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Human resources in the era of the fourth industrial revolution: Competencies 4.0

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Abstract: Manufacturing companies are undergoing significant transformations in their shift to Industry 4.0. This study investigates the key competencies required by workers during this transition, as well as the evolving roles and challenges faced by employees. A systematic literature review (SLR) identified 35 critical skills, which informed a survey with top and middle managers to evaluate the perceived importance of these skills across various roles and hierarchical levels. The findings reveal a shift in skill requirements, with soft skills gaining prominence over hard skills, especially for management roles. Middle managers, in particular, are highlighted as needing to balance a diverse skill set to effectively navigate Industry 4.0. This research addresses a gap in the literature by offering insights into skill prioritisation and workforce evolution, emphasising the importance of comprehensive upskilling strategies to ensure a successful digital transformation.

Keywords: Industry 4.0; competencies; human resources; skills; digitalisation.

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1 Introduction

Currently, we are witnessing the rapid advance and transformation of production support technologies that are presenting a wide range of challenges and possibilities for industrial companies. The so-called Industry 4.0 (I4.0) (Schwab, 2016), is based on a huge profusion of technologies covering areas such as artificial intelligence, robotics, the internet of things, 3D printing, nanotechnology, quantum computing, among many others, promising to revolutionise the way we live, work and interact.

The technologies in which the Fourth Industrial Revolution finds its foundations break down the boundaries between the physical, digital and biological spheres of manufacturing systems, affecting all disciplines from strategic planning to economics, and different industries, from manufacturing to services (Kearney, 2017). The fourth industrial revolution is more than just a change driven by technology. Instead, it is fuelled with breakthrough innovation in order to positively impact our major companies (Xu et al., 2018). This digitalisation wave promises to automate both operations and decision-making activities, resulting in improved accuracy, speed, and precision over manual activities and leading to higher production output and quality, reduced lead times, and enhanced customer satisfaction (Margherita and Braccini, 2024).

The magnitude of the consequences resulting from this transformation for work is still uncertain. However, in terms of breadth, areas involved, and complexity, the transformations we are facing will be unlike anything humanity has ever experienced, with millions of jobs disappearing at a pace never seen before, simultaneously with the emergence of others (Devezas et al., 2017).

I4.0, promises to automate many manual and repetitive tasks and at the same time create opportunities for human-computer cooperation (Margherita and Braccini, 2024). Operators can work aided by machines achieving a state of advanced human-machine interaction technologies and adaptive automation or human-automation symbiosis (Romero et al., 2016).

Regarding the consequences or impacts of the implementation of I4.0, studies show that it could contribute to increase competitiveness, enhance product evolution and reduce inefficiencies eliminating the obstacles between inventors and markets (Enyoghasi and Badurdeen, 2021; Naeem and Di Maria, 2020). These new technologies give access to new markets, speed up the new product development process and thus contribute to the maximisation of value creation for the customer (Stelzle et al., 2017). In addition, some indications were found that I4.0 may be able to enhance the sustainability of processes (Kamble et al., 2018; Müller et al., 2018).

While I4.0 technologies enable human-computer cooperation in certain aspects, there are also instances where they lead to the elimination of workers from certain operations, especially those that are repetitive and automatable (Margherita and Braccini, 2024). In the end, if a human focused approach is taken, adapting the factory floor to the skills and needs of the workers, and involving the work community through tools that allow participation in job design, training, and knowledge sharing, I4.0 technologies can even enrich factory work, promoting a more interesting work environment, autonomy, and self-development opportunities (Kaasinen et al., 2020).

Given this reality, it becomes clear that job profiles and the skills required to perform the work will change in many sectors and for many functions. This means that it is important to clarify the necessary transformations and adaptations in the educational development of employees (AlMalki and Durugbo, 2023; Jerman et al., 2018) with a focus on defining the portfolio of skills to be developed among the workforce, especially regarding the qualification of employees to deal with technological changes and emerging challenges (Hecklau et al., 2016), according to typical roles in production (Erol et al., 2016).

Several studies acknowledge the existence of gaps in knowledge and industry skills that need to be filled for the implementation of I4.0 (Hecklau et al., 2016; Pinzone et al., 2023; Vereycken et al., 2021). Examples include the lack of involvement of experts and expansion of their search of technical skills (Castelo-Branco et al., 2019), to include the social and personal (Erol et al., 2016; Pinzone et al., 2023), or even the leadership skills (Hecklau et al., 2016).

The search for talent could give rise to an increasingly segregated labour market. Low-skilled, low-wage jobs are potentially replaceable by computers and digitalisation as opposed to jobs requiring higher skills (Mpofu et al., 2019), which could potentially lead to an increase in social tensions (Mitrović, 2020). The assessment of individual employees' competencies can ensure they are prepared for the evolving work environments. This implies the need to conduct in-depth studies to pinpoint and address the specific competency needs for successful I4.0 implementation (Hecklau et al., 2016), not only in a more general approach, but also observing competency gaps for workers with distinct roles (Erol et al., 2016).

There is a lack of detailed insight into how digital technologies may differ in practice and how these changes affect employees' skills. The exact nature of the skill changes needed for I4.0 is not known (Vereycken et al., 2021).

Competencies and skills are concepts that both apply to individuals and refer to their ability to do something (Rodrigues et al., 2021). In this paper, we follow the approach of Rodrigues et al. (2021) that defines a skill as the ability to perform a specific task, while a set (domain) of tasks can be associated with a competence. Although a skill is an attribute of the individual, it is naturally related to a specific activity, with each task having an associated skill.

A skill can be assessed depending on how well the task is performed, thus being a relative concept. On the other hand, a skill is something that is acquired and can be improved by different means, mainly by learning and practicing.

When relating skills to an individual's level of performance on a particular task or the ability to perform a task well, which can be divided into technical and behavioural elements, it is important to understand that the technical elements determine the technical skills, or hard-skills, while the behavioural elements determine the soft-skills which

include the attitudes and approaches that professionals adopt in their work (Patacsil and Tablatin, 2017).

2 Purpose

Considering the above, the importance of studying the impact of I4.0 on workers and the jobs they perform is clear, since effective increases in efficiency cannot be carried out without due attention to the human capital, considered by many as the main resource of the firm (Al-delawi et al., 2023; Gruzina et al., 2021; Vithana et al., 2021).

A company that is aware of this new reality and that takes into account the proper treatment of these issues should naturally be able to better achieve its objectives, meeting the market requirements and thus obtaining a competitive advantage (Virmani et al., 2023). In this way, the biggest challenge facing companies, within the scope of this industrial revolution, may not be the technology itself, but people and the influence of new processes on their daily lives in their workplace.

The object of this study, therefore, is to discern any changes in the profiles of the workers' skills resulting from the current era of digitalisation, structuring the research questions as follows:

- RQ1 What are the key competencies for an I4.0 worker?
- RQ2 How does the importance of the different skills of an I4.0 worker change with the introduction of the current digitalisation era?
- RQ3 To what extent does the importance of the various skills, as well as their evolution, depend on the job and the hierarchical level in manufacturing industry?

3 Methodology

In order to answer the research questions, a research strategy was outlined that initially involves a systematic literature review (SLR) followed by a survey.

The SLR intends to fully explain the state of the art, based on systematic bibliographical research, in scientific databases chosen for the literature review such as Scopus and the Web of Science Core Collection. For the selection of the documents to be analysed, a search was carried out with specific keywords running on publications that deal with the impact of I4.0 on the profile of skills, work, workers and jobs following the methodology proposed by Keathley-Herring et al. (2016).

Conforming to the SLR, in order to establish a set of key competences for a professional of the I4.0 era, the articles are analysed and the terms used to define the various competences considered as key to an I4.0 worker are extracted from them, in order to address RQ1. For the subsequent steps of the work, the set of these various skills will then be assessed as the portfolio of competencies 4.0.

Using the list of skills obtained from the SLR, we tried to acquire a broader view of the sensitivity in the manufacturing industry for the issues under analysis. Professionals were given a survey to confirm some results highlighted in the SLR as well as to fill in some gaps that may eventually serve as a basis for new research questions to explore in the future. Specifically, the survey aimed to better understand which types of

competences would change in importance with I4.0 (RQ2) and whether this change would depend on the hierarchical level or function performed (RQ3).

4 Systematic literature review

4.1 Article selection

To perform the SLR the methodology proposed by Keathley-Herring et al. (2016). The search strategy began with a focus on the identification of potential search terms, using the online databases Web of Science and Scopus to determine the articles to be included. The search was conducted on December 14, 2021, looking for articles published after 2015 in the English language, without any restriction regarding the area of research.

The final strategy was to search for the fields, title, abstract and keywords, ensuring that the terms considered for research were the central focus of the article. We searched the whole set of expressions or words that could indicate that the focus of the publication would be I4.0 or others considered equivalent, in the aforementioned fields demanding that in the selected fields the expressions 'I4.0', 'fourth industrial revolution', '4th industrial revolution', 'industry digitisation', 'digital revolution', 'industrial internet', 'digital factory', 'smart manufacturing', 'intelligent factory' and 'factory of the future' were included.

To obtain articles on the relationship between the operationalisation of I4.0 and the change in the necessary skills or its influence on work and employment, the search was restricted to articles that also contained, in the selected fields, the expressions 'human resources', 'work organisation', 'competency profile', 'skills', 'competence', 'jobs', 'employment' or 'qualification'.

To determine exclusion criteria, the first 50 articles were analysed by relevance order in each of the consulted databases and, through these, an attempt was made to identify terms and phrases that could be used in the search to refine the Boolean expression. From the set of articles, a subset dedicated to the analysis of educational programs for the development of I4.0 competencies stood out. Despite this being a subject of undeniable importance, it is not the focus of this particular work, so we refined the Boolean expression in order to exclude these publications, along with a set of articles, usually from the medical field, whose focus is on ergonomic issues related to the execution of I4.0 tasks. This exercise resulted in the Boolean expressions that can be found in Appendix 1.

After applying the Boolean expressions to each of the databases, two sets of publications were obtained, consisting of 150 articles from the Scopus database and 96 articles from the Web of Science database. After eliminating duplicates from the two sets, we were left with 189 publications. This set was then subjected to a more refined reading, seeking to understand which ones effectively enumerated the fundamental competences for the I4.0.

Upon completion of this reading, the following list of exclusion criteria was applied to remove articles that deviated from the main focus of the research objectives:

- skills for operating or interacting with a specific machine, equipment or technology
- public policies to favour the acquisition of skills
- models for enhancing the use of skills
- the development of teaching curricula for the acquisition of competences
- economic advantages of having a certain skill
- worker's state of mind
- articles that, despite having an abstract and keywords in English, are written in another language.

After applying the aforementioned exclusion criteria, the resulting final set of publications consists of 65 articles. This final set must now be classified, particularly as it relates to the specific theme of the article. From a more complete reading of the articles, the set of topics covered was defined as well as the grouping of publications by topic. Each of the publications may be present in more than one of the sets of final articles. In this way, the themes covered by the remaining set of articles were extracted and the approach of these same themes by each of the articles was verified. The themes according to which the articles were classified are:

- 1 Skills Assessment 4.0
- 2 Skills Development 4.0
- 3 Impact of 4.0 skills on work
- 4 Importance of 4.0 skills for the maturity of I4.0 Implementation
- 5 Skills 4.0 in recruitment.

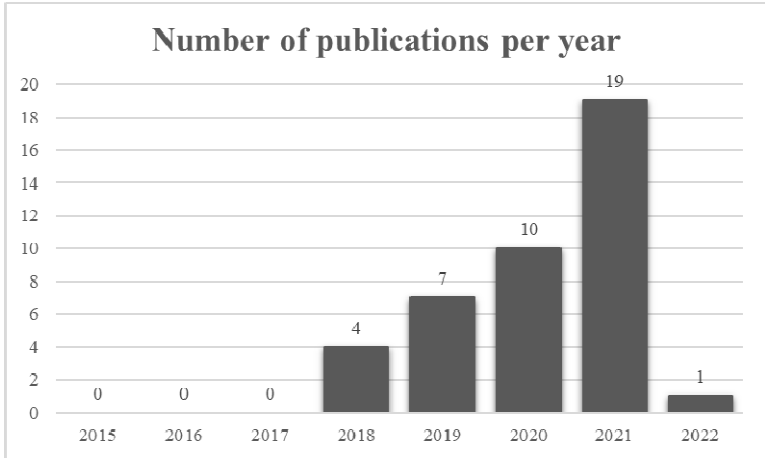
Being the purpose of this work, the study of the importance and the importance evolution of a set of skills, for the I4.0, we focused our attention on the articles addressing the theme 'skills assessment' which corresponds to a group of 41 articles.

4.2 Article analysis

Considering the 41 articles emerged as the ones listing the 4.0 competencies, we started by making a more qualitative analysis.

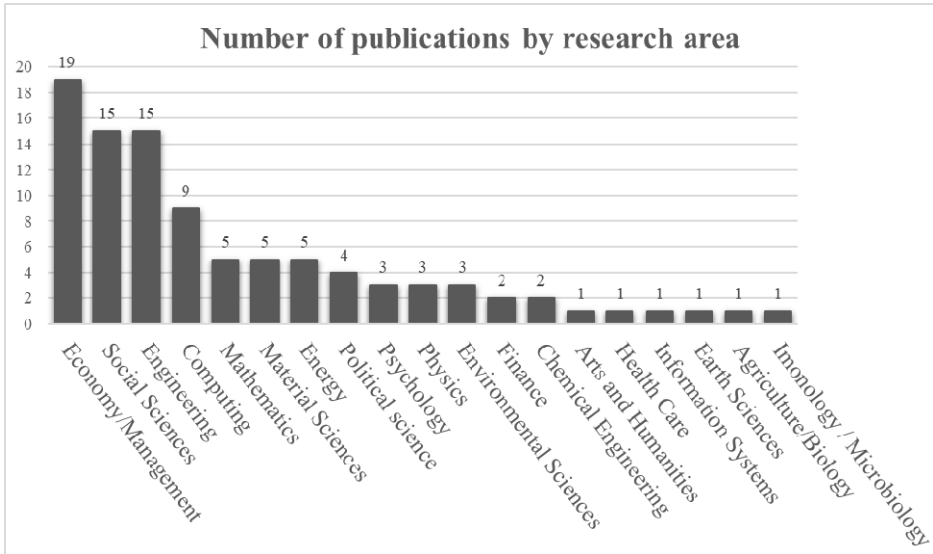
The first published article in this set dates from 2018, which shows that we are dealing with a subject that has only recently started to receive more research attention. However, it is a theme whose interest seems to be growing, reaching 19 articles in 2021, as shown in Figure 1.

Figure 1 Final set of papers per year

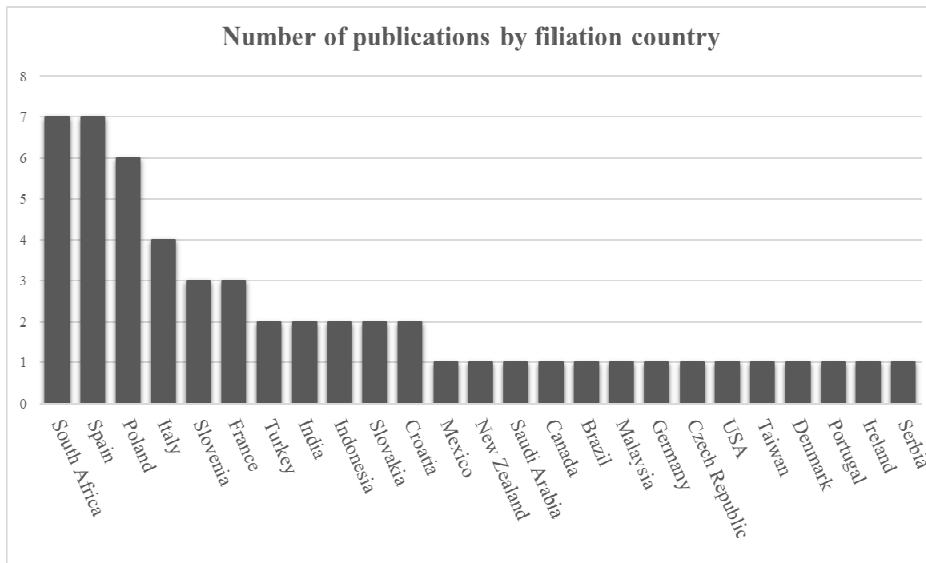


The number of articles per scientific area was analysed, and it was found that the most active research areas in terms of publications on the subject of key competences for implementing 14.0 are Economics and Management, Engineering, Social Sciences and Computer Science, as can be seen in Figure 2.

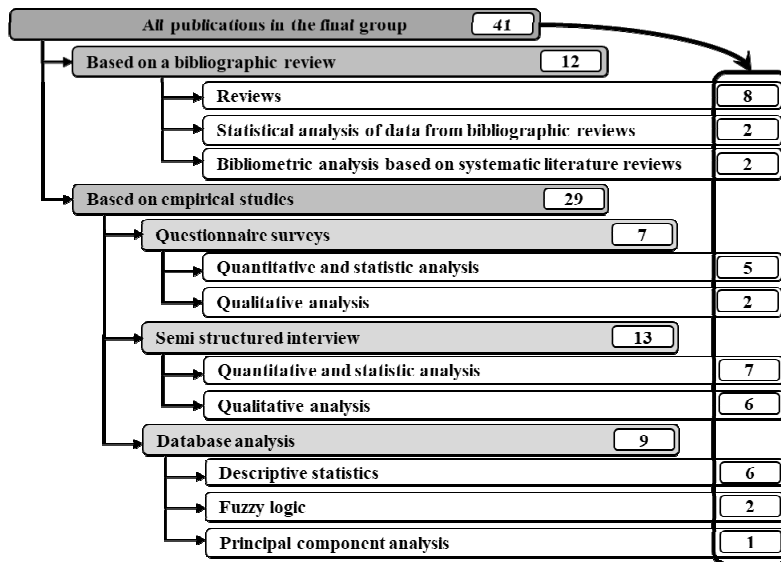
Figure 2 Final set of papers per research area



The analysis of the number of publications by country of affiliation of the authors reveals two distinct curiosities. First, it shows that after an initial phase where publications on the subject were centred on authors from European countries (Liao et al., 2017), its dissemination around the world is verified, namely, with authors from South Africa having the largest number of publications, as can be seen in Figure 3.

Figure 3 Final set of papers per authors' affiliation country

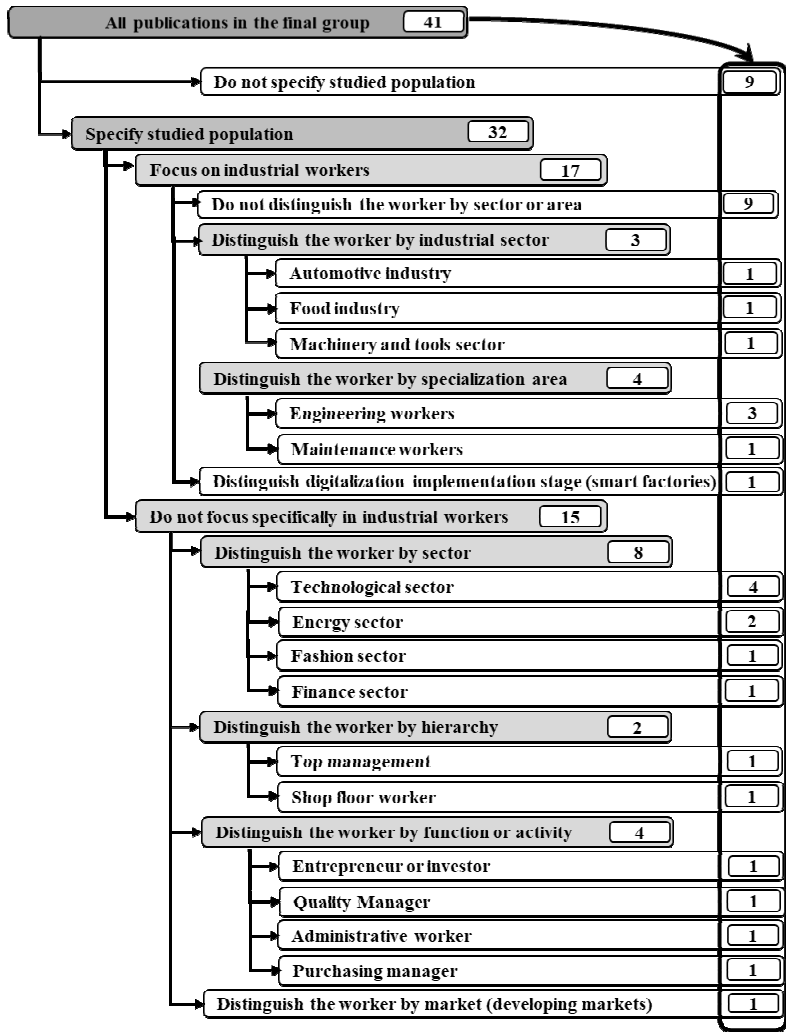
Analysing the number of citations of each of the articles comprised in this list, we arrive at an average of 8.4 citations per article, at the date of the analysis, with the 4 most cited reaching 58 (Kazancoglu and Ozkan-Ozen, 2018), 34 (Jerman et al., 2020), 29 (Flores et al., 2020), and 20 (Kipper et al., 2021) respectively.

Figure 4 Final set of papers by methodology

An analysis of the methodologies used results in a set of 12 publications resulting only from literature reviews and 29 resulting from empirical studies. The publications based

on literature reviews are divided into 8 review articles, 2 publications resulting from statistical analysis of data collected in literature reviews and 2 from SLRs, while those resulting from empirical studies are divided into 7 using surveys, 13 semi-structured interviews and 9 database analyses (Figure 4).

Figure 5 Final set of papers by studied population



With regard to the population studied by these articles, it appears that the population most studied is manufacturing workers, with 17 publications. One gap that stands out from this analysis is the scarcity of studies specifically focused on the comparison between manufacturing workers of different hierarchical levels and functions (Figure 5). This gap becomes even more prominent if we focus on shop floor workers. As this is a group of workers who may face numerous future challenges arising from the increasing automation of tasks, we would expect a greater number of studies on the impact of digitalisation on their skills.

4.3 Articles review

The review was conducted in search of the understanding of the key competencies required for workers to thrive in the context of I4.0, with a particular focus on the balance between hard and soft skills.

One of the major indications of this review is the increasingly significance of the soft skills in the published literature regarding I4.0. As automation takes over routine and repetitive tasks, skills such as communication, problem-solving, critical thinking, creativity, teamwork, and decision-making are highlighted as critical for modern workplaces (Chaka, 2020). These skills are crucial for workers to effectively interact with complex technologies and collaborate within digital environments (Lenarčič, 2019). The literature also discusses how the demand for hybrid competencies is rising, meaning the workforce needs to develop both technical knowledge and soft skills (Lenarčič, 2019).

The requirement for a combination of technical and interpersonal skills is emphasised in the literatures with indications that, workers in fields like manufacturing, banking, and finance must not only understand the technology they work with but also develop leadership, strategy formulation, and self-organisation skills to manage their increasingly autonomous and digitally-enabled roles (Santoso et al., 2020). Some studies highlight that soft skills will enable workers to navigate interdisciplinary challenges and lead innovation in their fields (Kipper et al., 2021; Poszytek, 2021).

A recurring theme is the potential impact of I4.0 technologies on employment (Bag et al., 2020). The automation of manual and repetitive tasks poses significant challenges, especially for low-skilled workers, whose jobs are at risk of becoming obsolete (Siguencia et al., 2019). However, the literature also highlights the opportunities created by new roles that demand higher levels of cognitive and complex problem-solving skills (Rasca, 2018).

This focus on reskilling and upskilling the workforce to adapt to the changing demands of digital transformation is essential. Many publications indicate the need for educational and training programs to shift their focus towards these emerging competencies (Ejsmont, 2021).

The literature takes note of an increasing acknowledgment that traditional education may no longer be sufficient to meet the demands of I4.0, with, lifelong learning, continuous skill development, and professional training assuming a decisive role for employees to stay competitive (Arcelay et al., 2021).

A notable suggestion in the literature is the development of competency databases, which integrate professional profiles and outline current and future skill needs for different jobs. This resource would guide both educational institutions and employers in designing relevant training and recruitment strategies for I4.0 (Pejic-Bach et al., 2020).

The literature also highlines some variation in skill requirements across different hierarchical levels within companies. The need for competencies grows with the level of responsibility. For instance, middle managers may need a stronger focus on leadership and adaptability compared to factory floor workers, who may require more technical skills (Chaka, 2020). Additionally, some studies suggest that lower-skilled factory jobs will be most impacted by automation, while roles requiring a high degree of autonomy and problem-solving will likely see a growth in importance (Chukwuekwe et al., 2016).

In resume, the literature reflects a nuanced understanding of how I4.0 is reshaping both the workplace and the skill sets required for future jobs, suggesting that a balanced

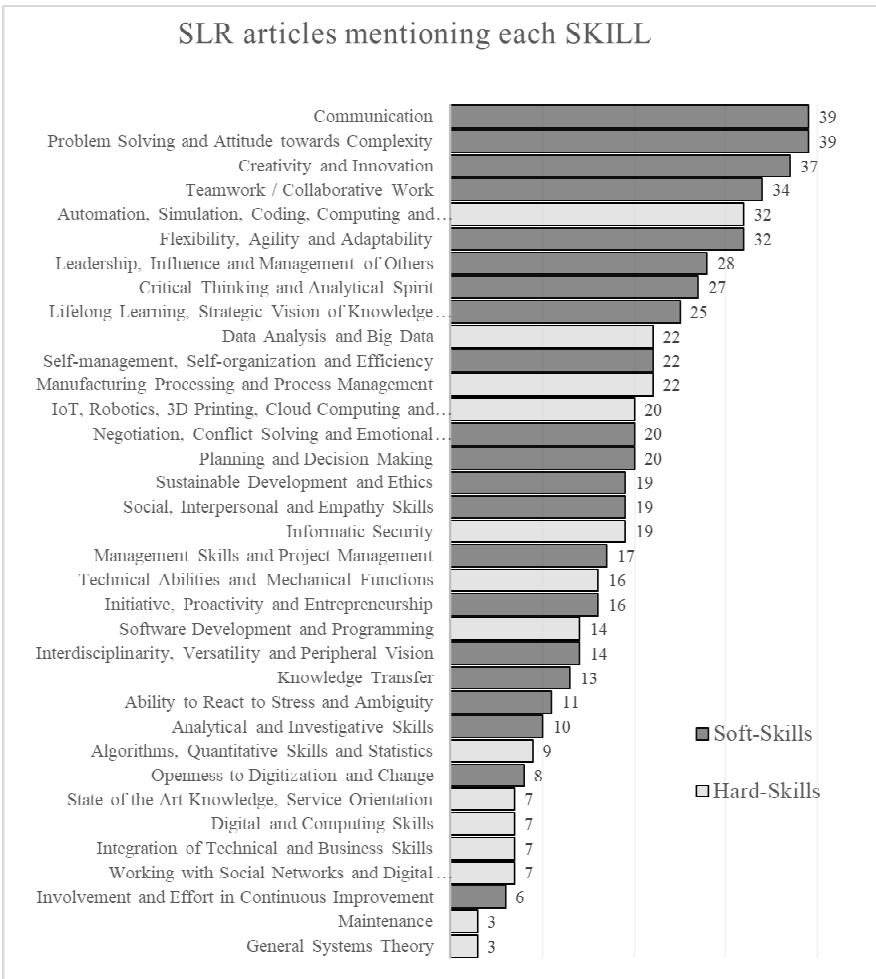
development of both technical and behavioural skills is essential for navigating the ongoing digital transformation.

From this reading, we confirm the topicality and relevance of this work, presenting further, the description of the process taken, in order to have a glamp over the importance of a set of skills and the way it evolved with the I4.0.

4.4 Competencies 4.0

The articles from the final paper set were revised and we collected all the different terms used to define the critical skills for I4.0, grouping them by similarity and complementarity of the concept expressed, and classifying each of the skills compiled into soft-skills or hard-skills, as shown in Appendix 3.

Figure 6 Number of publications in which each skill is mentioned



The result of the aforementioned analysis is a set of 35 distinct skills, of which 14 are hard-skills and 21 are soft-skills, which in itself shows some preponderance of the latter

over the former. This is reinforced by the analysis of the 10 most frequently mentioned: 8 being soft skills (communication; problem solving and attitude towards complexity; creativity and innovation; teamwork; flexibility, agility and adaptability; leadership, influence and management of others; critical thinking and analytical spirit; lifelong learning) and only 2 hard-skills (automation, simulation, coding, computing and IT systems; data analysis and big-data).

The number of articles mentioning each skill was counted, and the results, ordered by the number of mentions, are presented in Figure 6.

Analysing the total number of mentions to any of the skills, we arrive at a number of 644 mentions, in which 456 refer to soft-skills and 188 to hard-skills or 70.8% of the mentions of fundamental competencies for the implementation of I4.0 in the final paper set refer to soft-skills. It is also significant that the two most mentioned hard-skills are automation, simulation, coding, computing and IT systems and data analysis and big-data, that are only in the fifth and tenth places on the list. These hard skills easily fit the concept of technical knowledge necessary to operate with certain equipment or to perform some specific task.

5 Survey

5.1 Instrument design and sample

In an attempt to assess how companies assign different importance to the various skills that make up the portfolio obtained by analysing the final SLR set of articles, and particularly to shed some light on RQ2 and RQ3, we sent a self-administered survey to manufacturing professionals from both human resource management and operational management.

In addition to an initial set of questions aimed at characterising the sample of respondents, the questionnaire has two parts. In the first one, the respondents are asked to rate the importance of each of the mentioned 35 skills for the I4.0 implementation for three different hierarchical levels in the manufacturing industry: shop floor operators, middle managers and senior managers. The importance is rated from 1 to 5 on a Likert-type scale where 1 is the least important and 5 is the most important. In the second part, for each of the hierarchical levels mentioned, the respondents are asked whether the importance of each skill has increased, decreased or maintained, as a result of the ongoing digitalisation process.

A total of 39 responses were obtained, 28 from men and 11 from women, of which 21 were operational managers and 18 human resource managers. The sample of respondents to the survey can be classified as a convenience sample, made up of known company professionals available to answer the questionnaire.

5.2 Results

Tables in Appendix 4 and Appendix 5 show the average importance attributed to each skill, as well as indications of the change in its importance, according to the answers to the survey.

For each hierarchical level, we analysed which skills appear in the first ten places classified by importance. Table 1 confirms the superior importance of soft skills, as that

there are only two hard skills, one for shop floor operators and another for middle managers. It is also possible to verify that there are 6 common skills in all 3 hierarchical levels, those being teamwork/collaborative work, communication, flexibility, agility and adaptability, openness to digitisation and change, social, interpersonal and empathy skills and knowledge transfer. It seems that these are the base competences for a better implementation of I4.0 in manufacturing companies.

Table 1 Top ten skills classified by importance, for each hierarchical level

<i>Ranking</i>	<i>Top managers</i>	<i>Middle managers</i>	<i>Shop floor operators</i>
1	Teamwork/collaborative work	Communication	Teamwork/collaborative work
2	Communication	Teamwork/collaborative work	Social, interpersonal and empathy skills
3	Flexibility, agility and adaptability	Social, interpersonal and empathy skills	Flexibility, agility and adaptability
4	Openness to digitisation and change	Knowledge transfer	Openness to digitisation and change
5	Social, interpersonal and empathy skills	Problem solving and attitude towards complexity	Communication
6	Planning and decision making	Involvement and effort in continuous improvement	Technical abilities and mechanical functions
7	Leadership, influence and management of others	Openness to digitisation and change	Involvement and effort in continuous improvement
8	Knowledge transfer	Flexibility, agility and adaptability	Knowledge transfer
9	Lifelong learning, strategic vision of knowledge and growth mindset	Leadership, influence and management of others	Lifelong learning, strategic vision of knowledge and growth mindset
10	Problem solving and attitude towards complexity	Manufacturing processing and process management	Ability to react to stress and ambiguity
# Soft skills	10	9	9
# Hard skills	0	1	1

Table 2 Survey results – average importance attributed to soft and hard skills, by hierarchical level

<i>Skill type</i>	<i>Soft-Skills</i>	<i>Hard-skills</i>	<i>Overall</i>
<i>Hierarchical level</i>			
Top managers (TM)	4.33	3.55	4.02
Middle managers (MM)	4.27	3.76	4.07
Shop floor operator (SF)	3.69	3.03	3.43
Overall	4.10	3.45	3.43

Table 2 summarises the averages of responses regarding the importance attributed to soft-skills and hard-skills by hierarchical level and shows that a greater relative importance is attributed to soft-skills.

To verify whether the means obtained for the various hierarchical levels are statistically equal or different, a t-test was performed, with a 95% confidence interval, applicable to both independent and paired samples, serving to test hypotheses about mean difference of quantitative variables. As the sample size is greater than 30, the t tests do not require a normal distribution, so this requirement was not verified (Table 3).

Table 3 p-value for two-sample t-tests for the comparison of the overall importance of skills between the different hierarchy levels, with 95% confidence interval

	<i>Total</i>	<i>Soft-Skills</i>	<i>Hard-Skills</i>
TM – MM	0.668	0.606	0.163
MM – SF	0.000	0.000	0.000
SF – TM	0.000	0.000	0.001

Notes: TM: Top managers; MM: Middle managers; SF: Shop floor operators

When comparing the skills mean level of a top manager with a middle manager, we cannot reject the null hypothesis that we are facing equal means due to a p-value higher than the significance level of the test. Which is, contrary to what happens when comparing the mean of the shop floor operators with the other hierarchical levels. This suggests that the respondents to the survey attribute equal importance to the level of skills of top managers and middle manager and, clearly distinguishes them from shop floor operators. This can be seen either by dividing the competences into soft-skills and hard-skills, or by assessing the importance of all of them together.

The importance of the different type of skills results in a statistically higher average assessment for soft-skills than for hard-skills in all hierarchical levels, as verified with Student's t-tests for the equality of means (Table 4).

Table 4 p-value for two-sample t-tests for the comparison of importance between soft and hard skills, per hierarchy level, with 95% confidence interval

	<i>Total</i>	<i>Top managers</i>	<i>Middle managers</i>	<i>Shop floor operators</i>
SS – HS	0.000	0.000	0.000	0.000

Notes: SS: Soft-skills; HS: Hard-Skills

Figure 6 shows the trends in the changing importance of skills with the emerging digital era by hierarchical level. It shows that for the majority of skills their importance remains unchanged and only a few decrease, for all the responsibility levels. At the same time, there appears to be a relationship between the hierarchical level and the number of skills showing an increase of importance.

Analysing the variation in importance attributed by respondents to the various skills, it appears that, for all hierarchical levels, the number of responses indicating a decrease in importance is very low (Figure 6). Although the majority of the skills maintain their level of importance, according to the respondents around 40% of them need to be given greater importance. Simultaneously, there appears to be a slight relationship between the number of responses indicating an increase in the importance of skills and the hierarchical level

of the position, since this number decreases from top managers to middle managers and from this group to the shop floor operators.

Figure 6 Change in importance of all skills, in % of total answers, by hierarchical level

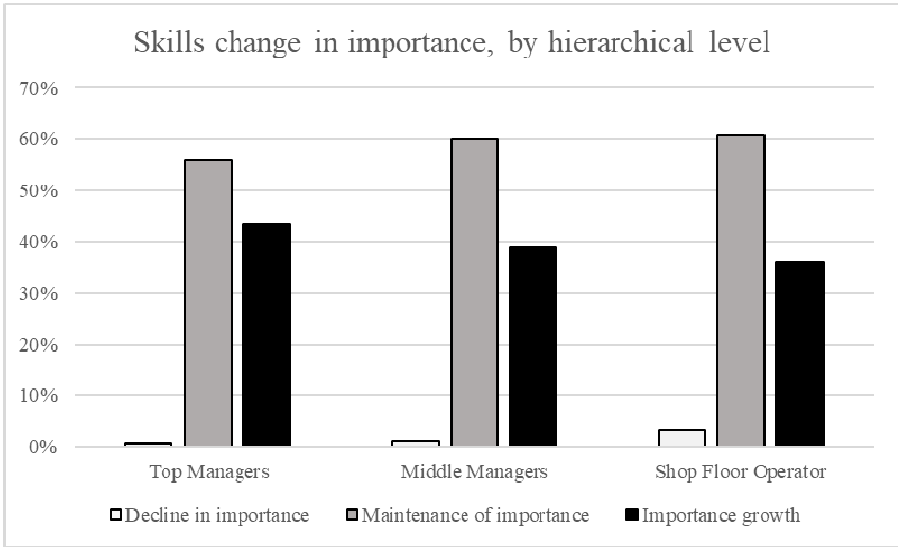
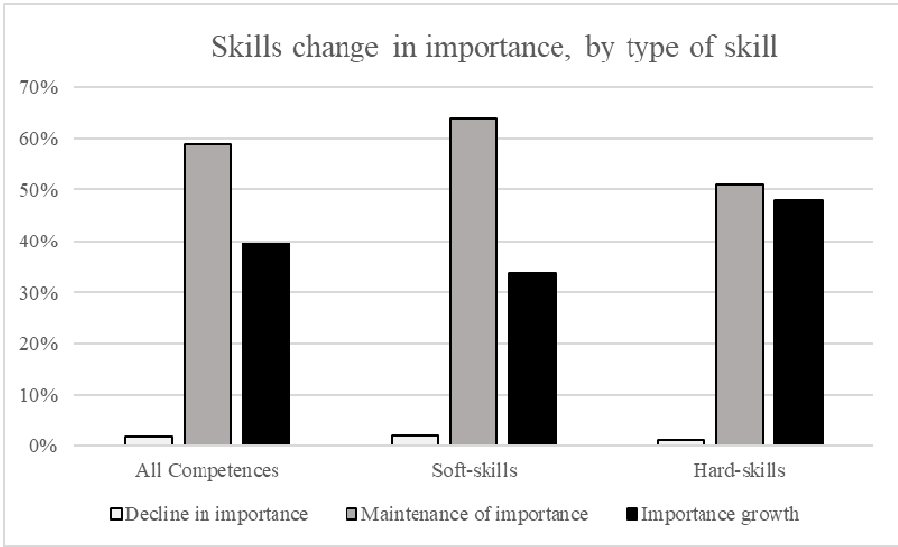


Figure 7 shows the percentage of responses indicating the change in the importance of each skill, grouped as soft and hard skills.

Figure 7 Change in importance of soft and hard skills, in % of the total responses



According to the survey results, hard-skills are the type of skills that showed greater growth in importance with the implementation of I4.0. On one hand soft-skills are classified as most important (Table 1) and on the other hand, in most cases, hard skills show the greatest increase in importance with the introduction of I4.0 (Figure 7).

In order to refine the analysis, this assessment was segmented by type and hierarchical levels as seen in Figures 8 and 9.

Figure 8 Change in importance of soft skills, by hierarchical level, in % of the total responses

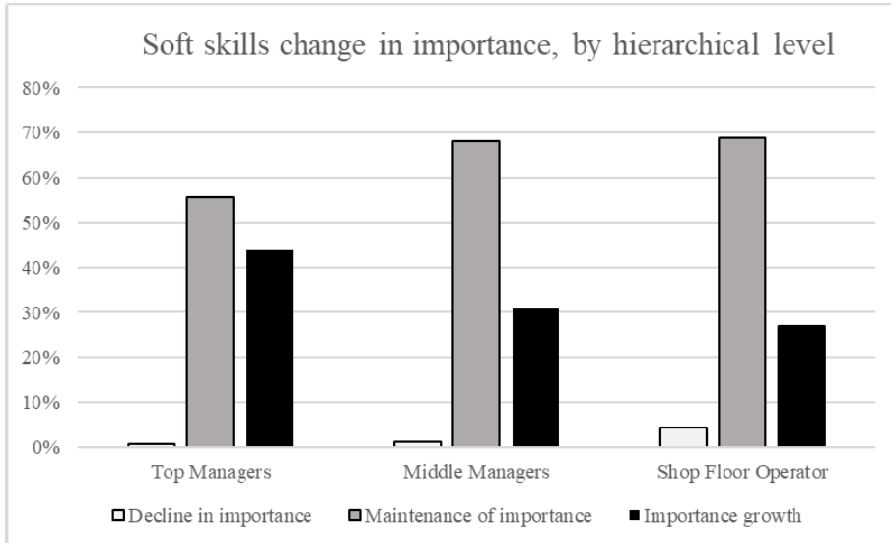
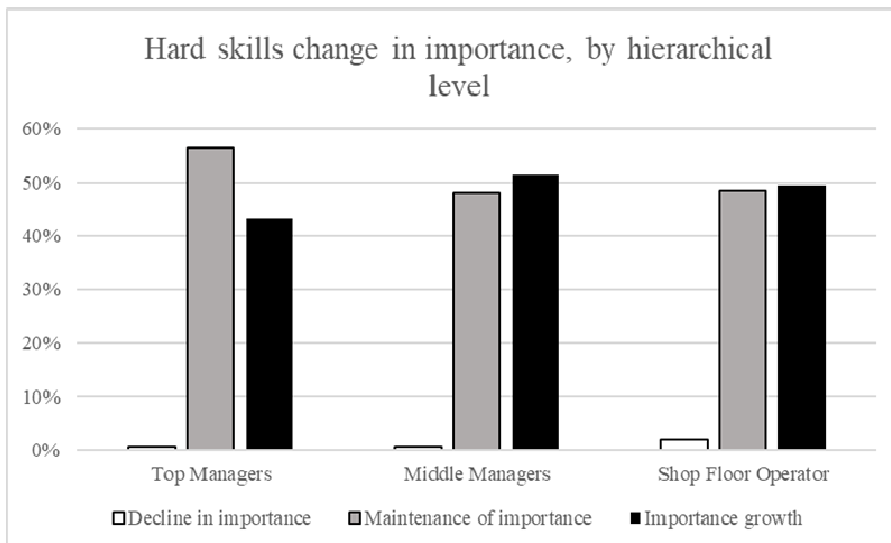


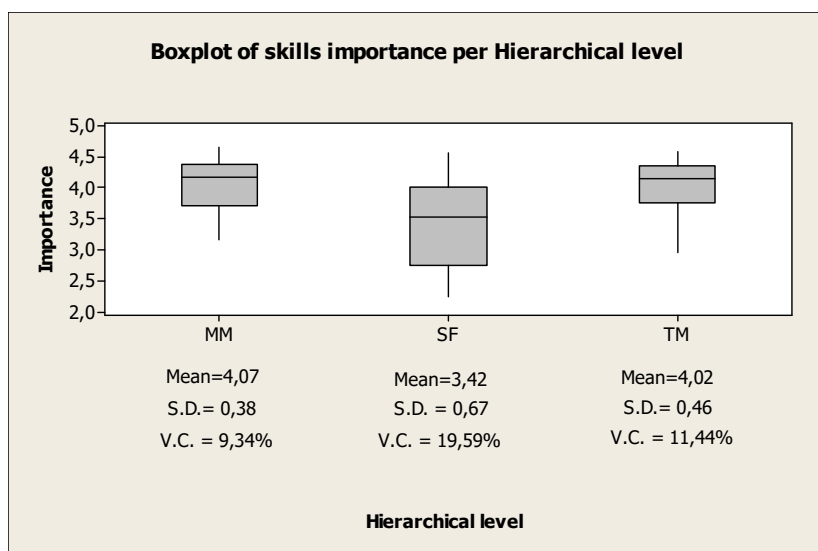
Figure 9 Change in importance of hard skills, by hierarchical level, in % of the total responses



Analysis of the figures shows that the trend of the increasing importance of hard-skills when compared to that of soft-skills, due to the implementation of I4.0, extends to all hierarchical levels. In addition, it seems that the higher the hierarchical level, the greater the number of responses pointing to an increase in the importance of soft-skills. As far as hard-skills are concerned, this relationship between the change in importance and the hierarchical level is no longer observed, with middle managers having the largest number of responses indicating a growth in importance, followed by shop floor operators and only then by top managers.

In Figure 10 the boxplot of the skills importance by hierarchical level can be found. It shows a smaller dispersion for the middle managers when compared to top managers and shop floor operators. This shows that even with a mean that cannot be considered statistically different, the concentration of skills with an importance closer to the mean is higher for the middle managers than for the top managers and lower for the shop floor operators.

Figure 10 Boxplot of the skills importance, per hierarchical level (see online version for colours)



These results suggest that middle managers might have a need for a more balanced and complete skills profile. It also suggests that middle managers are currently seen by professionals as the most fundamental hierarchical level for a good I4.0 implementation, which is why they need a distinctive skills portfolio.

6 Discussion

Both survey response analysis and the SRL's paper set reveal the fundamental importance of soft-skills in the transition to the digital age (Hernandez-de-Mendoza et al., 2020).

In fact, the survey's results do not differ a great deal from what was expected from review of the literature, where, not neglecting the importance of technical skills such

acknowledge of the state of the art of the industry or the understanding of business processes, greater importance is attributed to various soft-skills, such as social and cognitive skills, teamwork, flexibility, interdisciplinarity, problem solving, adaptability, leadership, strategic vision of knowledge or self-organisation and self-management (Ada et al., 2021; Akyazi et al., 2020c; Jerman et al., 2020; Kipper et al., 2021; Peña-Jimenez et al., 2021; Poszytek, 2021). These soft-skills are linked to personality traits and reflect a person's social advantages in a given environment (Blayone and VanOostveen, 2021; Flores et al., 2020).

A possible explanation for the greater importance obtained for soft-skills could be the fundamental role they play in managing the necessary and constant adjustment to an ever-increasing pace of environmental change aimed at obtaining competitive advantage and company success (Akyazi et al., 2020b; Liszka et al., 2019).

The results of the survey confirmed that the changes in competences with respect to the digital transformation of manufacturing companies must be studied by differentiating the hierarchical level or type of function performed. Top managers showed a greater need for growth in soft-skills, followed by middle managers and then shop floor operators, in contrast to hard-skills where middle managers show the highest number of responses indicating a growth in importance, followed by shop floor operators and lastly by top managers.

The need to enhance soft-skills appears even more prominent in the case of employees with management responsibilities (Lassen et al., 2021; Marnewick and Marnewick, 2020; Saniuk et al., 2021; Santos et al., 2021) is also confirmed from the survey response analysis, where top managers received the greatest scores for soft-skills. The results showed that top and middle managers clearly need a higher level of soft skills than the shop floor operators do.

Nevertheless, shop floor operators also require a higher level of soft skills than hard skills. It seems this also happens when studying interactions between human operators and devices, in which robots themselves become part of work teams (Blayone and VanOostveen, 2021; Marnewick and Marnewick, 2020). In these interactions, the relationship between people and machines is seen in a very similar way to that of the relationship between people (Kwiatkowska et al., 2021).

Despite the greater importance attributed to soft-skills overall, it is necessary to highlight the growth in importance given to hard skills, as provided by the surveys' responses.

The articles focused on the study of fundamental skills for a specific function are those where greater importance is attributed to certain hard-skills (Akyazi et al., 2020a; Alharbi, 2020; Bruzzi et al., 2021; Mazurchenko and Maršíková, 2019; Patalas-Maliszewska and Kłos, 2019), with a significant emphasis attributed to skills such as, IoT, Big Data, Artificial Intelligence or Augmented Reality, and perhaps the specific know-how necessary for the job or process assigned to it (Flores et al., 2020; Kazancoglu and Ozkan-Ozen, 2018; Malik et al., 2021). Another example of the growing importance of hard-skills, is the one pointed out by Santoso et al. (2020), in a publication dedicated to the identification of future talent needs in the banking industry of Indonesia. It reached the conclusion that the technological skills essential for highly automated and digital economic growth have limited and increasing demand but that people that possess these skills will become a minority. One of the major concerns of this study is the search for an interpretation of this apparent paradox found in literature. It is possible that the changes are in the profile or specific mix of hard-skills required, and perhaps this

question should be answered on a case-by-case basis, that is, with the specific skill profile of each job. Managers may also perceive hard-skills to be less important because they are easier to learn and therefore it is more important for companies to have employees who already possess the soft-skills necessary to adapt to change. Finally, it is possible that soft-skills have always been very important and still are, but now there is also the growing importance of some hard-skills. It is certain that the competences required for the 4th industrial revolution are more complex than the previous one.

From both the survey response analysis and the SLR, the balance between the various types of skills appears to be fundamental for the full development of a competent professional capable of helping companies in the transition to I4.0 (Ejsmont, 2021; Ivaldi et al., 2022; Saari et al., 2021). The greater importance attributed to soft skills and the growing importance of some hard skills, results in a vision of the ideal skills set for the workforce as a hybrid combination of technical and soft-skills (Blayone & VanOostveen, 2021; Chaka, 2020; Lenarčič, 2019).

Middle managers seem to need a more balanced and complete portfolio of skills, as they need to have properly developed soft-skills, while also possessing a set of technological skills that will enable them to understand and manage changes to processes carried out by both humans and machines.

The fact that middle managers obtained the largest number of responses indicating an increase in the importance of skills, suggests that they are presently seen by industry managers as the most fundamental hierarchical level for a better implementation of I4.0 and need a more balanced and complete skills portfolio.

7 Conclusions

In the current period of digital transformation, industrial companies are faced with a set of challenges, namely with regard to the definition of the portfolio of skills to be developed among their workforce, barriers to the implementation of this fourth industrial revolution and its impacts or consequences.

It is, therefore, essential for companies to understand and identify the right competences and reveal the gaps in the existing workforce in order to establish better training plans and other actions that will help them to be successful. The fundamental objective of this work is precisely to identify the competences suitable for the digital transition and to understand the resultant changes.

The results obtained indicate the need to further develop soft-skills, as they seem to provide the foundation for a more prepared workforce. Nevertheless, due attention must be given to hard-skills as there are some evidences of their increasing importance with the introduction of I4.0, especially for middle managers and shop floor operators.

The SLR revealed a lack of studies of the different competence portfolios of manufacturing workers from various levels of responsibility or functions. This study intends to contribute towards closing this gap, by surveying manufacturing managers on the importance and change in 35 types of skills identified in SLR, in three different levels: top managers, middle managers and shop floor operators.

Although many questions remain unanswered, this study clearly shows different requirements in competences between these hierarchical levels in manufacturing companies and adds new knowledge to this issue.

From the survey responses, the hierarchical level with the greatest growth in the importance of soft-skills is the top managers, followed by middle managers and then shop floor operators. Middle managers obtained the highest number of responses, indicating a growth in importance of hard skills, followed by shop floor operators and then top managers. It seems that the role of middle managers increases in importance with the digitalisation of the industry.

As middle managers play such a decisive role in this digital transition, it is necessary to understand the readiness of organisations to provide them with conditions that allow them to fully develop their potential. In the same sense, it is important to know whether educational institutions are properly developing their study plans to support the preparation of complete professionals, helping companies and, ultimately, the economy. The search for answers to these questions can naturally form the basis for future research.

It was verified that shop floor operators who need a lower level of competences, apparently the ones that suffer more from the consequences of I4.0. Few studies were found regarding the impact of this revolution on the required skills profile of shop floor operators. This issue must be addressed, especially when looking at the proposal for the society 5.0, where everyone has access to technological tools and inclusion and diversity are fundamental keywords in reducing social and economic disparities and problems. Therefore, it is imperative to have more studies aimed at understanding the necessary modifications for these professionals and determine their role in an industry that tends to be increasingly digital.

It is important to reflect on the reasons that may be at the root of the apparent paradox of a greater importance being attributed to soft-skills coupled with a more markedly growing importance of hard-skills. This could be the basis of future work.

On the other hand, there is also the question of whether or not it makes sense to have the same list of skills for all levels of responsibility. Thus, the construction and validation of a list of Competencies 4.0 for each function, hierarchical level and industry which could eventually serve as a basis for training and recruitment programs is also an opportunity for research.

The implications of this study are significant, as it highlights the need to adapt the competencies of professionals and managers to I4.0. This includes the development of technical skills (hard skills) and behavioural skills (soft skills) to deal with the changes resulting from the industrial revolution. In addition, the study highlights the importance of training and recruitment programs that are aligned with the demands of I4.0.

This kind of knowledge, can help organisations and their managers to thrive in the digital transformation pointing the way to the construction of a skills framework that enables them to identify and visualise actual skill gaps. From here, managers can develop and adjust policies geared to meeting organisational and human management requirements, namely by tuning their training and education programs to magnify the development of needed skills.

This study has some limitations, namely the dimension and characteristics of the sample survey. Naturally, a deeper and more enlightening study requires a larger and more varied sample in relation to the functions, industries and locations of the respondents, more comprehensive view and gain confidence in the generalisation of the results.

Systematic reviews are normally well accepted, since they are comprehensive, reproducible, and precise, but they are not immune to errors and could generate misleading results, if the data isn't appropriately handled or if they are biased. Some of

the weaknesses of this study include the lack of an assessment of publication bias and the fact that, the data extraction and validation were not done independently by more than the two involved researchers. Another question that has not been assessed is related with the methodological quality of the studies, even though, a qualitative analysis and summary was conducted for all the studies included.

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Appendix 1

Scopus

((TITLE (“industry 4.0”) OR TITLE (“fourth industrial revolution”) OR TITLE (“4th industrial revolution”) OR TITLE (“industry digitization”) OR TITLE (“digital

revolution”) OR TITLE (“industrial internet”) OR TITLE (“digital factory”) OR TITLE (“smart manufacturing”) OR TITLE (“intelligent factory”) OR AUTHKEY (“industry 4.0”) OR AUTHKEY (“fourth industrial revolution”) OR AUTHKEY (“4th industrial revolution”) OR AUTHKEY (“industry digitization”) OR AUTHKEY (“digital revolution”) OR AUTHKEY (“industrial internet”) OR AUTHKEY (“digital factory”) OR AUTHKEY (“smart manufacturing”) OR AUTHKEY (“intelligent factory”)) AND (TITLE (“human resources”) OR TITLE (“work organization”) OR TITLE (“competency profile”) OR TITLE (“Skills”) OR TITLE (“competence”) OR TITLE (“jobs of the future”) OR TITLE (qualification) OR TITLE (“Workforce Skills”) OR AUTHKEY (“human resources”) OR AUTHKEY (“work organization”) OR AUTHKEY (“competency profile”) OR AUTHKEY (“Skills”) OR AUTHKEY (“competence”) OR AUTHKEY (“jobs of the future”) OR AUTHKEY (qualification) OR AUTHKEY (“Workforce Skills”))) AND NOT (TITLE (“education program”) OR TITLE (school) OR TITLE (scholarship) OR TITLE (teacher) OR TITLE (“graduates”) OR TITLE (“Educational Methodology”) OR TITLE (“Higher Education”) OR TITLE (“learning institution”) OR TITLE (student) OR AUTHKEY (“education program”) OR AUTHKEY (school) OR AUTHKEY (scholarship) OR AUTHKEY (teacher) OR AUTHKEY (“graduates”) OR AUTHKEY (“Educational Methodology”) OR AUTHKEY (“Higher Education”) OR AUTHKEY (“learning institution”) OR AUTHKEY (student)) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (SRCTYPE, “j”))

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((TI = (“industry 4.0”) OR TI = (“fourth industrial revolution”) OR TI = (“4th industrial revolution”) OR TI = (“industry digitization”) OR TI = (“digital revolution”) OR TI = (“industrial internet”) OR TI = (“digital factory”) OR TI = (“smart manufacturing”) OR TI = (“intelligent factory”) OR AK = (“industry 4.0”) OR AK = (“fourth industrial revolution”) OR AK = (“4th industrial revolution”) OR AK = (“industry digitization”) OR AK = (“digital revolution”) OR AK = (“industrial internet”) OR AK = (“digital factory”) OR AK = (“smart manufacturing”) OR AK = (“intelligent factory”)) AND (TI = (“human resources”) OR TI = (“work organization”) OR TI = (“competency profile”) OR TI = (“Skills”) OR TI = (“competence”) OR TI = (“jobs of the future”) OR TI = (qualification) OR TI = (“Workforce Skills”) OR AK = (“human resources”) OR AK = (“work organization”) OR AK = (“competency profile”) OR AK = (“Skills”) OR AK = (“competence”) OR AK = (“jobs of the future”) OR AK = (qualification) OR AK = (“Workforce Skills”))) NOT (TI = (“education program”) OR TI = (school) OR TI = (scholarship) OR TI = (teacher) OR TI = (“graduates”) OR TI = (“Educational Methodology”) OR TI = (“Higher Education”) OR TI = (“learning institution”) OR TI = (student) OR AK = (“education program”) OR AK = (school) OR AK = (scholarship) OR AK = (teacher) OR AK = (“graduates”) OR AK = (“Educational Methodology”) OR AK = (“Higher Education”) OR AK = (“learning institution”) OR AK = (student))

Appendix 2**Table A1** SLR – list of publications in the final paper set

<i>Publication</i>	<i>Affiliation country</i>	<i>Research areas</i>	<i>Citations</i>
Ada et al. (2021)	Turkey	Mathematics; Engineering;	0
Hernandez-de-Menendez et al. (2020)	Mexico	Economics/Management; Computing	10
Ivaldi et al. (2022)	Italy	Mathematics; Engineering	1
Flores et al. (2020)	New Zealand	Social Sciences; Psychology	29
Alharbi (2020)	Saudi Arabia	Economy/Management	2
Saniuk et al. (2021)	Poland Slovakia	Economy/Management	0
Blayone and Van Oostveen (2021)	Canada Ireland	Computer Science and engineering	5
Kipper et al. (2021)	Brazil	Engineering; Physical	20
Saari et al. (2021)	Malaysia Indonesia	Economy/Management	0
Chaka (2020)	South Africa	Computing	10
Spöttl and Windelband (2021)	Germany	Engineering	6
Jerman et al. (2020)	Slovenia Croatia	Computing	34
Uys and Webber-Youngman (2019)	South Africa	Social Sciences	0
Jerman et al. (2018)	Slovenia Croatia	Economy/Management	15
Kruger and Steyn (2021)	South Africa	Social Sciences	3
Akyazi et al. (2020b)	Spain	Social Sciences	18
Patalas-Maliszewska and Klos (2019)	Poland	Social Sciences	7
Maisiri et al. (2019)	South Africa	Economy/Management	19
Kazancoglu and Ozkan-Ozen (2018)	Turkey	Social Sciences; Information systems; Economy/Management	58
Arcelay et al. (2021)	Spain	Material Sciences	5
Cimini et al. (2021)	Italy	earth sciences	2
Mazurchenko and Maršíková (2019)	Czech Republic	Computing Mathematics Engineering	4
Wang and Ha-Brookshire (2018)	USA	Economy/Management	17
Peña-Jimenez et al. (2021)	France Italy Spain	Health care; Social Sciences; Agriculture; Biology Immonology and Microbiology	0
Malik et al. (2021)	India France	Physical Engineering; Chemical engineering; Computing	4
Chang and Yeh (2018)	Taiwan	Material Sciences	8
Maisiri and Van Dyk (2021)	South Africa	Engineering	6
Lassen et al. (2021)	Denmark	Economics/Management;	3

Table A1 SLR – list of publications in the final paper set (continued)

<i>Publication</i>	<i>Affiliation country</i>	<i>Research areas</i>	<i>Citations</i>
Kwiatkowska et al. (2021)	Poland	Political science; Computing	2
Santos et al. (2021)	Portugal Spain Slovakia Serbia	Mathematics; Engineering	9
Liszka et al. (2019)	Poland	Energy	5
Shet et al. (2021)	India France	Engineering	5
Lenarčič (2019)	Slovenia	Social Sciences; Informatics Economics/Management	0
Akyazi et al. (2020a)	Spain	Arts and Humanities; Social Sciences; Engineering	7
Akyazi et al. (2020c)	Spain	Psychology	8
Santoso et al. (2020)	Indonesia	Economy/Management	2
Marnewick and Marnewick (2020)	South Africa	Finance; Economy/Management	7
Ejsmont (2021)	Poland	Social Sciences	6
Poszytek (2021)	Poland	Economy/Management	3
Bruzzi et al. (2021)	Italy Spain	Economy/Management	0
Venter et al. (2019)	South Africa	Political science	3

Appendix 3

Table A2 SLR – list of original terms used to defined the critical competencies, final name attributed and Soft/Hard skill classification

<i>Expressions used in original publications</i>	<i>Final name attributed</i>	<i>Soft-skill or hard skill</i>
Communication; Ability To Communicate Effectively; Language Skills; Giving And Receiving Feedback; Active Listening	Communication	Soft-skill
Problem Solving; Attitude towards Complexity; Solve Complex Challenges	Problem Solving and Attitude towards Complexity	Soft-skill
Creativity, Innovation; Creative Thinking	Creativity and Innovation	Soft-skill
Teamwork, Coordinating With Others; Participate and Work in a Team; Collaborative Work; Group Work Activities; Collaboration	Teamwork/Collaborative Work	Soft-skill
Automation; Simulation; Coding; Computing IT Systems	Automation, Simulation, Coding, Computing and IT Systems	Hard-skill
Flexibility; Cognitive flexibility; Agility; Adaptability; Continual Interdisciplinary Learning and Cooperation;	Flexibility, Agility and Adaptability	Soft-skill
People Management; Leadership; Lead; Influence on Others; Disruptive Leadership	Leadership, Influence and Management of Others	Soft-skill

Table A2 SLR – list of original terms used to defined the critical competencies, final name attributed and Soft/Hard skill classification (continued)

<i>Expressions used in original publications</i>	<i>Final name attributed</i>	<i>Soft-skill or hard skill</i>
Critical Thinking; Analytical Spirit	Critical Thinking and Analytical Spirit	Soft-skill
Lifelong Learning; Motivation for Learning; Strategic Vision of Knowledge; Growth Mindset	Lifelong Learning, Strategic Vision of Knowledge and Growth Mindset	Soft-skill
Data Analysis; Big Data; Data Processing and Visualization	Data Analysis and Big Data	Hard-skill
Self-management; Self-organization; Time Management; Work Autonomously; Efficiency Orientation	Self-management, Self-organization and Efficiency	Soft-skill
Manufacturing Processing; Process Management; Understanding of Processes; Understanding the Analogies of the Operation; Process Analysis; Combining Know-How Related to a Specific Job or Process; Organizational and Processual Understanding	Manufacturing Processing and Process Management	Hard-skill
IoT; Robotics; 3D Printing; Cloud Computing; Advanced Technologies; Industry 4.0 Knowledge and Skills; Machine Learning; Collaborative/Autonomous Robots; Augmented Reality; Reverse Engineering; Robotic Process Automation	IoT, Robotics, 3D Printing, Cloud Computing and Other Advanced Technologies	Hard-skill
Emotional Intelligence; Conflict Solving; Negotiating, Sales	Negotiation, Conflict Solving and Emotional Intelligence	Soft-skill
Judgement; Planning; Decision-making; Ability of Fault and Error Recovery	Planning and Decision Making	Soft-skill
Sustainable Development; Ethics; Social Responsibility; Sustainability Mindset; Compliance; Environmental Awareness; Energy Efficiency; Understanding of Standards and Legislation; Waste Reduction and Waste Management; Sustainable Resource Management; Water Conservation; Circular Economy	Sustainable Development and Ethics	Soft-skill
Social Skills; Interpersonal Skills; Empathy Skills; Act as Mediator; Cultural Empathy; Social Norms; Etiquette; Self-Presentation; Self-Confidence; Ingenuity; Ability to Compromise and Cooperate; Relationship Management; Cooperation; Cultural Awareness	Social, Interpersonal and Empathy Skills	Soft-skill
Understanding IT Security; Cybersecurity; Awareness of IT Security and Data Protection	Informatics Security	Hard-skill

Table A2 SLR – list of original terms used to defined the critical competencies, final name attributed and Soft/Hard skill classification (continued)

<i>Expressions used in original publications</i>	<i>Final name attributed</i>	<i>Soft-skill or hard skill</i>
Management Skills; Project Management; Risk Management; Planning and Change Management; Product Innovation	Management Skills and Project Management	Soft-skill
Technical capabilities; Technology-based Skills; Mechanical Functions	Technical Abilities and Mechanical Functions	Hard-skill
Initiative; Proactivity, Entrepreneurship; Industriousness; Resourcefulness; Risk-Taking; Business Acumen; Business Execution;	Initiative, Proactivity and Entrepreneurship	Soft-skill
Software Development; Coding; Computer Programming	Software Development and Programming	Hard-skill
Interdisciplinarity; Versatility; Peripheral Vision; Overview Competence; Integration Competence;	Interdisciplinarity, Versatility and Peripheral Vision	Soft-skill
Knowledge Transfer	Knowledge Transfer	Soft-skill
Reaction to Complex Situations; Reaction to Ambiguity; Work in Stressful Situations; Resilience; Optimism; Burn-out Prevention	Ability to React to Stress and Ambiguity	Soft-skill
Analytical Skills; Research Skills; Scientific Tasks; Curiosity	Analytical and Investigative Skills	Soft-skill
Algorithms; Quantitative Skills; Statistics; Mathematics; Numeracy	Algorithms, Quantitative Skills and Statistics	Hard-skill
Openness to New Technologies; Readiness to Digitalization; Embracing Change; Trust in New Technologies	Openness to Digitalization and Change	Soft-skill
Service Orientation; State of the Art Knowledge;	State of the Art Knowledge, Service Orientation	Hard-skill
Digital Skills; Computing Skills; Digital Literacy; Use of Complex Digital Communication Tools; Ability to Interact with Modern Interfaces; Knowledge of Servers	Digital and Computing Skills	Hard-skill
Integration of Technical and Business Skills; Financial Management; Business Intelligence	Integration of Technical and Business Skills	Hard-skill
Working with Social Networks; Digital Communication; Network Competence; Media Skills	Working with Social Networks and Digital Communication	Hard-skill
Effort and Involvement in Continuous Improvement; Professionalism	Involvement and Effort in Continuous Improvement	Soft-skill
Maintenance; Ability to Learn How to Maintain New Machines	Maintenance	Hard-skill
General Systems Theory; Manufacturing Execution System	General Systems Theory	Hard-skill

Appendix 4**Table A3** Survey results – average importance of each skill, by hierarchical level

<i>Skill</i>	<i>TM</i>	<i>MM</i>	<i>SF</i>	<i>AH</i>
Teamwork/collaborative work	4.59	4.59	4.56	4.58
Communication	4.56	4.67	4.21	4.48
Social, interpersonal and empathy skills	4.54	4.49	4.31	4.44
Flexibility, agility and adaptability	4.56	4.41	4.31	4.43
Openness to digitalization and change	4.56	4.44	4.26	4.42
Knowledge transfer	4.44	4.49	4.10	4.34
Involvement and effort in continuous improvement	4.33	4.49	4.15	4.32
Lifelong learning, strategic vision of knowledge and growth mindset	4.36	4.31	4.00	4.22
Problem solving and attitude towards complexity	4.36	4.49	3.72	4.19
Ability to react to stress and ambiguity	4.05	4.31	3.97	4.11
Critical thinking and analytical spirit	4.31	4.26	3.74	4.10
Sustainable development and ethics	4.21	4.18	3.79	4.06
Manufacturing processing and process management	3.87	4.36	3.90	4.04
Technical abilities and mechanical functions	3.74	4.18	4.21	4.04
Initiative, proactivity and entrepreneurship	4.31	4.18	3.62	4.03
Self-management, self-organization and efficiency	4.33	4.21	3.49	4.01
Planning and decision making	4.46	4.21	3.15	3.94
Negotiation, conflict solving and emotional intelligence	4.28	4.13	3.36	3.92
Creativity and innovation	4.31	4.10	3.36	3.92
Interdisciplinarity, versatility and peripheral vision	4.15	4.10	3.51	3.92
Leadership, influence and management of others	4.46	4.38	2.82	3.89
Digital and computing skills	4.03	4.08	3.56	3.89
State of the art knowledge, service orientation	3.82	4.23	3.44	3.83
Informatic security	3.74	3.72	3.15	3.54
Integration of technical and business skills	3.79	3.82	2.82	3.48
Management skills and project management	4.15	3.82	2.38	3.45
Maintenance	2.95	3.41	3.79	3.38
Analytical and investigative skills	3.77	3.62	2.74	3.38
Data analysis and big data	3.72	3.69	2.51	3.31
Automation, simulation, coding, computing and IT systems	3.51	3.72	2.59	3.27
Algorithms, quantitative skills and statistics	3.62	3.67	2.54	3.27
IoT, robotics, 3D printing, cloud computing and other advanced technologies	3.51	3.67	2.51	3.23
General systems theory	3.21	3.62	2.69	3.17
Software development and programming	3.13	3.36	2.23	2.91
Working with social networks and digital communication	3.08	3.15	2.31	2.85

Notes: TM: Top Managers; MM: Middle Managers; SP: Shop floor; AH: all hierarchies

Appendix 5

Table A4 Survey results – number of times answered to increase, maintain and decrease importance, by hierarchical level

<i>Skill</i>	<i>TM</i>			<i>MM</i>			<i>SF</i>		
	↑	→	↓	↑	→	↓	↑	→	↓
Openness to digitalization and change	31	8	0	32	7	0	24	14	1
Algorithms, quantitative skills and statistics	23	16	0	19	20	0	6	33	0
Data analysis and big data	14	24	1	22	17	0	23	16	0
Lifelong learning, strategic vision of knowledge and growth mindset	14	25	0	10	29	0	12	26	1
Self-management, self-organization and efficiency	16	23	0	9	30	0	6	29	4
Automation, simulation, coding, computing and IT systems	20	19	0	16	23	0	19	19	1
Ability to react to stress and ambiguity	11	27	1	15	23	1	12	24	3
Communication	14	25	0	16	22	1	14	24	1
State of the art knowledge, service orientation	10	27	2	23	16	0	23	16	0
Creativity and innovation	23	16	0	13	26	0	6	30	3
Software development and programming	21	18	0	16	22	1	21	18	0
Sustainable development and ethics	12	27	0	16	23	0	7	30	2
Involvement and effort in continuous improvement	16	23	0	13	26	0	17	21	1
Flexibility, agility and adaptability	25	14	0	17	21	1	15	22	2
Analytical and investigative skills	14	25	0	13	26	0	7	31	1
Management skills and project management	21	18	0	5	33	1	3	34	2
Digital and computing skills	22	17	0	19	20	0	29	10	0
Social, interpersonal and empathy skills	13	23	3	9	28	2	16	23	0
Technical abilities and mechanical functions	19	20	0	32	7	0	34	5	0
Initiative, proactivity and entrepreneurship	12	27	0	8	30	1	10	28	1

Notes: ↑ Increase of importance; → Maintenance of importance; ↓ Decrease of importance.

Table A4 Survey results – number of times answered to increase, maintain and decrease importance, by hierarchical level (continued)

<i>Skill</i>	<i>TM</i>			<i>MM</i>			<i>SF</i>		
	↑	→	↓	↑	→	↓	↑	→	↓
Integration of technical and business skills	18	21	0	5	32	2	6	30	3
Interdisciplinarity, versatility and peripheral vision	17	22	0	8	30	1	8	31	0
IoT, robotics, 3D printing, cloud computing and other advanced technologies	30	9	0	19	20	0	24	15	0
Leadership, influence and management of others	12	27	0	9	30	0	0	36	3
Maintenance	0	39	0	18	20	1	22	16	1
Negotiation, conflict solving and emotional intelligence	15	24	0	6	32	1	5	33	1
Critical thinking and analytical spirit	13	26	0	12	27	0	10	26	3
Planning and decision making	20	19	0	8	30	1	2	33	4
Manufacturing processing and process management	9	30	0	32	7	0	24	15	0
Problem solving and attitude towards complexity	15	24	0	11	28	0	16	23	0
Informatic security	15	24	0	22	17	0	26	13	0
General systems theory	15	24	0	29	10	0	3	31	5
Working with social networks and digital communication	19	20	0	8	31	0	10	28	1
Teamwork/collaborative work	21	17	1	11	28	0	23	15	1
Knowledge transfer	23	16	0	11	28	0	8	30	1

Notes: ↑ Increase of importance; → Maintenance of importance; ↓ Decrease of importance.