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CONSOLIDATING INDUSTRY 4.0 INDIVIDUAL SKILLS: AN UMBRELLA REVIEW

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ABSTRACT

Purpose: This study aims to consolidate existing knowledge on the competencies required in the context of Industry 4.0 through an Umbrella Review—a systematic review of systematic reviews—identifying recurrent individual skills and offering clear definitions.

Originality/Value: While several studies address isolated competencies for Industry 4.0, this work brings an original contribution by mapping, grouping, and standardizing these competencies under a unified framework. It also highlights gaps in the literature and suggests future paths for empirical validation through practitioner insights and emerging areas such as Project Management.

Methods: A comprehensive search was conducted in two major scientific databases, Scopus and Web of Science, without date restriction. The selection included systematic reviews focused on competencies within the Industry 4.0 context. The competencies identified were consolidated and thematically categorized.

Results: The review identified a wide range of competencies—including Communication, Problem Solving, Flexibility, Leadership, Technical Knowledge, Coding, Data Analytics, among others. Although some competencies appeared more frequently than others, their relative importance could not be determined, as frequency may reflect ease of study rather than market relevance.

Conclusions: This study confirms a growing academic and corporate interest in professional competencies for Industry 4.0, and it proposes that future research compare the mapped competencies with real-world professional reports and gray literature to validate their applicability. Additionally, integrating perspectives from areas such as Project Management and Product Development could enhance understanding and practical implementation.

Keywords: Competence Acquisition. Skill Development. Industry 4.0. Individual Skills. Systematic Literature Review.

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CONSOLIDANDO COMPETÊNCIAS INDIVIDUAIS DA INDÚSTRIA 4.0: UMA REVISÃO GUARDA-CHUVA

RESUMO

Objetivo: Este estudo tem como objetivo consolidar o conhecimento existente sobre as competências exigidas no contexto da Indústria 4.0 por meio de uma Revisão Guarda-Chuva (*Umbrella Review*) — uma revisão sistemática de revisões sistemáticas —, identificando competências individuais recorrentes e oferecendo definições claras.

Originalidade/Valor: Embora diversos estudos abordem competências isoladas relacionadas à Indústria 4.0, este trabalho apresenta uma contribuição original ao mapear, agrupar e padronizar essas competências em um framework unificado. Além disso, o estudo destaca lacunas na literatura e sugere caminhos futuros para validação empírica, por meio da incorporação de percepções de profissionais e de áreas emergentes, como a Gestão de Projetos.

Métodos: Foi realizada uma busca abrangente em duas importantes bases científicas, Scopus e Web of Science, sem restrição temporal. A seleção incluiu revisões sistemáticas focadas em competências no contexto da Indústria 4.0. As competências identificadas foram consolidadas e categorizadas tematicamente.

Resultados: A revisão identificou uma ampla gama de competências — incluindo Comunicação, Resolução de Problemas, Flexibilidade, Liderança, Conhecimento Técnico, Programação e Análise de Dados, entre outras. Embora algumas competências tenham aparecido com maior frequência, sua importância relativa não pôde ser determinada, uma vez que a frequência pode refletir a facilidade de estudo e não necessariamente a relevância para o mercado.

Conclusões: O estudo confirma o crescente interesse acadêmico e corporativo nas competências profissionais voltadas à Indústria 4.0 e propõe que pesquisas futuras comparem as competências mapeadas com relatórios profissionais e literatura cinzenta para validar sua aplicabilidade. Ademais, a integração de perspectivas de áreas como Gestão de Projetos e Desenvolvimento de Produtos pode ampliar a compreensão e a implementação prática dessas competências.

Palavras-chave: Aquisição de Competências. Desenvolvimento de Habilidades. Indústria 4.0. Competências Individuais. Revisão Sistemática da Literatura.

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1. INTRODUCTION

The development of new technologies and the consequent digital transformation that companies are going through, has driven the need to develop specific skills (Mendes, 2023). Industry 4.0 technologies have great potential to contribute to the development of companies, such as the development of products and services, production management and innovation of business models (Lenart, 2019). These contributions significantly change the way people work, mainly due to the lack of trained professionals to deal with such technologies, so that for their adoption to be successful, companies need to have resources and team engagement (Menendez et al., 2020; Cordeiro et al., 2023). A literature review by Grzybowska e Łupicka (2017) highlights three categories of skills that need to be developed: (1) Techniques, comprising all work-related knowledge and skills, such as knowledge of specific tools; (2) Management Skills, consisting of the skills necessary for problem solving and decision making; (3) Social Skills, defined as social values such as motivation and ability to work in a team.

The concept of skills has changed to adapt to new market scenarios, making companies look for new professionals to meet the need for new skills (Sá & Paixão, 2013). The development of skills for Industry 4.0 differs from the others because these, in addition to technical and cognitive skills, individual skills play a significant role in the use of these technologies (Maisiri et al., 2019). In this way, it becomes important both the development of hard skills, those related to technical skills, and the development of soft skills, which are related to behavioral skills. To meet this demand, educational institutions need to promote innovation in knowledge acquisition methods (Maisiri et al., 2019). These technologies have developed very quickly, making it necessary to develop skills in these professionals more quickly, as knowledge becomes obsolete more quickly (Maisiri et al., 2019; Bianco, 2020). Thinking about this dynamic scenario, it is important to identify which skills should be developed, and if there is an order in their acquisition, for the proper improvement of professionals working in Industry 4.0.

It is important to understand what can be considered competence, this question was raised by Eraut (1998), where through the analysis of several meanings attributed to competence he brought a definition for the term, differentiating competence from ability. Eraut (1998, p. 135) says "... definition of competence as the ability to perform the tasks and roles required to the expected standard should remain; but we need to remember that it refers to performance in a particular job or category of job. Change the job and the definition of competence will also

change". So, the skills of a given individual only become a competence when applied to a given activity, and once the activity changes, the skills used to become competent change as well, as seen in Figure 1 - Eraut (1998).

The same concept of applying skills for the proper performance of activities is used by Mulder (2011), who defines Competence as the Ability to perform effectively. In a systematic review of the definitions of competence, Schneider (2019) concludes that competence is performing specific actions within a given environment, which make you efficient specifically within that environment. Stating that in order to acquire competence it is important to define in which environment these will be used, in the case of this article, the environment is composed of companies that use Industry 4.0 technologies.

Based on the information presented, this article has the following objective: **"Understand which Industry 4.0 individual competencies academic literature considers most important.".**

2. THEORETICAL FRAMEWORK

The structure was separated into 3 categories: (1) Industry 4.0 Skills, addressing how it has changed the way we work, (2) Skills Development, explaining how these can contribute to the development of companies; (3) Learning Theory, necessary to understand how a consolidate theory defines the distincts Organizational Learning.

2.1 INDUSTRY 4.0 SKILLS

The concept of Industry 4.0 (fourth industrial revolution) is still in the process of improvement, in general it can be said that Industry 4.0 represents the automation of industries from the integration of different technologies from tools such as: (i) IOT: internet of things consists of technologies that make use of the internet to share and acquire knowledge; (ii) Network/Cloud: are computer networks that use the cloud for data management; (iii) Connectivity: internet access, whether via WiFi, 4G or 5G; (iv) Information security: technologies that protect the data collected; (v) Wearable: garments that provide information and help in monitoring; (vi) Blockchain: information sharing networks of a segment; (vii) Artificial intelligence: robots that make decisions based on programming and especially learning; (viii) Machine Learning: systems that use experiments to improve the type of machine response; (ix) Big Data: management of large volume of data; (x) others such as impressoras 3G, virtual reality (Sacomano et al., 2018; Bianco, 2020). The function of these technologies is

to automate, streamline, provide more effective solutions and cheapen processes, being essential for various segments to meet the requirements of the actual markets, it is worth noting that the success of these tools depends in most cases on companies and their employees (Simic & Nedelko, 2019). These are not only emerging technologies, but rather disruptive technologies that change the way work is organized, acted and delivered (Bianco, 2020).

For the proper use, configuration and interpretation of the data provided by these new technologies it is necessary to develop new professional competencies (Alhloul & Kiss, 2022), in addition, social activities such as leadership, are also impacted by these technologies, since they provide a new work environment for professionals (Bianco, 2020). An analysis by Townsend et al. (2022) through 3 rounds of interviews with 63 industry 4.0 professionals pointed out 4 competency groups with 18 specific competencies important for Industry 4.0 professionals: (1) Technical (technical skills, systemic understanding of processes, IT security skills, project management trend, analytical skills and business knowledge), (2) personnel (flexibility, learning motivation, decision making, tolerance of ambiguity and ability to work under pressure), (3) methodological (creativity, digital mindset and entrepreneurial thinking) and (4) social skills (communication skills, teamwork skills, being committed and proactive, conflict resolution and leadership skills).

Table 1 - Industry 4.0 Skills

Type of Competencies	Specific Skills
Technique	Technical skills; Systemic understanding of processes; IT Security Skills; Project management trend; Analytical skills; Business knowledge
Staff	Flexibility; Learning motivation;Decision-making; Tolerance of ambiguity; Ability to work under pressure
Methodological	Creativity; Digital mindset; Entrepreneurial thinking
Social	Communication skills; Teamwork skills; Be committed and proactive; Conflict resolution; Leadership skills

Source: Adapted from Townsend et al. (2022)

The mapping of these competencies is important for the development of employee training projects, since this new industrial revolution requires the combination of physical and digital activities, making the skills currently required obsolete in a few years (Aires et al., 2017; Simic & Nedelko, 2019; Alhloul & Kiss, 2022; Townsend et al., 2022)

2.2 SKILLS DEVELOPMENT

The definition of competencies goes beyond the acquisition of knowledge or skills acquired through teaching programs or professional experiences, this is what Bomfim (2012) states that through his bibliographic review showed that the concept of competencies depends on the proper application of these skills in specific situations that can be solved through this knowledge, that is, knowledge without practical applicability in the administrative routine does not fit as competence. This serves as a justification for the statement of Lazzareschi (2016) who points out the need to update skills due to the new market demands that have arisen due to the insertion of new technologies in our routine. This change in the competencies required by companies is not a recent perception, the study of Guglielmino and Carroll (1979) pointed out that from the 70s many companies began to worry about the development of their employees since this development could generate results for the company, John (2009) and Kowal et al. (2022) complement stating that from the end of the 90s the skills valued by companies also began to change, before having a training in the area of work and professional experience was a guarantee of employability, but companies began to seek behavioral skills such as good communication, leadership and creativity, the so-called soft skills, instead of just technical skills such as language mastery and knowledge of systems, the so-called hard skills. The initiatives of companies, and even the use of financial resources and time, to stimulate the development of skills in their employees that contribute to the company's long-term strategies have been the focus of several authors such as Guglielmino and Carroll (1979), Homer (2001), Wallo et al. (2020) and Mamatelashvilli et al. (2020).

Corporate training, also called in-company, has shown potential to assist in this development of mutual interest between companies and employees, can develop both hard and soft skills (Panagiotopoulos et al., 2018). Cosenza and Guerra (2011) explain that the set of skills and capacities necessary to achieve certain objectives are called executive functions, and that because of the change in the world, strategies must be defined that favor this learning: "The modern world is very different from the one in which our brain evolved. Today, there is not always an adequately structured environment for the development of executive functions" (Cosenza & Guerra, 2011, p98). The search for efficient ways to develop competencies in collaborators has been the focus of many researches for several decades, we can highlight the articles by Chute (1984) and Huang et al. (1991) that talked about innovative forms of training such as interactive videos, but this has remained present in several studies to this day, as we can see in the studies of Faraz et al. (2009), Chopra (2017), Titko and Bierne (2019) and Allal-

Chérif (2022). One of the reasons for this being a constant theme of studies is the very change in market demands, so that the knowledge needed today will not be the same as in the next decade, making agility and efficiency in teaching even more important (Santos, 2021).

2.3 INDIVIDUAL LEARNING

A learner is an individual who actively engages in acquiring new knowledge and skills, adapting continuously to challenges, and staying competitive in their field (Kinyua, 2015). This concept is supported by Individual Learning Theory (ILT), which shares similarities with psychology and cognitive research, as learning begins at the individual level (Mumford, 1991; Brandi & Elkjaer, 2012). For individual learning to translate into actionable knowledge, the information must be internalized, enabling the person to apply it effectively to achieve personal and professional goals (Cha et al., 2008). Anyone looking to remain competitive needs to learn from their own mistakes and successes, constantly seeking new ideas by observing their environment, acquiring new knowledge, and dedicating resources to their personal development (Kinicki & Kreitner, 2009). The development of individual learning capabilities shapes one's beliefs and behaviors, fostering innovation and growth as new learning is integrated into one's skill set (Tortorella et al., 2020).

According to ILT, for learning to occur, individuals must go through three stages: data acquisition, interpretation, and adaptation/action (Adhikari et al., 2021). Data acquisition is the process where an individual creates a "memory" of actions and outcomes, which is continually updated (Hult et al., 2000; Kinyua, 2015). The interpretation stage involves continuously comparing actual results with expected ones, where unexpected outcomes are critically evaluated to add new information that explains their causes (Hult et al., 2000; Kinyua, 2015). The adaptation/action stage is when the individual uses the knowledge acquired in the previous steps to make informed decisions about their future actions, based on the memory of past actions and results. This adaptation process should be ongoing, adjusting to both internal and external environmental conditions (Hult et al., 2000; Kinyua, 2015). Once this adaptation process is complete, the individual's knowledge base must be updated with new action-result records (Adhikari et al., 2021).

According to Zahller (2011), learning is based on 12 independent constructs, representing the relationship between actual results and expected outcomes: (1) Levels of Learning (individual or organizational); (2) Learning Processes (cognitive, vicarious, deductive, experiential, digitalization, or grafting); (3) Type of Learning (action-result,

probability); (4) Complexity of the Environment; (5) Degree of Personal Change; (6) Environmental Dynamism (rapid change, slow change); (7) Stress (functional or dysfunctional); (8) Strategic Approach (prospective, analytical, defensive); (9) Stage of Personal Development; (10) Personal Structure (centralized or decentralized); (11) Sociocultural Environment (endogenous factors, technology, administrative processes); and (12) External Environment.

The constructs presented by the Individual Learning theoretical lens show significant alignment with the objectives of this discussion, particularly concerning levels, processes, and types of learning, degree of personal change (which accelerates with the advent of new challenges), stress level, and environmental dynamism.

3. METHODOLOGICAL PROCEDURE

This study is an umbrella review (a review of systematic reviews) employing PRISMA to synthesize prior systematic literature review (SLR) on Industry 4.0 competencies. Our population comprised all peer-reviewed SLRs on Industry 4.0 competencies. The universe was defined by publications from 2010–2024 in Scopus and WoS, in English, Portuguese, or Spanish. After de-duplication (n=67), title/abstract screening (n=17), and full-text eligibility (n=16), we arrived at our final sample of 16 SLRs covering 1,263 primary studies. For improved readability, the main elements of the research design, data sources, and sample characteristics are summarized in Table 2.

Table 2 - Methods Summary

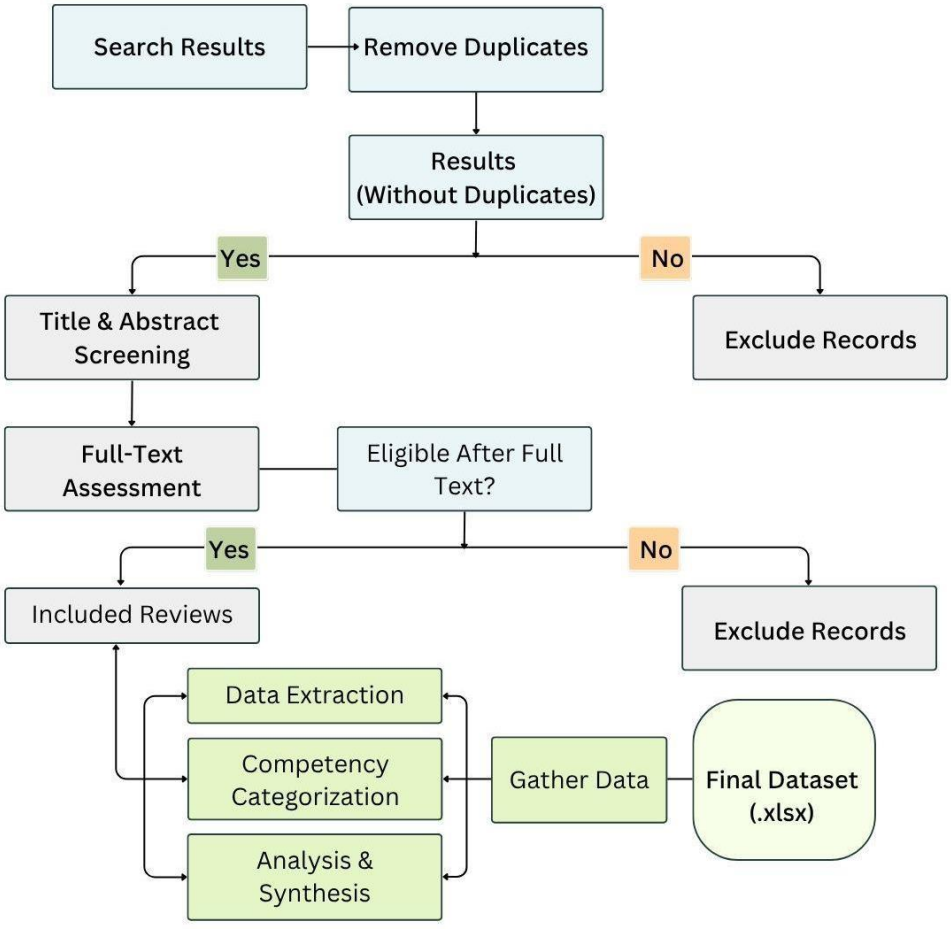
Research Type	Umbrella Review (review of systematic reviews), following PRISMA protocol.
Databases	Scopus; Web of Science
Selection Criteria	Publications from 2010–2024; systematic reviews in English and Portuguese
Tools & Instruments	Excel extraction sheet; Rayyan for screening; coding schema for competencies
Population & Initial Pool	Systematic reviews on Industry 4.0 skills; 67 reviews identified
Final Sample	16 reviews included; covering 1,263 primary articles

Source: Developed by the Author

In order to find in the literature the articles that can meet the objective of this research: "Understand which Industry 4.0 competencies the literature considers most important.", a systematic literature review (SLR) was carried out, based on the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) proposed by Liberati et al. (2009), which provides a standardized checklist and flow diagram to ensure transparency and rigor.

Figure 1 illustrates the overall PRISMA-based workflow—from search results through duplicate removal, title/abstract screening, full-text assessment, and final data extraction—culminating in the master dataset. Figure 2 (page 10) provides the detailed article-selection scheme, showing the number of records at each stage (identification, screening, eligibility, inclusion).

Figure 1 - Methodology Workflow



Source: Developed by the Author

Before starting the PRISMA protocol, a bibliographic survey was carried out in order to provide a prior understanding of the research context, as well as the relevant keywords and databases that best correspond to the research. This first survey was made in the Scopus

database with the following search string: TITLE-ABS-KEY (("Administration" OR "Business") AND ("Skill development" OR "Competence development")). The research was limited to articles written in Portuguese, English or Spanish since the year of 2015, the reason to choose this range of date is because this is the rise of the Industry 4.0. These search criteria brought 515 articles, which after reading the titles and abstracts, 27 were selected for full reading. The content of these articles brought to light new keywords and clarified how this field of research has been explored, not necessarily a new SLR about Industry 4.0 skills, despite this, there is no standard for the studies carried out, causing each one to create their own way of presenting and naming such skills. For this reason this SLR is going to analyze the results of previews SLR, allowing it to reach a larger amount of studies and create a standard for those results (Shi & Wallach, 2022).

After this previous study, the stages of the PRISMA Protocol were initiated. In the first step of the process, the databases that the documents will be collected are selected. To reach a representative number of articles, a search was performed in two databases: Scopus and Web of Science. The choice was due to their scope, having articles in several areas of knowledge, and also due to their international recognition.

The second step of the process corresponds to the selection of keywords for the searches in the bases. In addition to the word "development", the synonyms "enhance", "foster", "improve" "build" and "acquire" were adopted, it was required in the search that the title, the abstract or the key-words had at least one of these variations and also one of the four terms related to "skill", "ability", "competence" and "capability". Those key words represent the "Skill Development" terms, but also was required that those studies were a Systematic Literature Review about industry 4.0 skill, so the terms "Systematic Literature Review" and "Industry 4.0" were added. The combination of those words create the following search string: TITLE-ABS-KEY (((develop* OR enhanc* OR foster* OR improv* OR build* OR acquir*) AND (skill* OR abilit* OR competence* OR capabilit) AND "Industry 4.0") AND "Systematic Review"). It was added the symbol "*" after the radical of the words to allow variations as "acquire" and "acquiring" to arise in the searches made.

The third stage of the protocol consists of searching on the selected databases. The searches were performed individually in the databases, considering the select search string , always filtering by peer-reviewed articles, to ensure the credibility of the study, and written in Portuguese, English or Spanish, allowing the complete understanding of the articles. As for the period of analysis, a deadline for the search of the articles was not specified, in order to map

the emergence and growth of the theme in literature. The databases brought the following results (Table 3): 48 articles in Scopus and 3 in the Web of Science, during the exploratory research, 4 extra articles were added on this research, since his content has a high affinity with the research, but they were not available on those databases. All articles were exported and inserted into an Excel file, adding up to a total of 67 articles after the deletion of duplicates.

Table 3 - List of Articles by Base

Research String	Articles in each Base			
	Scopus	WoS	Extras Articles	Total Without duplication
TITLE-ABS-KEY (((develop* OR enhance* OR foster* OR improve* OR build* OR acquire*) AND (skill* OR ability* OR competence* OR capability*) AND "Industry 4.0") AND "Systematic Review")	48	16	4	67

Source: Developed by the Author

In the fourth stage, the analysis of keywords and reading of the abstracts of the articles were performed, with the objective of performing a pre-selection of which ones would have their complete content analyzed. The following premises were used as inclusion criteria (I) and exclusion (E):

(I) articles about industry 4.0 skill;

(E) articles that do not talk about the development of Management competencies, even if they talk about learning in other areas;

(E) articles aimed at developing skills in specific audiences, such as children, elderly or people with disabilities;

(E) articles focus on developing organization skills;

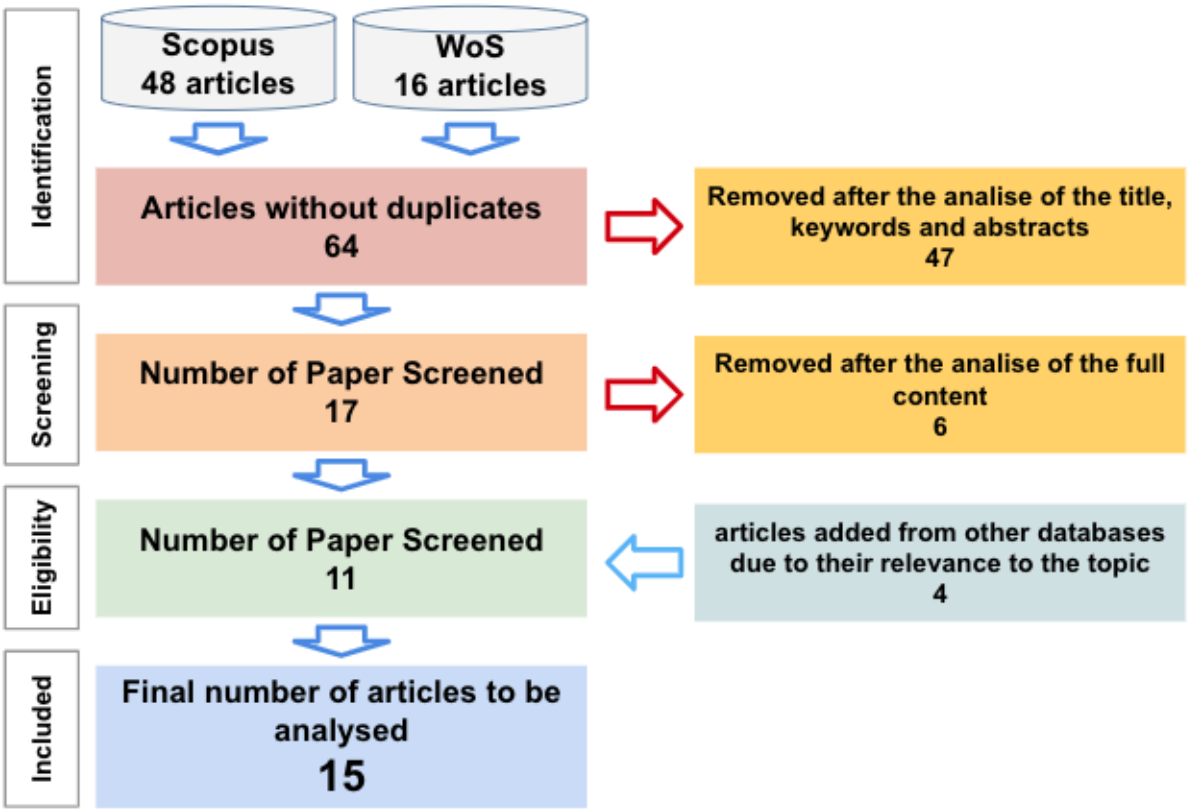
(E) articles that are not a Systematic Literature Review.

After reading the abstracts and keywords, 47 articles were identified that did not fit the objective of this analysis. The conclusion of this first analysis brought a total of 17 articles kept for the next stage.

The fifth and final stage of the review was reading the complete content of the articles for a better understanding if they fit the theme, respecting the same rules presented in the fourth stage. After the completion of this last stage, 11 articles were selected, adding more 4 extra articles, getting the total of 16 articles for cross-referencing of the content.

Figure 2 shows the complete path followed to attend the PRISMA Protocol, highlighting the amount of articles selected on each step of the SLR.

Figure 2- Article Selection Scheme



SOURCE: Developed by the Author

The 15 selected articles had their content analyzed and compared, but also, were analyzed the content of the articles used on those SLR, considering the amount of articles included on each SLR selected we are able to cross the content of 1.263 articles.

4. RESULTS

For the proper analysis of systematic reviews, it is necessary not only to analyze their content and findings, but also the content of the articles that were the focus of these reviews, unfolding their conclusions, their keywords and especially which competencies they addressed. This in-depth analysis is necessary to meet the objective of this study, defining a standard in the various studies on Industry 4.0 competencies, allowing a consolidated view of the literature on which individual competencies are most present in Industry 4.0 research, considering findings present in 1.263 articles, probably there is a duplicity of articles within all those mentioned in the 15 systematic reviews, unfortunately, only 2 authors provided the list of articles sought, making it impossible to remove duplicates, the SLR that has the most articles has 419 articles analyzed without duplicates, thus this way, this can be considered the minimum number of articles explored.

To begin the presentation of the results, it is important to demonstrate the profile of the selected articles, all of which deal with industry 4.0, as seen, this topic is very recent, where most articles on the subject were published from 2020, thus, As the survey focuses on systematic reviews of these articles, the date range becomes even smaller, as a result, only articles published from 2019 onwards were found, with 13% published in 2019, 20% in 2020, 33% in 2021 , 27% in 2022 and 7% in 2023. Since the articles are so recent, there was little time interval for them to be cited, with an average of 31 citations per article. Of these articles, 3 have not yet been cited, 2 of the articles raised stand out and have 147 and 134 citations, the latter being one of those added to the systematic review, even though it is not available in the two databases that were the focus of this study. Here we see how current this topic is, but even in systematic reviews it has a very wide range in the literature, making it difficult for researchers to decide which approach to use. Mainly due to the sample size of this SLR and the date range, there was no author who was repeated among the selected articles.

As for the scope of the selected studies, we have a wide range of keywords used in the strings of these systematic reviews to refer to the skills of the users of these technologies, terms derived from “Skill” appeared in 46% of the articles and those derived from “Skill” in 27% of them, the other terms were variations of the words “Knowledge”, “Ability”, “Training”, “Education”, “Learn”, “Capability”, “Study” and “Qualification”, but which appeared in less than 20% of the articles raised. It is worth noting that despite clearly speaking about competencies, article “A15” “Basic competencies for human work in industry 4.0” did not use any of these words in its search string, focusing its search on variations of terms that refer to Industry 4.0 workers.

In the theoretical scope, through the theoretical lens of organizational learning, we can relate the constructs presented by Zahller (2011) with the articles analyzed in this systematic review. As for the Level of Learning, articles A3, A4, A5, A10, A13 and A14 talk about the difference between the skills developed at the individual and organizational level, highlighting how each process takes place and the difference and complexity of each one, when talking about of individual skills, aspects such as motivation and the importance of knowing why that is being learned stand out. The constructs Learning process and Type of learning were seen in articles A2, A9, A12, highlighting the learning approaches used, such as active methodologies and the use of technologies for better use and absorption of knowledge. The Stress construct (functional or dysfunctional) was worked on in articles A4 and A12, speaking only of functional stress, as

a form of motivation for learning. Dysfunctional Stress was not addressed in the articles surveyed, but it is present in the business environment.

The constructs Complexity of the Environment, Level of Organizational Change, Dynamism of the Environment, Stage of Organization Development, Organization Structure, Sociocultural Environment and External Environment, were not addressed by the articles explored in this systematic review, since these focus on the development of individual competencies, which end up having less or no impact from the Organizational and External Environment.

The systematic reviews addressed in this study brought a total of 29 important skills for Industry 4.0 professionals, it is worth noting that some articles addressed these skills more generically, such as A10, which only mentions the need for technical skills, adaptation and readiness, not detailing which are the skills within those mentioned, unlike what was done in A15, where 10 types of Industry 4.0 professionals were presented and the necessary skills for each of them, mentioning 18 skills that were repeated among the mentioned professionals, in addition to specifications of technical skills that unfolded in skills such as Systems Tester, Knowledge of Components, Graphic Skills, Management of Productive Resources and Machine Operation, all of these by definition enter into technical skills, not being necessary for this research to unfold each one from them. It is worth noting that even with the grouping of technical skills, these were not the most cited, the survey highlighted Communication skills, which was cited in 92% of the articles, followed by Problem Solving and Flexibility, which were cited in 69% of the articles, so Teamwork, being cited in 54% of the articles. Even with the grouping of the various Technical Skills, these appeared in only 46% of the articles. The most common grouping of skills found was the differentiation between Soft Skill and Hard Skill, these skills were organized according to the definition given by the theoretical lens of Individual Learning". The list of skills found, their group, their definition and their representativeness in the studies, can be seen in Table 4 (pages 13-14).

Table 4 - List of Skills

Category	Skills	%	Articles	Definition
Soft Skills	Communication	92%	1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 14, 15	The act of giving, receiving, and sharing information with clarity.
	Problem Solving	69%	1, 2, 3, 5, 8, 12, 13, 14, 15	The act of defining a problem, determining the cause, identifying, prioritizing and selecting a solution.
	Flexibility	69%	1, 3, 6, 8, 10, 13, 14, 15	Being able to quickly adapt to new circumstances as they arise.
	Teamwork	54%	1, 3, 4, 12, 13, 14, 15	Been able to work together toward a common goal.
	Leadership	46%	3, 6, 7, 12, 13, 15	The action of leading a group of people or an organization.
	Time Management	38%	1, 4, 6, 12, 14	The coordination of tasks and activities to maximize the effectiveness of an individual's efforts.
	Anticipating problems	38%	1, 6, 12, 14, 15	The ability to plan ahead considering distincts possibilities.
	Motivation	38%	3, 4, 13, 14, 15	Enthusiasm for doing something.
	Creativity	38%	3, 5, 13, 14, 15	The ability to make or otherwise bring into existence something new, whether a new solution to a problem.
	Proactivity	31%	13, 14, 15	The act or habit of thinking and acting so as to prepare for, intervene in, or control expected events.
	Innovation	31%	6, 13, 14, 15	The practical implementation of ideas that result in the introduction of new goods, services or improvements.
	Autonomy	23%	1, 3, 4, 6, 8, 10, 13, 14, 15	The ability to make your own decisions about what to do rather than being influenced by someone else.
	Feedback	23%	1, 6, 14	The transmission of evaluative or corrective information about an action, event, or process.
	Tolerance	23%	3, 13, 14	The ability to deal with something unpleasant, or to continue producing despite bad or difficult conditions.
	Sustainable	23%	3, 14, 15	The ability to utilize resources without causing depletion (not only natural resources).
	Conflict Solving	23%	3, 14, 15	The ability to negotiate with different teams to find a solution and keep the good relationship.
	Decision Making	23%	3, 14, 15	The ability to decide about something important, especially in a group of people or in an organization.
	Work under Pressure	15%	3, 14	The ability to keep the good quality of the work even under pressure from different sources.
	Intercultural	15%	3, 14	The ability to deal with different cultures.
	Network	15%	3, 14	Ability to build useful connections to the activities to be carried out.
	Empathy	15%	6, 14	The ability to share someone else's feelings or experiences by imagining what it would be like.

Table 4 (continued) - List of Skills

Category	Skills	%	Articles	Definition
Hard Skill	Technical	46%	3, 4, 7, 10, 13, 15	Specifics skills to deal with systems, machines and technologies.
	Coding	38%	3, 5, 13, 14, 15	The knowledge to read and write codes.
	Mathematical Knowledge	38%	4, 6, 8, 14, 15	The knowledge to use numbers, measurements and mathematical logic.
	Data Analytics	38%	4, 6, 8, 10, 15	The knowledge to analyze distincts amounts of data, transforming those into information and insights.
	Language	15%	3, 14	Knowledge of languages other than your native.
	Media	15%	3, 4	Understand the use of different digital file formats.
	Research	15%	3, 14	The ability to discovery new information on distincts sources.
	Transfer Knowledge	8%	3	The ability to teach knowledge to others.

Source: Developed by the Author

The analysis of the skills presented in the systematic reviews that analyzed 1.236 articles showed that even with the transformations that technology has brought to the job market, behavioral skills, called soft skills, are still the most relevant for work. The literature has shown that even though it is important to have technical knowledge such as data analytics, knowledge of tools and use of different media formats, knowing how to deal with the environment around you remains the most important. Highlighted skills such as flexibility, creativity and innovation, have shown potential for professionals to follow the transformations provided by technology.

This organization of skills related to industry 4.0 professionals will shed light so that companies can direct the training of their teams, making it not only focus on how to use certain systems or interpret data, but also on how to use these new possibilities for the optimization of the work performed.

4.1 Practical Impacts Of Industry 4.0

Although this study does not generate new primary data, its greatest practical value lies in providing practitioners, educators, and policy-makers with a consolidated framework of 29 key competencies for Industry 4.0 roles. By identifying which skills appear most frequently in 15 systematic reviews (e.g., communication in 92 % of reviews; problem solving and flexibility in 69 %), organizations can:

Prioritize Training and Development: Learning & Development teams can structure upskilling programs around the top-ranked soft skills (communication, problem solving,

flexibility, teamwork) before investing in more specialized technical modules; Vocational and higher-education providers can design curricula that balance foundational "hard" skills (e.g., data analytics, coding) with the "human" competencies that drive cross-disciplinary collaboration;

Align Recruitment and Performance Management: HR professionals can refine job descriptions and interview guides to assess the most critical Industry 4.0 competencies, ensuring hirees possess both digital fluency and adaptive mindsets; Managers can use the taxonomy to set clearer performance objectives (e.g., "demonstrates proactive problem solving under ambiguous conditions" or "communicates data insights to non-technical stakeholders");

Inform Organizational Change and Culture: Change agents can anticipate cultural barriers by recognizing the need for continuous learning and data-driven decision-making, and thus build targeted communication campaigns and coaching interventions; Leadership teams can benchmark their existing workforce against the mapped competencies to identify gaps, then plan mentoring or job-rotation schemes that accelerate competence acquisition; By emphasizing technical skills like data analytics and coding alongside problem-solving, firms can accelerate automation projects, streamline workflows, and achieve measurable productivity improvements (e.g., reduced cycle times, fewer defects);

Guide Policy and Workforce Planning: Industry associations and government agencies can leverage these findings to develop competency frameworks, certification programs, or grants that incentivize training in emerging areas—such as project management for digital environments; Regional economic development initiatives can map local skills supply against these standardized competencies to attract investment in smart-manufacturing hubs; By upskilling in modular design, additive manufacturing, and digital-twin technologies, firms can implement flexible production lines that deliver mass-customized products in response to real-time market demands

Finally, because frequency of mention does not necessarily equate to market relevance, we recommend empirical validation (for example, practitioner surveys or focus groups) to test which of these competencies drive real-world outcomes (productivity gains, innovation metrics, employee retention) and to refine the framework over time.

Although we report frequency counts for individual competencies, the co-occurrence patterns among competencies (e.g., communication + leadership) remain to be mapped in future meta-analytic work.

5. DISCUSSION

The discussion of the results in light of the theoretical framework highlights the close alignment between the identified competencies and the concepts explored in the literature. The skills mapped by Townsend et al. (2022), categorized into technical, personnel, methodological, and social competencies, are consistent with the challenges presented by Industry 4.0, as identified in the theoretical framework. For instance, the need for a "systemic understanding of processes" and "IT security skills" aligns with the technical demands of Industry 4.0, which require a deep understanding of interconnected systems and cybersecurity, as discussed by Sacomano et al. (2018) and Bianco (2020). The results support the idea that competencies in Industry 4.0 go beyond traditional technical skills, encompassing a broader set of capabilities.

Furthermore, the results resonate with the theoretical framework's emphasis on the evolving nature of competencies in the context of Industry 4.0. The theoretical discussions by Bomfim (2012) and Lazzareschi (2016) on the need for continuous updating of skills are reflected in the results, which highlight the dynamic and rapidly changing requirements of Industry 4.0. The identification of competencies such as "learning motivation," "creativity," and "entrepreneurial thinking" in the results underscores the importance of adaptability and continuous learning in this new industrial paradigm. This aligns with the argument presented by Guglielmino and Carroll (1979) and Santos (2021) that the competencies required by companies are constantly evolving, necessitating a proactive approach to skill development.

Finally, the discussion also illustrates how the results contribute to understanding the interplay between individual learning and organizational needs in Industry 4.0. The results reflect the stages of individual learning, such as data acquisition, interpretation, and adaptation/action, as outlined by Kinyua (2015) and Hult et al. (2000). The identified competencies align with these stages, indicating that effective skill development in Industry 4.0 requires not only technical knowledge but also the ability to interpret and adapt to new information continuously. This supports the theoretical perspective that individual learning is a critical component of competency development in the context of rapidly advancing technologies.

6. FINAL CONSIDERATIONS

The articles found in this systematic review pointed out that this is a topic with great potential, both for the number of researchers and companies that have been interested in the

subject in recent years, and for the promising results that research has pointed out, bringing direct relations with the improvement in learning. In addition, the articles seek to answer current and important questions for the future, for example, how and what competencies should be developed in twenty-first century professionals.

The article mapped, standardized and grouped the main competencies highlighted in the literature, namely Communication, Problem Solving, Flexibility, Teamwork, Leadership, Time Management, Anticipating problems, Motivation, Creativity, Proactivity, Innovation, Autonomy, Feedback, Tolerance, Sustainable, Conflict Solving, Decision Making, Work under Pressure, Intercultural, Network, Empathy, Technical, Coding, Mathematical Knowledge, Data Analytics, Language, Media, Research, Transfer Knowledge. Although some of these competencies appear more frequently than others, it was not possible to measure their importance, that is, some competencies may appear more frequently than others more for a matter of ease of study or coverage of areas than because they are truly more relevant to the market. Assessing the relevance of one of these competencies is a proposal for future studies.

This study explored 2 large databases, Scopus and Web of Science, without date cut, but wasn't able to bring a significant volume of articles for analysis, the application of the same protocol in other databases may be relevant, but should bring a smaller number of articles. It is pointed out as a suggestion for future studies the comparison of these elements found in the literature with reports of professionals who need to develop management skills in their times and with the gray literature, in order to validate and bring a practical look of the market to the issues found. In addition, studies that seek to bring light to the development of competencies from other areas as Project Management, Management and Product Development, can contribute to the creation of new solutions, since this review did not find articles that spoke in depth about these areas.

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