where different processes are executed repetitively, that may be susceptible to errors, so an augmented reality technology can offer an assistance system that can mitigate errors and try to reach the minimum errors (Hoellthaler et al., 2018). Some traditional tools, such as Kanban, are already digitalized in E-Kanban, which is the same logic of a traditional Kanban, but in an intangible way, so without the card, the signal for new supply is given electronically (Pekarcikova et al., 2020).

2.2 Operator 4.0 and Competences 4.0

Operator 4.0 can be defined as "a smart and skilled operator who performs not only 'cooperative work' with robots, but also 'work aided' by machines as and if needed, using human cyber-physical systems, advanced human-machine interaction technologies and adaptive automation towards 'human-automation symbiosis work systems' (Romero et al., 2017).

According to Li et al. (2022), technologies 4.0 will assist employees essentially on three fronts, being physical, sensorial and cognitive. Physical capacity is characterized by multiple attributes, which include the description of physical function (e.g. lifting capacity) together with its non-functional properties (e.g. speed, strength, precision, and dexterity). Collaborative robots, automated guided vehicles, and exoskeletons are technologies that support the collaborator in this facet. As far as the sensory support feature of the tasks is concerned, technologies provide the employee with the ability to acquire data from the environment, thus creating a first level of information creation necessary for orientation and decision-making. Visual computing technologies, where augmented and virtual reality are housed, as well as sensors, are the most direct examples currently in use. The tasks' cognitive support will assist the operator's ability to take on the mental tasks. Technologies such as artificial intelligence, real-time optimization and machine learning are examples of what kind of support industry 4.0 can give.

There is yet another concept, closely associated with Operator 4.0, which is called Smart Working. This term refers very much to companies whose goal is to increase the flexibility of their manufacturing system because they consider workers to be the most adaptable and resilient element in the socio-technical manufacturing system (Marcon et al., 2021). It should be noted that the definition of smart working can be considered an expansion of the concept of Operator 4.0. While the latter focuses on the capability of the workforce, the smart working concept takes a broader perspective on work processes and the way tasks are performed in the manufacturing field (Dornelles et al., 2022).

As already mentioned before, the human factor is one of the biggest challenges in industry 4.0 and, on another hand, the biggest concerns of employees are the fear of losing jobs because they lack skills or are already outdated (Ligarski et al., 2021). For this reason, there is a need to put employees in training (Ligarski et al., 2021). The idea that machines will replace humans should not be a threat but then an opportunity to develop the workforce. According to some studies, people are a key factor to achieve the development of the digitalization transition (Koleva, 2019).

Nowadays, there is a wide range of jobs that have been replaced by the introduction of technologies, which makes the remaining jobs more complicated, broader, and with greater interdisciplinary cooperation (Scheffer et al., 2021). This requires companies to work on adjusting their skills or competences to the needs boosted by Industry 4.0. In fact, the new digital paradigm has brought a need for a more educated and qualified workforce (Kannan & Garad, 2021), which is why several authors have been studying the topic of competencies 4.0.

Competence can be defined as “a set of skills, abilities, knowledge, attitude and motivations an individual need to cope with job-related tasks and challenges effectively” (Kannan & Garad, 2021). Hecklau et al. (2016) propose four dimensions to aggregate the competencies for this digital paradigm: technical, methodological, social, and personal. All job-related knowledge and abilities are included in technical competence. All skills and capacities for general making decisions and problem-solving are included in methodological competences. All talents and abilities, as well as the disposition to collaborate and interact with others, are included in social competences. Social ideals, motives, and attitudes are all examples of personal competences.

Shet & Pereira (2021) point out 14 managerial competencies as crucial to the fourth industrial revolution: agility; entrepreneurial intelligence; connected technology architecture; business acumen; design thinking; problem-solving and decision making; collaborative mindset; disruptive leadership; research orientation; sustainability; robotic process automation; data analytics; digital intelligence modelling and project leadership.

In short, and although there is still no consensus regarding skills 4.0 for certain professions, the ability to interact with new technologies and the ability to exploit knowledge in distinct collaborative environments are two important points in the new digital paradigm (Hernandez-de-Menendez et al., 2020).

2.3 The management of workforce in I4.0

As mentioned before, the new digital paradigm has brought several challenges to human capital, so human resource management also must keep up with this new change over. It is therefore necessary to review recruitment and talent management practices (Hronová & Špaček, 2021). Regarding recruitment, companies should look to recruit people with a broader range of skills, validated using tests (Shamim et al., 2016). When it comes to employee training, organizations should focus on the long-term of their teams and can provide education and training aligned with the new industry needs (Hronová & Špaček, 2021). Regarding evaluation, this should be objective, based on matrices to assess performance quantitatively, and it is also important that employees receive continuous feedback to take corrective action as needed from managers (Shamim et al., 2016).

In the present era of industry 4.0, where emerging technologies are transforming the interactions between people and their job, with possible costs for their wellbeing, an organization's obligation to public health is to improve good work experiences and promote employee work engagement (Molino et al., 2020). Work engagement will be described as a desired cognitive-affective situation that ties a person with his or her job, producing emotions of well-being and contentment, and being associated with heightened sensations of inspiration and joy for professional output (Urrutia Pereira et al., 2021). Participatory methods to workplace and industrial process design are used to increase staff engagement. The future socially sustainable factory must become an environment of knowledge sharing and adaptive learning that promotes individualized skill development and learning as human operators work to achieve company and production goals (Romero et al., 2020). In that way, the four pillars to foster engagement are: (i) knowledge sharing and collaboration, using for that collaborative platforms with questions and answers in order to increase knowledge sharing among workers and to assist them in problem solving situations; (ii) visualization of information, offering context related information at the workplace (iii) participatory design, with a view to deliver workers the opportunity to co-design the workplace and plan working procedures with other stakeholders; and (iv) training, supporting and teaching work tasks on-site (Aromaa et al., 2019).

Planning and measuring the skills of a team allows identifying and mitigating gaps (Doll, 2021). Furthermore, this management at the organizational level can improve performance and facilitate the decision-making for the managers (Coates et al., 2007). The skill matrix, considered a Lean tools (Punna Rao et al., 2020), is used in a systematic way to manage the skill shifts in a team, which allows to identify the gap between the current situation and the expected one (Kobus, 2016). It can be used as a table to shows the skills levels of a certain person in different tasks (Princy, 2016).

As Salvadorinho & Teixeira (2021) argue, there is a need to preserve traditional Lean tools and if possible, improve them with digital concepts from industry 4.0. So, a digital skills matrix can be a good way to improve the allocation of the workforce in the tasks.

Careful management of human capital can bring advantages to the organization such as increased quality, efficiency and also the well-being of people (Ciccarelli et al., 2022). Much of this management is still done "manually" and industry 4.0 can add tools, such as integrated platforms, that enable easier monitoring of human well-being (Ciccarelli et al., 2022).

3. Practical Case

3.1 Objectives and Methodology

The main objective of this study is to present a concept and the respective list of the requirements to design a tool that supports the management and visualization of competence maps and contributes to better decision making in the human resource area.

In the first phase, a literature review was performed on the Scopus, ScienceDirect, and Google Scholar platforms. In addition, documents more focused on the area of human resources management, such as case studies supporting documents presenting the human resource management (HRM) practices of large entities, and documents from consulting firms in the area, were analyzed. After consulting these two kinds of documents (scientific documents and reports with practical views), a draft with a first version of the list of requirements was prepared and, consequently a focus group guide for further validation of the model. The focus group took place in two moments, with a duration of one hour and fifteen minutes and counted with the participation of people from academia and industry, involving three companies: one in the metal-mechanic sector, another in the chemical sector, and another that operates in the furniture retail sector. The participants come from the human resources and information systems areas, with more detailed information in Table 1. Between the two focus group moments, there was a review of the requirements, where changes were made to those initially proposed and others were added to validate them in the second moment. The last phase was the elaboration of the requirements and their representation using UML notation. This methodology is schematized in Figure 1.

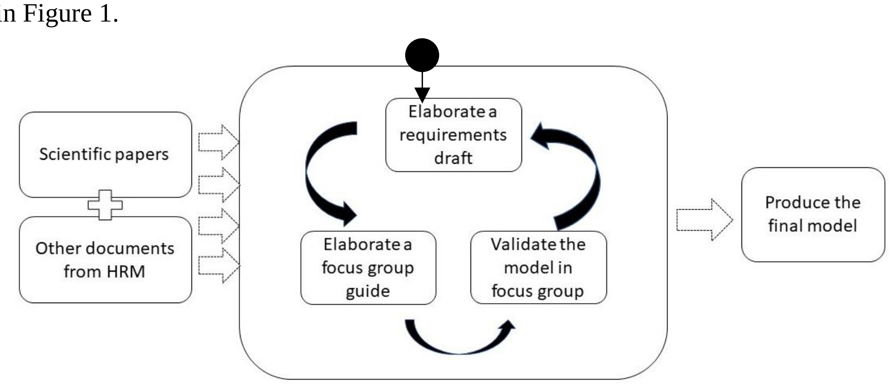

Figure 1-Framework reporting the methodology used in the research

Table 1- Characterization of focus group participants

Participant	Type of organization	Work area	Occupation
Participant 1	Industry	Human Resource (HR)	HR management
Participant 2	Industry	Human Resource (HR)	HR management
Participant 3	Industry	Human Resource (HR)	HR management
Participant 4	Academia	Human Resource (HR)	Teacher/Researcher
Participant 5	Academia	Information Systems (IS)	Teacher/Researcher
Participant 6	Academia	Information Systems (IS)	Researcher

3.2 Results and Discussion

3.2.1 The preliminary Concept based on Literature Review

At the skills level, the digital paradigm is forcing some changes in employee's curricula. Also, due to the volatility of industrial environments, there are reshapes at the level of HRM practices (assessment, individual plan development, and training). In addition, there is a need to understand what employees' preferences and goals are for their career development. In this framework emerges the concept of a tool that aims to support these points. Thus, a preliminary set of requirements was created, accompanied by frameworks of possible solutions for them:

- The first one concerns the possibility for the employee to view his or her skills profile. To satisfy this requirement it was necessary to create a structure of competency levels, and to this end, a structure with 4 levels was proposed (Beginner, Intermediate, Advanced and Mastery). Thus, for each competence, the employee would have a bar with four levels (the levels described above) and each of them would be filled with one of four colors (White: has no level, nor has any intention to improve it; Light green: has that level; Dark green: is in training to have that level; Purple: intends to develop that level).
- The second requirement would be the possibility for the employee to introduce a preference for developing future competencies. This functionality would be achieved with the possibility for the employee to fill in purple the respective level in the competence bar.
- The third requirement was to allow employees to enter a preference for the skills they most like to use. For this purpose, a box will be placed to allow the employee to express their interest in using the skill in question.
- The fourth requirement arising from the initial analysis was the possibility of showing the employee the difference between the profile expected for a particular role and their profile for the same role. That idea is based on the model proposed by Hecklau et al. (2016), the authors describe a list of competences for the digital revolution and aggregate that in radar chats (certain competence has a determined level for each function) to allow an easier way to see the gap between employee´s competencies and the desirable profile. This was made possible using radar charts.
- The fifth requirement relates to helping the employee allocate people to certain roles. This was achievable using a skills matrix. The sixth requirement proposed was the possibility for the team manager to visualize indicators about his team.

3.2.2 The validated Concept based on Focus Group

After presenting the concept previously elaborated, described in section 3.2.1, some notes from focus group resulted in changes in requirements. There was a need to modify ones and add others. In the following topics were presented the main conclusions of focus group:

- The entities do not have the list of competencies of each employee, they only have whether the operator is qualified to perform a certain function.
- As concerned at the competency mapping for the collaborator, they agreed on the progress bar notation for visualizing the skill level, with three levels for each competency, to the detriment of the 4 proposed in the preliminary version of concept, and the color coding for each skill level (both explained in the section below 3.2.1). They said it would be important for managers to know the preferences of employees.

- In terms of assessing employee potential, they believe that a scale with four degrees of potential would be appropriate, with the caveat that this potential would only be visible to the employee and not introduced by him or her.
- To facilitate the visualization of the employee skills in a particular role, they find the idea of radar charts interesting, adding that it would be important for the employee to self-evaluate (its skills), thus getting three overlapping charts (the one of the job profiles and two of the employee's profile, one from the employee's point of view and another from the manager's point of view).
- Regarding the supervisor, they find the notation of circle charts interesting to understand who the most capable employees are to perform certain functions. They add that the leaders should have access to talent review that allows them to perceive the operators with the best performance rate and greatest potential.

So as a result, we came up with a list of requirements, already validated in a focus group, for a tool that can help three HRM tasks: evaluation, individual development plans and training. For evaluation, the radar graph can facilitate the comparison between employees' profiles and the profiles expected for the job. When it comes to development plans, the charts with progress bars, combined with the proposed color system, can make it easier for HR managers to align training for the employee. For individual development plans and training, there is the possibility for employees to introduce their preference in the skills to be developed and the skills to be used are two requirements that promote engagement, because as mentioned in the literature, the participative role of employees in the workspace design and production processes is a way to increase engagement (Romero et al., 2020).

3.2.3 Requirements of the Skill@Mgmt tool

In this section, the requirements will be presented as well as graphical representations from a low-fidelity prototype to better understand the features. Table 2 presents the main requirements categorized by the three main actors – collaborator, supervisor, and HR manager.

Table 2 – Requirements for the technological tool by actor

Entity	Requirements
Employee	- View skills in progress bars (with a structure of 3 levels) - Enter the preference of skills that want to develop - Enter the preference by using a particular skill - Visualize the gap between his/her skills, and the skills needed to perform a certain function (radar chart) - Observe the potential that the company associates to him/her - Enter your self-assessment regarding your job skills
Supervisor	- Visualize the most suitable employees to perform each function - View profiles of each employee, both individually and collectively - View indicators such as the number of employees that does the better match (between competence and function profile), the number of employees by competence level and potential level, the number of employees in training, the number of employees who intend to develop a certain competence, check how many employees there are for each level in a certain competence - View the talent review (a report that shows, from the population, the employees who stand out the most and, therefore, the functions said to be the most important)
RH Responsible	- Insert skill levels and description - Enter, or update, the requirements that each job should demand

Regarding **collaborator**, there are a few notes to keep in mind. For each competence there are 3 levels (Beginner, Intermediate and Advanced), after the analysis of functions and finding what is expected of each level, each employee will have a certain level associated. Thus, the visualization of the level of their competencies will be done using progress bars. For each competence there are the three levels mentioned above that can be filled in one of 4 colors: White, Light Green, Dark Green and Purple (also mentioned in chapter 3.2.1).

As visible in Figure 2, for each competence, a set of 3 spaces is presented, each space can be filled by one of the 4 colors mentioned above.

This purple filling in would be done by the employee in the application, thus allowing him/her to answer the requirement to indicate the intention to develop the competence, which will emit a signal for his/her supervisor and HR Responsible. For each competence, below the progress bar there would be a button for the employee to indicate whether he/she prefers using that competence, visible in Figure 2, this preference, as the intention to develop, is communicated to his/her supervisor and HR Responsible.

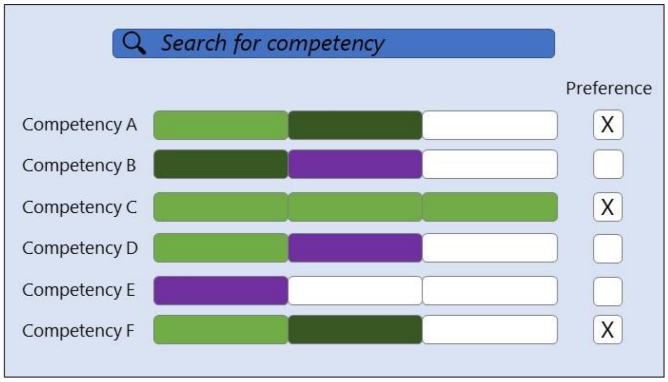

Figure 2-Interface of the employee profile at the skill level

Another requirement is to allow the employee a quick overview of the differences that exist between his or her competencies and the ideal competency level for performing a role. So, the radar map would allow to overlay the job map with two employee's maps (one concerning the manager evaluation and the other concerning to employee self-assessment) and thus see the differences. That radar chart is visible in Figure 3. The employee can choose a function and see the differences, between his profile and job profile desirable. Note: a function requires a minimum of 3 competencies to allow a visible area in the radar chart.

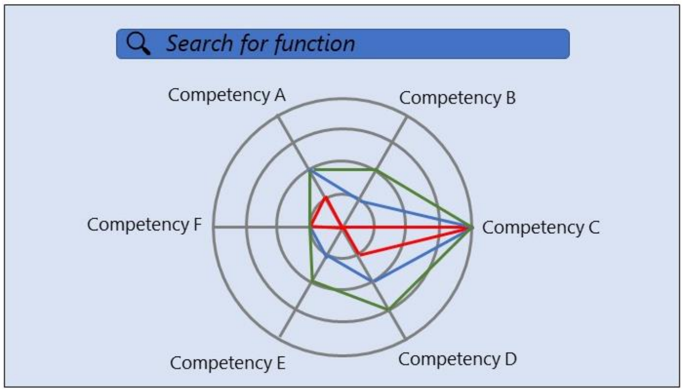

Figure 3- Interface with the employee's profile in the function

As far as the **supervisor** is concerned, the aptitude of each employee for a certain function can be visualized graphically. Each function has a set of competencies and each competency in a certain function has a specific weight. This aptitude is calculated based on the difference between competence level for the function and the proficiency level that the person has in that competence considering this weight. Having these inputs, for each function it will be possible for the supervisor to have access to a digital skills matrix, visible in Figure 4.

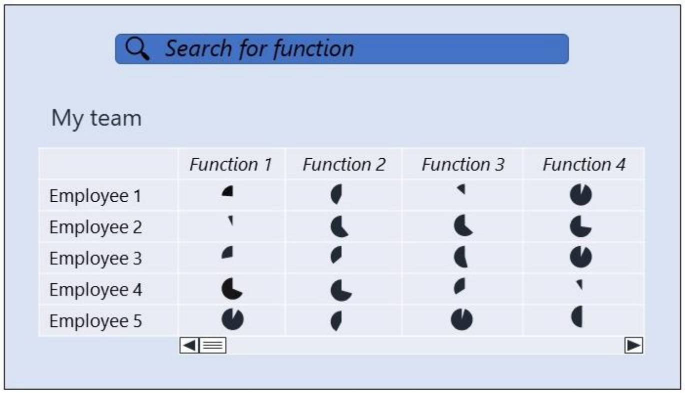

Figure 4-Interface with digital skills matrix that facilitates the people allocation

Regarding indicators, each supervisor can perceive some such as the number of employees with a good match between their profile and the functional requirements, the number of collaborators that do not fit so well the job profile or the number of employees in training, as shown in Figure 5. Another important aspect visible in Figure 6 is the total of team members in each level for a specific competency.

Figure 5-Interface with the team KPI´s

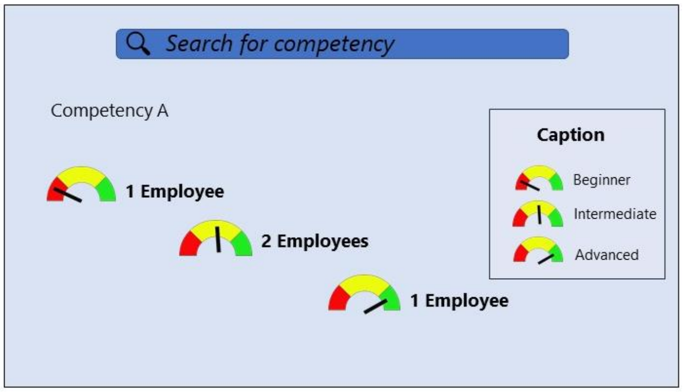

Figure 6-Total of team members in each level for a specific competency

4. Conclusion

Increasing customer demand has led to a need to produce in a more customized way and at the same time at low costs. This led to a change in the industrial paradigm, more supported by digitalization and advanced technologies, the fourth industrial revolution.

This paradigm shift brought some challenges in terms of human capital management. Because of this, arises the concept of Operator 4.0, which refers to an operator capable of working in this new paradigm. Beyond this point, other authors have dedicated themselves to the study of which competencies would be necessary to facilitate adaptability and consequently the achievement of greater success in this fourth revolution.

Human capital management thus presents challenges, namely at the level of individual employee development, employee evaluation, and recruitment. Another adjacent focus of human resource management is the concern for increasing work experience and consequently increasing engagement. One of the most successful practices in increasing the latter is employee participation in decisions and training, as people feel more able to take responsibility, with a higher degree of proficiency. In this perspective, here is provided a concept of a tool that can assist in the challenges of I4.0 when it comes to HRM and also engagement, through the fostering of training.

With this tool it intends to provide the following features: 1- a visual interface that allows supervisors an easier allocation of employees at jobs; 2- collaborators can introduce his/her preferences regarding for use certain competences and concerning for those which they want to develop; 3- workers can easily perceive the difference, at competency level, between the two profiles (his/her and the desirable for the function); 4- supervisor can view team indicators which facilitate his/her analysis and decision-making; and 5- the lean tool, skills matrix, presents great advantages in terms of people allocation, for this reason, the tool considers the digitalization of this same matrix. This artifact combines concepts of industry 4.0 and Lean, so it can be framed in the Lean 4.0 theme.

The digital paradigm presents itself as being a volatile environment, where customization is high and workforce turnover becomes increasingly prevalent. It is therefore essential to create mechanisms that facilitate the management task, in terms of allocating resources to tasks, as well as mechanisms that encourage employee retention by raising the engagement component. This labor retention is essential so that organizational knowledge is preserved, since with the departure of an employee, tacit knowledge is often lost (knowledge that is in people's minds and, therefore, is not stored in the company), which has not been reprocessed into explicit knowledge (standardized knowledge that is stored in databases, work instructions, for example). Therefore, this technological tool helps in these two processes, giving employees a voice so that they can envisage their career and, therefore, be more active in their path in the company, fostering work engagement. In addition, they provide matrix support to the supervisor, so that a suitable allocation is made to jobs more quickly. The digital age is being so forcibly implemented through the introduction of technology, yet it has not placed the necessary emphasis on human capital. In that sense, these kinds of tools, which preserve what companies already have in a non-digital form, can be the launch pad for a more central positioning of the workforce in the fourth industrial revolution.

The study, despite having a good literary support, had a focus group with three industrial contexts, which can be seen as a limitation of the article. Future work may involve adding features that can help design corresponding training to meet the needs and preferences of employees in terms of development plans. It will also be important to create a database structure and prototype the application for testing in factory environments.

Thus, this tool concept may emerge as the basis for the development of a tool that may bring countless advantages in the management of human capital in the industry 4.0 paradigm.

Acknowledgements

The present study was developed in the scope of the Augmented Humanity project [POCI-01-0247-FEDER-046103], financed by Portugal 2020, under the Competitiveness and Internationalization Operational Program, the Lisbon Regional Operational Program, and by the European Regional Development Fund. It is also carried out within the Institute of Electronics and Informatics Engineering of Aveiro (UIDB/00127/2020), and the research unit on Governance, Competitiveness and Public Policy (UIDB/04058/2020), both funded by national funds through FCT - Fundação para a Ciência e a Tecnologia.

References

Alcácer, V., & Cruz-Machado, V. (2019). Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. In *Engineering Science and Technology, an International Journal* (Vol. 22, Issue 3, pp. 899–919). https://doi.org/10.1016/j.jestch.2019.01.006

Aromaa, S., Liinasuo, M., Kaasinen, E., Bojko, M., Schmalfuß, F., Apostolakis, K. C., Zarpalas, D., Daras, P., Özturk, C., & Boubekeuer, M. (2019). User Evaluation of Industry 4.0 Concepts for Worker Engagement. *Advances in Intelligent Systems and Computing*, *876*, 34–40. https://doi.org/10.1007/978-3-030-02053-8_6

Atkeson, A., & Kehoe, P. J. (2001). *The transition to a new economy after the second industrial revolution*. National Bureau of Economic Research Cambridge, Mass., USA. https://doi.org/10.3386/w8676

Benotsmane, R., Kovács, G., & Dudás, L. (2019). Economic, social impacts and operation of smart factories in Industry 4.0 focusing on simulation and artificial intelligence of collaborating robots. *Social Sciences*, *8*(5), 143. https://doi.org/10.3390/socsci8050143

Caldarola, E. G., Modoni, G. E., & Sacco, M. (2018). A Knowledge-based Approach to Enhance the Workforce Skills and Competences within the Industry 4.0. *The Tenth International Conference on Information, Process, and Knowledge Management, Rome*. https://www.researchgate.net/publication/324222694

Chen, J., Li, K., Zhang, Z., Li, K., & Yu, P. S. (2021). A survey on applications of artificial intelligence in fighting against COVID-19. *ACM Computing Surveys (CSUR)*, *54*(8), 1–32. https://doi.org/10.1145/3465398

Ciccarelli, M., Papetti, A., Germani, M., Leone, A., & Rescio, G. (2022). Human work sustainability tool. *Journal of Manufacturing Systems*, *62*, 76–86. https://doi.org/10.1016/j.jmsy.2021.11.011

Coates, G., Thompson, C., & De Leon, R. (2007). A study of capturing the skill competencies of the workforce within a small manufacturing engineering company. *Proceedings of ICED 2007, the 16th International Conference on Engineering Design*, *DS 42*.

Doll, J. L. (2021). Developing Workforce Planning Skills in Human Resource Management Courses: A Data-Driven Exercise. *Management Teaching Review*, *7*(1), 89–108. https://doi.org/10.1177/23792981211057227

Dornelles, J. de A., Ayala, N. F., & Frank, A. G. (2022). Smart Working in Industry 4.0: How digital technologies enhance manufacturing workers' activities. *Computers and Industrial Engineering*, *163*(November 2021). https://doi.org/10.1016/j.cie.2021.107804

Gil-Vilda, F., Yagüe-Fabra, J. A., & Sunyer, A. (2021). From Lean Production to Lean 4.0: A Systematic Literature Review with a Historical Perspective. *Applied Sciences*, *11*(21), 10318. https://doi.org/10.3390/app112110318

Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia Cirp*, *54*, 1–6. https://doi.org/10.1016/j.procir.2016.05.102

Herceg, I. V., Kuč, V., Mijušković, V. M., & Herceg, T. (2020). Challenges and driving forces for industry 4.0 implementation. *Sustainability (Switzerland)*, *12*(10), 4208. https://doi.org/10.3390/su12104208

Hernandez-de-Menendez, M., Morales-Menendez, R., Escobar, C. A., & McGovern, M. (2020). Competencies for Industry 4.0. *International Journal on Interactive Design and Manufacturing*, *14*(4), 1511–1524. https://doi.org/10.1007/s12008-020-00716-2

Hoellthaler, G., Braunreuther, S., & Reinhart, G. (2018). Digital Lean Production-An Approach to Identify Potentials for the Migration to a Digitalized Production System in SMEs from a Lean Perspective. *Procedia CIRP*, *67*, 522–527. https://doi.org/10.1016/j.procir.2017.12.255

Hronová, Š., & Špaček, M. (2021). Sustainable HRM practices in corporate reporting. *Economies*, *9*(2), 75. https://doi.org/10.3390/economies9020075

Jagtap, S., Bader, F., Garcia-Garcia, G., Trollman, H., Fadiji, T., & Salonitis, K. (2020). Food Logistics 4.0: Opportunities and Challenges. *Logistics*, *5*(1), 2. https://doi.org/10.3390/logistics5010002

Kannan, K. S. P. N., & Garad, A. (2021). Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia. *International Journal of Quality and Reliability Management*, *38*(3), 839–871. https://doi.org/10.1108/IJQRM-04-2019-0124

Kobus, J. (2016). Demystifying lean IT: Conceptualization and definition. *Multikonferenz Wirtschaftsinformatik, MKWI 2016*, *3*, 1429–1440.

Koleva, N. (2019). Conceptual framework to study the role of human factor in a digital manufacturing environment. *Industry 4.0*, *4*(2), 82–84.

Leesakul, N., Oostveen, A. M., Eimontaite, I., Wilson, M. L., & Hyde, R. (2022). Workplace 4.0: Exploring the Implications of Technology Adoption in Digital Manufacturing on a Sustainable Workforce. *Sustainability (Switzerland)*, *14*(6), 3311. https://doi.org/10.3390/su14063311

Li, D., Fast-Berglund, Å., Paulin, D., & Thorvald, P. (2022). Exploration of digitalized presentation of information for Operator 4.0: Five industrial cases. *Computers and Industrial Engineering*, *168*(February), 108048. https://doi.org/10.1016/j.cie.2022.108048

Li, D., Landström, A., Fast-Berglund, Å., & Almström, P. (2019). Human-centred dissemination of data, information and knowledge in industry 4.0. *Procedia CIRP*, *84*, 380–386. https://doi.org/10.1016/j.procir.2019.04.261

Ligarski, M. J., Rożałowska, B., & Kalinowski, K. (2021). A study of the human factor in industry 4.0 based on the automotive industry. *Energies*, *14*(20), 6833. https://doi.org/10.3390/en14206833

Manda, M. I., & Dhaou, S. Ben. (2019). Responding to the challenges and opportunities in the 4th industrial revolution in developing countries. *ACM International Conference Proceeding Series, Part F148155*, 244–253. https://doi.org/10.1145/3326365.3326398

Michael, Markus, L., Philipp, G., Manuela, W., Jan, J., Pascal, E., & Harnisch. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. *Boston Consulting Group*, *9*(1), 54–89. http://www.inovasyon.org/pdf/bcg.perspectives_Industry.4.0_2015.pdf

Mikulić, I., & Štefanić, A. (2018). The adoption of modern technology specific to industry 4.0 by human factor. *Annals of DAAAM and Proceedings of the International DAAAM Symposium*, *29*(1), 941–946. https://doi.org/10.2507/29th.daaam.proceedings.135

Miqueo, A., Torralba, M., & Yagüe-Fabra, J. A. (2021). Operator-centred Lean 4.0 framework for flexible assembly lines. *Procedia CIRP*, *104*, 440–445. https://doi.org/10.1016/j.procir.2021.11.074

Mohajan, H. (2019). The First Industrial Revolution: Creation of a New Global Human Era. *Journal of Social Sciences and Humanities*, *5*(4), 377–387.

Molino, M., Cortese, C. G., & Ghislieri, C. (2020). The promotion of technology acceptance and work engagement in industry 4.0: From personal resources to information and training. *International Journal of Environmental Research and Public Health*, *17*(7), 2438. https://doi.org/10.3390/ijerph17072438

Nagy, J., Oláh, J., Erdei, E., Máté, D., & Popp, J. (2018). The role and impact of industry 4.0 and the internet of things on the business strategy of the value chain-the case of hungary. *Sustainability (Switzerland)*, *10*(10), 3491. https://doi.org/10.3390/su10103491

Neumann, W. P., Winkelhaus, S., Grosse, E. H., & Glock, C. H. (2021). Industry 4.0 and the human factor – A systems framework and analysis methodology for successful development. *International Journal of Production Economics*, *233*, 107992. https://doi.org/10.1016/j.ijpe.2020.107992

Pattanapairoj, S., Nitisiri, K., & Sethanan, K. (2021). A gap study between employers' expectations in thailand and current competence of masterâ's degree students in industrial engineering under industry 4.0. *Production Engineering Archives*, *27*(1), 50–57. https://doi.org/10.30657/pea.2021.27.7

Pekarcikova, M., Trebuna, P., Kliment, M., & Rosocha, L. (2020). Material flow optimization through e-kanban system simulation. *International Journal of Simulation Modelling*, *19*(2), 243–254. https://doi.org/10.2507/IJSIMM19-2-513

Princy, K. (2016). a Study on Employees Skill Matrix At Automobile Industry in Vellore, Tamil Nadu. *EPRA International Journal of Multidisciplinary Research*, *2*(6).

Punna Rao, G. V., Nallusamy, S., Chakraborty, P. S., & Muralikrishna, S. (2020). Study on productivity improvement in medium scale manufacturing industry by execution of lean tools. *International Journal of Engineering Research in Africa*, *48*(1), 193–207. https://doi.org/10.4028/www.scientific.net/JERA.48.193

Rogall, C., Mennenga, M., Herrmann, C., & Thiede, S. (2022). Systematic Development of Sustainability-Oriented Cyber-Physical Production Systems. *Sustainability*, *14*(4), 2080. https://doi.org/10.3390/su14042080

Romero, D., Stahre, J., & Taisch, M. (2020). The Operator 4.0: Towards socially sustainable factories of the future. In *Computers and Industrial Engineering* (Vol. 139, p. 106128). Elsevier. https://doi.org/10.1016/j.cie.2019.106128

Romero, D., Wuest, T., Stahre, J., & Gorecky, D. (2017). Social factory architecture: Social networking services and production scenarios through the social internet of things, services and people for the social operator 4.0. *IFIP Advances in Information and Communication Technology*, *513*, 265–273. https://doi.org/10.1007/978-3-319-66923-6_31

Salvadorinho, J., & Teixeira, L. (2021). Stories told by publications about the relationship between industry 4.0 and lean: Systematic literature review and future research agenda. *Publications*, *9*(3), 29. https://doi.org/10.3390/publications9030029

Scheffer, S., Martinetti, A., Damgrave, R., Thiede, S., & van Dongen, L. (2021). How to make augmented reality a tool for railway maintenance operations: Operator 4.0 perspective. *Applied Sciences (Switzerland)*, *11*(6), 2656. https://doi.org/10.3390/app11062656

Shamim, S., Cang, S., Yu, H., & Li, Y. (2016). Management approaches for Industry 4.0: A human resource management perspective. *2016 IEEE Congress on Evolutionary Computation, CEC 2016*, 5309–5316. https://doi.org/10.1109/CEC.2016.7748365

Shet, S. V., & Pereira, V. (2021). Proposed managerial competencies for Industry 4.0 – Implications for social sustainability. *Technological Forecasting and Social Change*, *173*, 121080. https://doi.org/10.1016/j.techfore.2021.121080

Silva, N., Barros, J., Santos, M. Y., Costa, C., Cortez, P., Carvalho, M. S., & Gonçalves, J. N. C. (2021). Advancing logistics 4.0 with the implementation of a big data warehouse: A demonstration case for the automotive industry.

Electronics (Switzerland), *10*(18), 2221. https://doi.org/10.3390/electronics10182221
Tang, C. S., & Veelenturf, L. P. (2019). The strategic role of logistics in the industry 4.0 era. *Transportation Research Part E: Logistics and Transportation Review*, *129*, 1–11. https://doi.org/10.1016/j.tre.2019.06.004
Thorvald, P., Fast Berglund, Å., & Romero, D. (2021). The cognitive operator 4.0. *Advances in Transdisciplinary Engineering*, *15*, 3–8. https://doi.org/10.3233/ATDE210003
Urrutia Pereira, G., de Lara Machado, W., & Ziebell de Oliveira, M. (2021). Organizational learning culture in industry 4.0: relationships with work engagement and turnover intention. *Human Resource Development International*, 1–21. https://doi.org/10.1080/13678868.2021.1976020
Valamede, L. S., & Akkari, A. C. S. (2020). Lean 4.0: A new holistic approach for the integration of lean manufacturing tools and digital technologies. *International Journal of Mathematical, Engineering and Management Sciences*, *5*(5), 854–868. https://doi.org/10.33889/IJMEMS.2020.5.5.066
Wang, Y., Ma, H. S., Yang, J. H., & Wang, K. S. (2017). Industry 4.0: a way from mass customization to mass personalization production. *Advances in Manufacturing*, *5*(4), 311–320. https://doi.org/10.1007/s40436-017-0204-7

Biographies

Tiago Bastos graduated from the University of Aveiro with a licentiate's degree in Industrial Engineering and Management in 2020. He is an MSc in Engineering and Industrial Management student at University of Aveiro and works as a research fellow for the ANI-funded Augmented Humanity Project. His main research areas are : Human Resource Management 4.0; Business Process Management; BPMN 2.0; Information Systems; Operator 4.0; Information Systems Modelling.

Juliana Salvadorinho completed a MSc. degree in Industrial Engineering and Management in 2020 from University of Aveiro. She is currently pursuing a PhD in Industrial Engineering and Management (also from University of Aveiro) acting as a researcher for the Foundation for Science and Technology (FCT). She also collaborates in the Augmented Humanity Project funded by the National Agency for Innovation. She has published several scientific articles in international conferences and journals and has received 17 awards that recognise her academic path. Her focus is on Engineering Sciences and Technologies, with emphasis on the following terms of contextualization of scientific and technological production: Industry 4.0; Lean Manufacturing; Business Process Management; BPMN 2.0; Information Systems; Manufacturing Execution System; Data Visualization; Human Factor; Knowledge Management; Information Systems Modelling.

Andreia Vitória has a PhD in Industrial Engineering and Management, a master's degree, and a degree in Management from University of Aveiro. Currently, Andreia is an Assistant Professor at Department of Economics, Management, Industrial Engineering and Tourism of University of Aveiro, lecturing courses in Human Resource Management and Behaviour and Leadership in Organizations. She is a member of the research unit on Competitiveness, Governance and Public Policy (GOVCOPP), from University of Aveiro. Her research involves Human Resource Management, Organizational Behaviour, Leadership and Entrepreneurship. She has published in journals such as Leadership Quarterly and International Journal of Human Resource Management.

Leonor Teixeira graduated in Industrial Engineering and Management, received a MSc. degree in Information Management, and a PhD in Industrial Management (Information Systems area), in 2008, from the University of Aveiro, Portugal. She is currently an Associate Professor of the Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT) at the University of Aveiro. She is also a researcher (Integrated Member) at the Institute of Electronics and Informatics Engineering (IEETA) / Intelligent Systems Associate Laboratory (LASI), and collaborator at research unit on Competitiveness, Governance and Public Policies (GOVCOPP) of University of Aveiro. Her current research interests include Industrial Management in general, and in Information Systems applied to Industry in particular. She has over 200 publications in peer-reviewed journals, book chapters and proceedings, and has several communications at international scientific conferences, some of which as invited speaker. She serves as a member of Program Board and Organizing Committees for several Scientific Committees of International Conferences and has collaborated as reviewer with several journals. She is associated with IIIS and APSI/PTAIS.