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WHAT IS INDUSTRY 4.0: A REVIEW OF THE LITERATURE USING THE CONCEPTUAL BIBLIOGRAPHIC METHOD

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ABSTRACT

Purpose: Scientific production has tried to understand the various evolutionary intricacies of Industry 4.0, the so-called fourth industrial revolution. As discoveries increase and deepen, there must also be an effort to understand the frontiers of scientific knowledge, its most noticeable and studied aspects, and those attributes that have only now been perceived. It is, therefore, necessary to periodically take stock of what science knows about the phenomenon to understand where it is headed and which paths have already been taken. Therefore, the need to take inventory of the current state of knowledge about Industry 4.0 was the theoretical justification for this study.

Theoretical framework: The theoretical architecture of this study consisted of the transformations that the industrial revolutionary stages caused in production systems, firstly, and then for the entire society. It involves aspects from various areas of scientific knowledge to understand the different perceptions contained in the scientific literature on the phenomenon of Industry 4.0.

Design/Methodology/Approach: The conceptual bibliographic method was used to generate answers to three guiding questions: What are the main approaches to Industry 4.0? What are its main attributes? What is its irradiation logic? All conceptual definitions in scientific studies published in English and Portuguese available in the Google Scholar database from 2019 to 2020 were analyzed, with a total of 19 studies. The semantic analysis technique was used to identify the approaches and attributes, which were then organized by semantic proximity, constituting the semantic groupings on which the results were generated and interpreted.

Findings: The results showed the existence of eight groups of approaches (procedures, evolution, time, grouping, transformation, layer, organization, and model) and twelve groups of attributes (industrialization, transformation technologies, information technologies, integrated system, processes, society, quality, knowledge, planning, market, value chain, and automation). These discoveries made it possible to understand that Industry 4.0 has a driving force: knowledge, which spreads similarly in waves until it reaches the entire society and is not limited only to the interior of factories and economic organizations.

Research, Practical, and Social Implications: Two implications of these findings stand out. The first is the dynamic nature of implementing Industry 4.0 in organizations, whether economic or not, which is done more quickly if knowledge

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and technologies are available or more slowly when expertise and technologies are fragile or non-existent. The second is teleological since the purpose of Industry 4.0 and all industrial revolutions is to continually improve production processes, even though these benefits often generate unwanted externalities, such as environmental impacts. This means that the progress of knowledge and its developments cannot be stopped but can be directed towards other purposes.

Originality/Value: The main contribution of this study to science is to point out the current stage of the evolution of Industry 4.0 about previous revolutions. Three other contributions are also significant: identifying the main approaches to the phenomenon, its most prominent characteristics, and its irradiation dynamics.

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O QUE É A INDÚSTRIA 4.0: UM BALANÇO DA LITERATURA COM O USO DO MÉTODO BIBLIOGRÁFICO CONCEITUAL

RESUMO
Propósito: A produção científica tem tentado dar conta da compreensão dos vários meandros evolutivos da Indústria 4.0, a chamada quarta revolução industrial. E como as novas descobertas vão se avolumando e aprofundando, é necessário que haja também o esforço de tentar compreender as fronteiras do conhecimento científico, seus aspectos mais perceptíveis e estudados, assim como aqueles atributos que apenas agora puderam ser percebidos. É preciso, portanto, que periodicamente se faça um balanço do que a ciência sabe sobre o fenômeno para que se possa entender para onde está caminhando e quais os caminhos que já foram trilhados. Dessa forma, a necessidade de se fazer um balanço do estágio atual do conhecimento sobre a Indústria 4.0 foi a justificativa teórica para a realização desse estudo.
Estrutura Teórica: A arquitetura teórica desse estudo consistiu nas transformações que os estágios revolucionários industriais provocaram nos sistemas de produção, em primeiro lugar, e depois para toda a sociedade. Envolve aspectos de várias áreas do conhecimento científico, com o intuito de se compreender as diferentes percepções contidas na literatura científica sobre o fenômeno da Indústria 4.0.
Desenho/Metodologia/Abordagem: Foi utilizado o método bibliográfico conceitual para gerar as respostas para três questões norteadoras: quais são as principais abordagens da Indústria 4.0, quais são seus principais atributos e qual é a sua lógica de irradiação. Foram analisadas todas as definições conceituais contidas nos estudos científicos publicados em língua inglesa e portuguesa disponíveis na base de dados Google Acadêmico no período de 2019 a 2020, com um total de 19 estudos. Utilizou-se a técnica de análise semântica para identificar as abordagens e atributos, que depois foram organizados por proximidade semântica, constituindo-se os agrupamentos semânticos sobre os quais foram gerados e interpretados os resultados.
Achados: Os resultados mostraram a existência de oito agrupamentos de abordagens (procedimentos, evolução, tempo, agrupamento, transformação, camada, organização e modelo) e doze grupos de atributos (industrialização, tecnologias de transformação, tecnologias de informação, sistema integrado, processos, sociedade, qualidade, conhecimento, planejamento, mercado, cadeia de valor e automação). Essas descobertas permitiram compreender que a Indústria 4.0 tem uma força motriz, que é o conhecimento, que se espalha de forma semelhante como acontece com as ondas, até alcançar toda a sociedade, e que não está circunscrito apenas ao interior das fábricas e organizações econômicas.
Pesquisa, Implicações Práticas e Sociais: Duas implicações dessas descobertas chamam a atenção. A primeira é a natureza dinâmica da implantação da Indústria 4.0 nas organizações, sejam elas de natureza econômica ou não, que se faz mais rapidamente, se conhecimentos e tecnologias estiverem disponíveis, ou mais lentamente, quando conhecimentos e tecnologias são frágeis ou inexistentes. A segunda é de natureza teleológica, uma vez que a finalidade da Indústria 4.0 e de todas as revoluções industriais é aperfeiçoar continuamente os processos produtivos, ainda que muitas vezes esses benefícios gerem externalidades indesejadas, como os impactos ambientais. Isso quer dizer que não se pode frear a marcha do conhecimento e seus desdobramentos, mas que se pode direcioná-la para outras finalidades.
Originalidade/Valor: A principal contribuição desse estudo para a ciência é apontar o estágio atual da evolução da Indústria 4.0 em relação às revoluções anteriores. Três outras contribuições são também significativas: a identificação das principais abordagens sobre o fenômeno, suas características mais salientes e sua dinâmica de irradiação.

Palavras-chave: Indústria 4.0, Abordagens da Indústria 4.0, Atributos da Indústria 4.0, Lógica de Irradiação da Indústria 4.0, Método Bibliográfico Conceitual.

QUÉ ES LA INDUSTRIA 4.0: UNA REVISIÓN DE LA LITERATURA MEDIANTE EL MÉTODO BIBLIOGRÁFICO CONCEPTUAL

RESUMEN

Objetivo: La producción científica ha intentado comprender los distintos entresijos evolutivos de la Industria 4.0, la llamada cuarta revolución industrial. Y a medida que los nuevos descubrimientos aumentan y se profundizan, también debe haber un esfuerzo por intentar comprender las fronteras del conocimiento científico, sus aspectos más visibles y estudiados, así como aquellos atributos que recién ahora han sido percibidos. Por tanto, es necesario hacer un balance periódico de lo que la ciencia sabe sobre el fenómeno para poder comprender hacia dónde se dirige y qué caminos ya se han recorrido. Por tanto, la necesidad de hacer un balance del estado actual del conocimiento sobre la Industria 4.0 fue la justificación teórica para la realización de este estudio.

Estructura Teórica: La arquitectura teórica de este estudio consistió en las transformaciones que las etapas revolucionarias industriales provocaron en los sistemas de producción, primero, y luego en toda la sociedad. Involucra aspectos procedentes de diversas áreas del conocimiento científico, con el objetivo de comprender las diferentes percepciones contenidas en la literatura científica sobre el fenómeno de la Industria 4.0.

Diseño/Metodología/Enfoque: Se utilizó el método bibliográfico conceptual para generar respuestas a tres preguntas orientadoras**:** cuáles son los principales enfoques de la Industria 4.0, cuáles son sus principales atributos y cuál es su lógica de irradiación. Se analizaron todas las definiciones conceptuales contenidas en estudios científicos publicados en inglés y portugués disponibles en la base de datos Google Scholar de 2019 a 2020, con un total de 19 estudios. Se utilizó la técnica del análisis semántico para identificar los enfoques y atributos, los cuales luego fueron organizados por proximidad semántica, constituyendo los agrupamientos semánticos sobre los cuales se generaron e interpretaron los resultados.

Hallazgos: Los resultados mostraron la existencia de ocho grupos de enfoques (procedimientos, evolución, tiempo, agrupación, transformación, capa, organización y modelo) y doce grupos de atributos (industrialización, tecnologías de transformación, tecnologías de la información, sistema integrado, procesos, sociedad, calidad, conocimiento, planificación, mercado, cadena de valor y automatización). Estos descubrimientos permitieron comprender que la Industria 4.0 tiene un motor, que es el conocimiento, que se propaga de forma similar a las ondas, hasta llegar a toda la sociedad, y que no se limita sólo al interior de las fábricas y organizaciones económicas.

Implicaciones de investigación, prácticas y sociales: dos implicaciones de estos hallazgos son dignas de mención. El primero es el carácter dinámico de la implementación de la Industria 4.0 en las organizaciones, sean de carácter económico o no, que se hace más rápidamente, si se dispone de conocimientos y tecnologías, o más lentamente, cuando los conocimientos y las tecnologías son frágiles o no están disponibles. existente. El segundo es de naturaleza teleológica, ya que el propósito de la Industria 4.0 y de todas las revoluciones industriales es mejorar continuamente los procesos de producción, aunque estos beneficios a menudo generan externalidades no deseadas, como impactos ambientales. Esto significa que el progreso del conocimiento y sus desarrollos no se pueden detener, sino que se pueden dirigir hacia otros fines.

Originalidad/Valor: La principal aportación de este estudio a la ciencia es señalar el estado actual de la evolución de la Industria 4.0 en relación con revoluciones anteriores. Otras tres aportaciones también son significativas**:** la identificación de las principales aproximaciones al fenómeno, sus características más destacadas y su dinámica de irradiación.

Palabras clave: Industria 4.0, Enfoques de la Industria 4.0, Atributos de la Industria 4.0, Lógica de Irradiación de la Industria 4.0, Método Bibliográfico Conceptual.

INTRODUCTION

Information and communication technologies have wholly transformed practically all people's ways of life (Estrela et al., 2023; Celin et al., 2023; Jiang et al., 2022; Contreras-Cruz et al., 2023). These changes reached a deep level in all production systems, causing an increase in quantity and quality like never before seen in human history. The changes were and continue to be so profound that they are being called a revolution (Fokam et al., 2023; Roudometof, 2023; Jung, 2023). A revolution is a phenomenon that encompasses all spheres and ways of life, which naturally includes how societies produce their subsistence. By extension, as all forms of production have been affected by the changes produced by information and communication technologies, this revolution has been called Industry 4.0 to designate this revolutionary specificity precisely. The world is, therefore, experiencing the fourth great global revolution based on knowledge and the resulting technologies.

Industry 4.0 is not a reality exclusive to manufacturing plants because knowledge and technologies are not restricted to this production environment. It also involves commercial organizations of all types (Lopes et al., 2022; Suzuki et al., 2022), services (Saha et al., 2023; Antony et al., 2023), governments (Paz et al., 2023; Febiandini & Sony, 2023) and non-economic organizations (Dhamija, 2022; Thoha, 2022). It also encompasses organizations of all types and sizes, from micro-enterprises to large conglomerates (Caballero-Morales et al., 2023; Suchek et al., 2023). Many technologies were developed to create a vast web of ramifications, such as big data, machine learning, the Internet of Things, and computer vision, among countless others. As current reality indicates, the near future will be much more revolutionary, as Industry 5.0 (Wang et al., 2024; Gladysz et al., 2023), Industry 6.0 (Almusaed et al., 2023) structures are already being developed; Chourasia et al., 2023) and even Industry 7.0 (Iordache, 2022; Chernysh et al., 2023).

Scientific production has been extraordinary in trying to understand the various evolutionary intricacies of this phenomenon. Technology often seems to arrive before scientific explanations can be established. As discoveries increase and deepen, there must also be an effort to understand the frontiers of scientific knowledge, its most noticeable and studied aspects, and those attributes that have only now been perceived. It is, therefore, necessary to periodically take stock of what science knows about Industry 4.0 to understand where it is heading and what paths have already been taken. Therefore, the theoretical justification for carrying out this study was the need to take stock of the current knowledge about Industry 4.0.

This study aims to take stock of the scientific literature on what Industry 4.0 is. To achieve this, three guiding questions were formulated: What are the main approaches to I4.0? What are its most common attributes? What is its operational logic? The answers were obtained with the help of the conceptual bibliographic method developed by Nascimento-e-Silva (2020a; 2021a; 2021b; 2021c; 2023), consisting of the stages of formulating guiding questions, collecting data in scientific databases, organizing data for generating discoveries and presenting responses for publication (Nascimento-e-Silva, 2013; 2020b).

LITERATURE REVIEW

The review of the literature on the evolution of industrial revolutions suggests a continuous and accelerated movement of replacement of the driving force of the human body's productive systems for extraphysical phenomena. In general, this movement starts from physical aspects, such as the body (human and animal) and materials in a natural state, such as sticks and stones, in the primitive period, to virtual aspects, such as modern information and communication technologies. Between the primitive and contemporary eras, great intermediate leaps were made, each causing revolutionary developments. Disruption is a characteristic of all industrial revolutions because they cause fundamental changes in society and the economy (Islam, 2023; Kumaraswamy et al., 2019). It represents a substitutive movement from traditional forms of production to more technologically evolved ones (Ugar, 2023). Sometimes, the revolution constitutes a true explosive leap in the industrial process, producing an unusual effect on societies (Udoshukwu & Agunwamba, 2021; Kumaraswamy et al., 2019). In this revolutionary period, productivity and efficiency increased using machines (Seleke & Chukwuere, 2023) and other artifacts in production systems.

Industry 1.0 had the mechanization of production systems, which used water and electricity as driving forces as its main characteristic. This first revolution promoted humanity's most essential advances until then, starting in the 1760s most markedly (Skalli et al., 2022; Lewandowska, 2020). The steam engine was a tremendous transformative invention, beginning the era of mechanization (Tavares et al., 2020; Mustafa, 2023). The conception of the world at that time was that the world was like a great machine and that each of its aspects was pieces or parts of that great gear. Organizations and their production systems were also seen in this same way, making it possible for them to function as accurately as clocks, admired as great works of art and human capacity to reproduce nature's behavior—the railways and the increasingly extensive railway networks where the blueprint for the integration machines could provide.

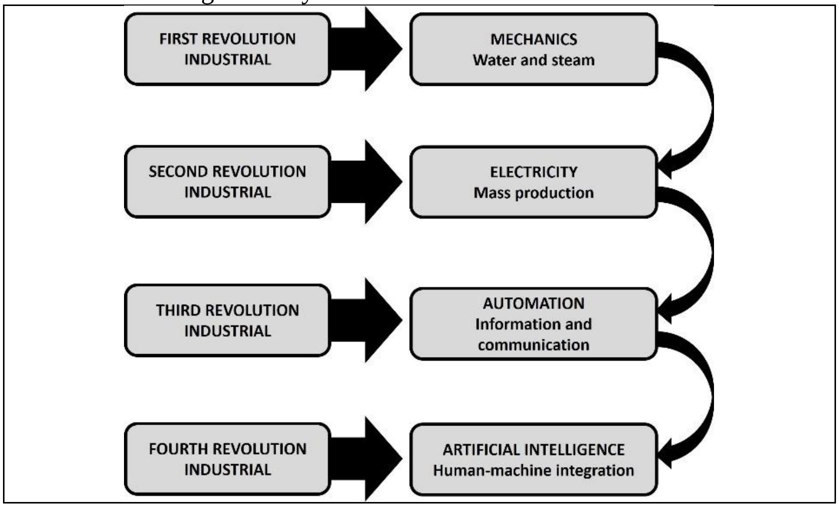
The beginning of the second industrial revolution is dated around the 1840s and is characterized by mass production provided by the dominance of electrical energy (Skalli et al., 2022; Tavares et al., 2020). The revolution in production systems and its driving force were the most notable consequences of the scientific and technological evolution of the time, which began a continuous process of increasingly accelerated discoveries. In Industry 2.0, gasoline engines, airplanes, and chemical fertilizers were invented in addition to revolutionary mass production (Lewandowska, 2020), taking the revolution to various places on the planet. Electrical energy also increasingly began to lighten homes and communities that were increasingly distant. At the same time, production systems freed the human workforce from using their bodies as a driving force while demand increased by labor (Mustafa, 2023). Mass production meant the availability of goods previously limited to only a few wealthy consumers.

Industry 3.0 was the era of automation and information and communication technology, which began in the 1950s. This revolution marked the use of computers to support production management (Skalli et al., 2022). The invention of these machines was made possible by the discoveries of semiconductors, mainframe computing, personal computing, and the Internet. Objects and artifacts that were previously analog began to migrate increasingly quickly to digital technologies (Lewandowska, 2020; (Mustafa, 2023)). The internet started the digital revolution, which became widespread (Tavares et al., 2020). At this stage, production systems began to multiply their productive capacities and vary production to satisfy the most diverse needs of practically all consumers.

Industry 4.0, like all previous revolutions, is a continuation of Industry 3.0, caused by substantial advances in science and technology, transforming production methods, and the systematic organization and use of resources (Skalli et al., 2022). For example, there are robots operating production lines, gene sequencing and editing, artificial intelligence, miniaturized sensors, and 3D printing (Lewandowska, 2020). The stock of human knowledge allowed advanced digitalization in factories and all types of organizations, ushering in the era of intelligent objects and causing a paradigm shift in history (Tavares et al., 2020). In the fourth revolution, new technologies can combine the physical, digital, and virtual worlds, enabling high levels of automation and data exchange (Nazarova, 2023) and making artificial intelligence possible (Lazar et al., 2023).

As in all revolutions, Industry 4.0 left the factories and entered all organizational universes. Competition from alternative communication channels (e-exchange) and the accelerated growth and dissemination of other emerging technologies have increased, such as the Internet of Things, social media, and cognitive computing (Iminova & Xamidullayev, 2023). Humans, devices, and systems are connected along the entire value chain (Nazarova, 2023), which in turn are restructuring the individual and collective mindsets of the planet's inhabitants. The most fundamental objective of the current revolution is to minimize the human factor in production with the use of increasingly precise technologies, which minimize margins of error, increase the effective and perceived quality of products, and make production systems increasingly more efficient, flexible, adjusting to the demands to be met. This combination effectively integrates human beings with machines through intelligent production (Mustafa, 2023).

Figure 1. Dynamics of industrial revolutions.



Source: Prepared by the authors.

Figure 1 shows, in a synthetic way, the dynamics of the great industrial revolutions. Each revolution is the consequence of other revolutions with more minor impacts or localized consequences. It is noted that the first revolution was based on physical elements (water and steam) that were invented and handled by human beings, just as happened in the second revolution (mass production and electricity). However, in the third revolution, the driving forces were no longer predominantly outside the human being but within him. The information and communication technologies that provided automation were in their minds and creative capabilities. This internalization and virtualization of driving forces became more accentuated in the fourth revolution when artificial intelligence also became part of the objects created by humans. As every revolution is born from the previous revolution, the following industrial revolutions are likely already being born in research centers and industries. Only later will the public become aware and suffer their negative and positive impacts.

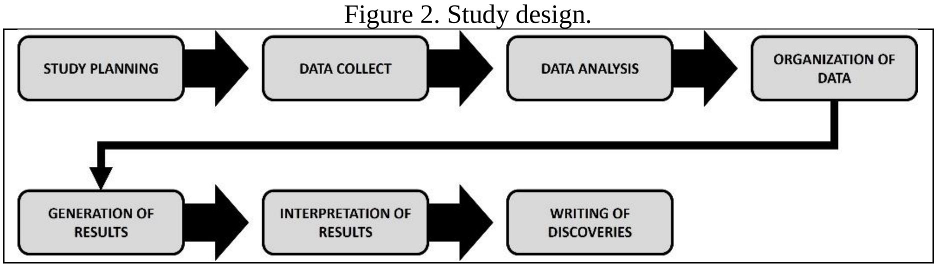
RESEARCH METHODOLOGY

This study aimed to take stock of the literature on what Industry 4.0 is using the conceptual bibliographic method. To this end, the following guiding questions were formulated: What are the main approaches in the literature on Industry 4.0? What are the main attributes of Industry 4.0? What is the logic behind the attributes of Industry 4.0? The entire methodological design of this investigation followed the guidelines contained in the studies by Nascimento-e-Silva (2020a; 2020b; 2021a; 2021b; 2021c; 2023).

Study Design

This research design consisted of seven stages based on a similar study developed by Craveiro et al. (2023), who used the conceptual bibliographic method. The first stage consisted of defining the objectives, guiding questions of the study, and their respective response patterns. The second was data collection in the Google Scholar database, which was then transferred to a table with the references and responses collected. The third stage was data analysis, where the equivalence terms of each definition were separated from their attributes so that both contents of the definitions could be adequately understood.

Figure 2. Study design.



Fonte: Craveiro et al. (2013).

The fourth stage was the organization of the data, where it was possible to identify the answers to the guiding questions formulated in the first stage. The fifth stage was generating results, which was carried out by counting the data frequencies and grouping them by semantic similarities, as determined by the conceptual bibliographic method (2020a; 2021a). The sixth stage was interpreting the results, which was carried out through comparison with the literature review and similar studies in the database. The seventh and final stage was writing the manuscript for submission for publication and communication to the scientific community (Nascimento-e-Silva, 2020b)

Population and Sample

The population of this study comprised all conceptual definitions contained in scientific studies published between the years 2019 and 2023 in the Google Scholar database. The sample comprised 38 studies that met the established criteria, that is, that the) contained the response pattern "Industry 4.0 can be defined as" and b) had been published in scientific articles or annals of scientific events. Consequently, course completion studies and technical documents were left aside. These criteria were aimed at the study's requirement to take stock of the scientific literature.

Instruments and Techniques for Collecting, Analyzing, and Organizing Data

The data was collected with the help of a two-column table called data mass (Nascimento-e-Silva, 2023). The references were placed in the first column, and the responses were collected in the second. Then, the data was separated regarding equivalence and attributes, constituting all definitions (Nascimento-e-Silva, 2021b; 2023). As the approaches and attributes found were numerous, they were organized into groups following their semantic proximity, as they appear in the conceptual definitions. Each semantic grouping received a name that summarized all the approaches that comprised it. The same procedure was used to organize the attributes, generating tables 1 and 2.

Generation and Interpretation of Results

The results were generated by the logic that structures every conceptual definition, which can be summarized in the formula f(I40) = TE + At1 + At2 + ... + An, where f(I40) is the definition of the concept of Industry 4.0, TE is the equivalence term that begins the definition and At are the attributes that give meaning to the equivalence term (TE) and that give it meaning, so that it is equivalent to Industry 4.0. This logic was applied to understand various approaches and attributes and then organize them into semantic groups. The generation of results considered that the approaches represent the way scientists see the phenomenon, and the attributes are the characteristics of the phenomenon under study. The result relating to the irradiation logic of Industry 4.0 was generated by superimposing the approaches' findings and the attributes' dynamics, as shown in Figure 5. The interpretation was also made based on comparing our findings with those contained in the scientific literature reports.

The results were interpreted by comparing the semantic groups and their contents with current scientific studies. For example, the semantic group “time” synthesized approaches that saw Industry 4.0 as a phase, era, and stage, for example, configuring temporal passage. At the same time, framework and philosophy represented a kind of portrait, a specific moment over time. It was discovered that there are studies that see the phenomenon from a longitudinal, diachronic aspect, while others consider it transversal, synchronic. The result of this interpretation is contained in Figure 3. The attributes were interpreted similarly to find some logic between the groupings since attributes are characteristics of something as if they were groups of pieces of a puzzle. This procedure allowed us to understand that the starting point of every industrial revolution is knowledge, which grows in layers, causing increasingly more significant effects, as if in waves, until it involves the entire society, as shown in Figure 4.

RESULTS AND DISCUSSION

This section presents the findings of the study. The presentation logic follows the script of the guiding questions. First, the first question is answered, and then the answer to the second is presented. The third question was generated from the discussion of the results. This procedure was chosen to understand better the complex intricacies of Industry 4.0 captured from its various conceptual definitions analyzed.

Industry 4.0: Main Approaches

The literature review presented a series of words equivalent to Industry 4.0, organized into semantic groups, as detailed in the methodology section. The first group formed procedures. This grouping specifies that Industry 4.0 is structured into a set of procedures (Bataglini, 2021; Checa & Alvarado, 2018; Steffens, 2020), procedures that are also present in organizational processes (Gonçalves et al., 2022) and projects (Ferreira, 2019) and control (Baro-Tijerina et al., 2021; Tijerina & Monarrez, 2021). The conception of procedure concerns the specification of how a given idea or project should be materialized, something like a rule that considers that what is going to be done will serve as input for another project or idea, and so on. Industry 4.0 is an extensive set of procedures that constitute a new and different approach (Omri, 2021) because it builds these instructions considering the interconnections to which each process is linked.

Evolution is another type of Industry 4.0 approach. Evolution means that the present is the consequence of what was done in the past. This can be seen in the study by Bigliardi et al. (2022), which presents the equivalence term development with this meaning. Evolution is not a phenomenon limited to the reality of living beings, in which changes occur over time, often leading to the emergence of new species, which are passed on to descendants. Technologies also evolve, as with Industry 4.0, demonstrating why evolution can be defined as descent with modification. Every technological evolution will always intend to leave humanity in constant evolution. Evolution depends on its diffusion and adoption (Bajic et al., 2022), terms that mean, in practice, entry into the digital world of digitalization (Bolz, 2022; Jesus, 2020).

Time was a semantic group created to account for the historical developments of Industry 4.0. The study by Cortés (2022) considers it a painting, as if it were a photograph of the present reality, in contrast to other past historical paintings. A framework marks temporality, as well as phase (Schneider, 2019), era (Jazzar et al., 2021), and stage (Reis), defining the specific character of an era that is different from past ones and that will probably unfold into others in the future. This transitory character has appeared as a philosophy (Fassini, 2021), which also characterizes the phenomenon of Industry 4.0

Several studies point to Industry 4.0 as a grouping of different things that converge to generate various intended results. This idea of meeting appears in the literature as sum (Grabowska et al., 2022b), fusion (Pató et al., 2022), group (Arucu, 2021), incorporation (Carraro et al., 2019), integration (Almatani, 2021; Cruzara et al., 2021; Karanina et al., 2022; Rawat & Purohit, 2019) and configuration (Lazzareschi et al., 2021). These groupings of technologies, procedures, processes, philosophies, and methods form an extensive network (Abubakar et al., 2022), like a web, differentiating the current stage of organizations from those of the past. Thus, Industry 4.0 is not an attribute but a wide variety of interconnected phenomena.

Table 1. Industry 4.0 approaches

References	**Approaches**	**Semantic groups**
Bataglini (2021); Checa & Alvarado (2018); Steffens (2020)	Set	Procedures
Gonçalves et al. (2022)	Law Suit	
Ferreira (2019)	Project	
Baro-Tijerina et al. (2021); Tijerina & Monarrez (2021)	Control	
Omri (2021)	Approach	
Bigliardi et al. (2022)	Development	Evolution
Bajic et al. (2022).	Diffusion	
Bajic et al. (2022)	Adoption	
Bolz (2022); Jesus (2020)	Digitization	
Rubio Cortés (2022)	Frame	Time
Schneider (2019)	Phase	
Jazzar et al. (2021)	Era	
Reis (2021)	Internship	
Fassini (2021)	Philosophy	
Grabowska et al. (2022b)	Sum	Grouping
Pató et al. (2022)	Fusion	
Arucu (2021)	Group	
Carraro et al. (2019)	Incorporation	
Almatani (2021); Cruzara et al. (2021); Karanina et al. (2022); Rawat & Purohit (2019)	Integration	
Ivascu (2020)	Combination	
Lazzareschi et al. (2021)	Settings	
Abubakar et al. (2022)	Network	
Sivanuja & Sandanayake (2022)	Transformation	Transformation
Kazancoglu et al. (2021)	Transition	
Grabowska et al. (2022a)	Step	
Pereira et al. (2022	Movement	
Nwankwo (2022)	Change	
Lemos et al. (2022); Rodrigues (2021; Turel & Elife (2019)	Revolution	
Keskin et al. (2022)	Level	Layer
Jasiulewicz-Kaczmarek et al. (2020); Lakmali et al. (2020)	Term	
Câmara (2020)	Factory	Organization
Baro-Tijerina et al. (2021); Tijerina & Monarrez (2021)	Organization	
Sarı et al. (2020); Verma et al. (2020)	System	
Črešnar et al. (2022)	Paradigm	Model

References	Approaches	Semantic groups
Mohammed & Trzcieliński (2021)	Platform	
Wikström & Gedda (2022)	Methodology	
Walentynowicz & Pienkowski (2020)	Attempt	
Bayram & Ömer (2022)	Prevention	

Source: Data collected by the authors.

The transformation was the semantic grouping created to show that Industry 4.0 develops over time. In this, it is a transition (Kazancoglu et al., 2021), step (Grabowska et al., 2022a), movement (Pereira et al., 2022), and change (Nwankwo, 2022), always with the sense of the dynamics of transformation (Sivanuja & Sandanayake, 2022), in which the current stage is just the germination of the future. This transformation may happen slowly, but it gains strength and speed until it becomes a revolution (Lemos et al., 2022; Rodrigues, 2021; Turel & Elife, 2019). It is in this sense, therefore, that Industry 4.0 is a transformation.

Layer was another semantic grouping constructed to suggest that the Industry 4.0 phenomenon materializes as changes in the value chain. The study by Jasiulewicz-Kaczmarek et al. (2020) precisely shows the changes generated collectively in the organization's technological scope that affect its value chains. For example, the transport layer offers the application level a set of functions and procedures for accessing the communication system to allow the creation and use of applications independently of the network implementation. This is the meaning of the term Industry 4.0, as pointed out in studies by Jasiulewicz-Kaczmarek et al. (2020) and Lakmali et al. (2020), which characterizes the current stage of evolution of value chains, as if they were organized and transformed into large factories for good.

The semantic grouping organization was created with the meaning that Industry 4.0 is the driving force in human groupings that have at least one objective in common. This phenomenon shows its more significant potential in organizations, as shown by studies by Baro-Tijerina et al. (2021) and Tijerina & Monarrez (2021), considering that the types and forms of organizations are practically infinite, both in formal and informal forms. However, factories (Câmara, 2020) are the producing and radiating center of Industry 4.0 transformations. They are internally and externally interconnected, forming large systems (Sarı et al., 2020; Verma et al., 2020) and organizational ecosystems. As societies are also organizations, the philosophy and foundations of Industry 4.0 permeate every socioeconomic corner of the planet.

The model semantic group was created to show that Industry 4.0 can be seen this way. This group's approaches see the phenomenon as a paradigm (Črešnar et al., 2022). This reference is considered for the organization of the value chain in organizations. It is also considered a platform (Mohammed & Trzcieliński, 2021), methodology (Wikström & Gedda, 2022), attempt (Walentynowicz & Pienkowski, 2020), and prevention (Bayram & Ömer, 2022). All these terms of equivalence are aimed at the conception that Industry 4.0 is a product of human action, modeled with data from reality based on humanity's current knowledge and technologies.

Attributes of Industry 4.0

The first semantic grouping of attributes constructed was automation. The idea of automation arises from the system in which operational processes in factories, commercial establishments, hospitals, telecommunications, etc. They are controlled and executed through mechanical or electronic devices, replacing human work and automation. The primary purpose of industrial automation is to create mechanisms and tools capable of developing products with the best quality at the lowest possible cost. This is why, for example, the study by Abubakar et al. (2022) demonstrates the need to control the most complex industrial networks.

For this control to exist, there must be industrial evolution and, at the same time, the integration of production and manufacturing processes, as demonstrated by the study by Reis (2021), in which information and communication technology are aligned so that they have the practical possibility of exchanging information. The study by Almatani (2021) exemplifies integration through complex physical devices, where software with sophisticated technologies can predict, control, and plan the expected results. The study by Bataglini et al. (2021) shows that technological advances can reduce processes, production lines, and mass customization costs, especially for companies and organizations that intend to visualize their businesses' present and future scenarios.

The value chain was the second semantic grouping constructed. The value chain allows the company to organize all its processes, observing the links and how each can generate value for the customer. The value chain allows the company to understand how the organization and practice of its production and strategic processes work. It is essential to understand that each company has a value proposition: its products and services advantages over the competition, the problems it aims to solve for its customers, and how it differentiates itself from others. This is the value perceived by the customer.

The study by Baro-Tijerina et al. (2021) shows that Industry 4.0 tends to exert a new reorganization and level of control over the entire value chain. The study by Ivascu (2020) presents the concepts of value applied to technology combinations that can be applied to organizational processes. Grabowska et al. (2022 a) exemplify value creation within organizations, how they are focused and directed towards sustainability, with disruptive innovations derived and implemented in the organizations' value chain. Bolz (2022) explains that all physical assets and their mass integration are necessary to transform a product or service from a mere concept or raw material to the finished phase and mass integration for its value stream stakeholders. Mohammed et al. (2021) define a new platform for product organizations through which they can be integrated using the Internet of industrial things to produce and add value to products, targeting the customer and the organizations' internal processes. Finally, the study by Turel et al. (2019) predicts that the new values of advanced information technologies should bring new values and services for customers to the organization.

Table 2. Industry 4.0: Attributes and semantic groups

References	**Attributes**	**Semantic groups**
Grabowska et al. (2022b); Pereira et al. (2022; Sivanuja & Sandanayake (2022); Turel & Elife (2019); Gonçalves et al. (2022); Nwankwo (2022)	Automation	Automation
Abubakar et al. (2022); Almatani (2021); Baro-Tijerina et al. (2021); Omri (2021); Sivanuja & Sandanayake (2022); Tijerina & Monarrez (2021)	Control	
Reis (2021)	Evolution	
Almatani (2021)	Devices	
Bataglini (2021); Steffens (2020)	Advances	
Baro-Tijerina et al. (2021); Checa & Alvarado (2018); Grabowska (2022b); Jesus (2020); Tijerina & Monarrez (2021); Jasiulewicz-Kaczmarek (2020)	Value chain	Value chain
Ivascu (2020)	Concepts (value)	
Grabowska et al. (2022b); Bigliardi et al. (2022); Grabowska et al. (2022a)	Creation (value)	
Bolz (2022)	Value stream	
Mohammed & Trzcieliński (2021)	Value	
Turel & Elife (2019).	Values (new)	
Câmara (2020); Mohammed & Trzcieliński (2021); Turel & Elife (2019)	Customers	Market
Câmara (2020)	Suppliers	
Câmara (2020)	Partners	
Cruzara et al. (2021)	Logistics	
Bolz (2022)	Stakeholders	
Lemos et al. (2022).	Models (business)	
Abubakar et al. (2022); Almatani (2021)	Complexity	
Almatani (2021)	Forecast	
Câmara (2020); Bataglini (2021); Steffens (2020)	Efficiency	Planning
Ferreira (2019)	Strategy	
Pereira et al. (2022	Flexibility	
Pisz (2021)	Design	
Jesus (2020)	Objects	
Reis (2021); Bayram & Ömer (2022)	Information (exchange)	Knowledge
Ferreira (2019)	Informatization	
Reis (2021); Sarı et al. (2020)	Communication	
Keskin et al (2022)	Knowledge	

References	Attributes	Semantic groups
Almatani (2021); Bataglini (2021)	Improvement	Quality
Checa & Alvarado (2018)	Monitoring	
Bataglini (2021)	Agility	
Grabowska et al. (2022b)	Modularity	
Keskin et al. (2022); Abubakar et al. (2022); Jesus (2020); Sivanuja & Sandanayake (2022); Gonçalves et al. (2022)	Person	Society
Grabowska et al. (2022b)	Transparency	
Bataglini (2021)	Personalization	
Lakmali et al. (2020)	Paradigm	
Steffens (2020)	Customization	
Jasiulewicz-Kaczmarek et al. (2020)	Changes	
Bayram & Ömer (2022)	Process (decision-making)	Process
Arucu (2021); Cruzara et al. (2021); Jazzar et al. (2021); Omri (2021)	Process	
Steffens (2020); Turel & Elife (2019); Reis (2021)	Process (productive)	
Grabowska et al. (2022b); Mohammed & Trzcieliński (2021)	Law Suit	
Carraro et al. (2019)	Processes (digital)	
Carraro et al. (2019)	Processes (physical)	
Sivanuja & Sandanayake (2022)	(Smart) processes	
Ivascu (2020)	Processes (organization)	
Carraro et al. (2019)	(Virtual) Processes	
Lemos et al. (2022); Sarı et al. (2020); Fassini (2021)	Production	
Jazzar et al. (2021); Ferreira (2019); Reis (2021); Schneider (2019); Wikström & Gedda (2022); Verma et al. (2020)	Manufacturing	
Bataglini (2021); Steffens (2020)	Cost reduction	
Lemos et al. (2022); Jesus (2020)	System	Integrated system
Gonçalves et al. (2022)	computing system	
Jazzar et al. (2021); Gonçalves et al. (2022); Lakmali et al. (2020); Rawat & Purohit (2019); Rawat et al. (2018)	Systems (cyber-physical)	
Abubakar et al. (2022); Karanina et al. (2022); Keskin et al (2022)	Systems (industrial)	
Abubakar et al. (2022); Rawat & Purohit (2019); Rawat et al. (2020)	Systems (information)	
Bigliardi et al. (2022); Čršnar et al. (2022) Lazzareschi et al. (2021).	Systems (production)	
Câmara (2020)	Connection (network)	
Črešnar et al. (2022); Reis (2021); Steffens (2020); Verma (2020); Bolz (2022); Câmara (2020)	Integration	
Abubakar et al. (2022); Arucu (2021); Câmara (2020); Jazzar et al. (2021); Bayram & Ömer (2022)	Intelligence	
Carraro et al. (2019)	Interaction	
Jesus (2020); Mohammed & Trzcieliński (2021); Lazzareschi et al. (2021)	Interconnection	
Omri (2021)	Synchronization	
Jazzar et al. (2021); Ferreira (2019); Lazzareschi et al. (2021); Nwankwo (2022); Arucu (2021); Bajic et al. (2022); Checa & Alvarado (2018); Ivascu (2020); Reis (2021)	Technology	Information Technologies
Sivanuja & Sandanayake (2022); Črešnar et al. (2022); Lemos et al. (2022)	Advanced technology	
Karanina et al. (2022); Turel & Elife (2019)	ICT	
Jazzar et al. (2021); Gonçalves et al. (2022); Lakmali et al. (2020); Mohammed & Trzcieliński (2021); Cruzara et al. (2021)	Internet of things	
Bajic et al. (2022); Črešnar et al. (2022); Gonçalves et al. (2022); Grabowska et al. (2022b); Schneider (2019)	Digitization	
Pató et al. (2022)	Virtual reality)	

References	Attributes	Semantic groups
Bigliardi et al. (2022)	Digital world	
Bigliardi et al. (2022)	Real world	
Turel & Elife (2019)	Services (new)	
Checa & Alvarado (2018); Gonçalves et al. (2022)	Smart factories	
Jazzar et al. (2021); Walentynowicz & Pienkowski (2020)	Technologies (production)	Transformation technologies
Grabowska et al. (2022b)	Innovations	
Carraro et al. (2019)	(Smart) Products	
Pató et al. (2022); Checa & Alvarado (2018)	Reality (physical)	
Lazzareschi et al. (2021)	Dimension (physical-virtual)	
Checa & Alvarado (2018)	Physical world	
Grabowska et al. (2022b)	Mobility	
Wikström & Gedda (2022)	Transformation	Industrialization
Sivanuja & Sandanayake (2022); Pereira et al. (2022; Kazancoglu et al. (2021); Kazancoglu et al. (2021)	Industry	
Abubakar et al. (2022); Almatani (2021); Gonçalves et al. (2022); Mohammed & Trzcieliński (2021); Sivanuja & Sandanayake (2022); Sarı et al. (2020)	Machines	
Câmara (2020); Gonçalves et al. (2022); Grabowska et al. (2022b); Mohammed & Trzcieliński (2021)	Products	
Grabowska et al. (2022a)	Sustainability	
Bolz (2022)	Active	
Nwankwo (2022); Cruzara et al. (2021)	Practices (Industrial)	
Bataglini (2021)	Production line	

Source: Data collected by the authors.

The third semantic grouping created was market. The market must be understood as the "place" in which the forces of supply and demand operate, through sellers and buyers, so that the transfer of ownership of the merchandise occurs through purchase and sale operations. It is the systematic process of establishing and using standards. The study by Câmara et al. (2020) states that everyone must have flexible and intelligent integration between their actors, customers, partners, and suppliers with their products for greater efficiency. To carry out its business, the company must have a set of purchasing and selling activities for a particular good or service in a specific region.

According to scientific literature, industry 4.0 has been causing numerous changes in markets. The study by Cruzara et al. (2021) exemplifies that the Internet of Things will integrate manufacturing and logistics processes. The study by Bol (2022) explains that stakeholders must have mass integration of the value stream, while that of Lemos et al. (2022) describes that the fourth industrial revolution, every year, has been changing business models for companies around the world, and that of Abubakar et al. (2022) foresees the formation of a horizontal and vertical intelligent network of people and machines, linked through information systems, to control the most complex industrial systems.

The fourth semantic group constructed was Planning, a word covering several areas. It works as a technique to identify and reach a specific target. It intends to organize and apply the best ways and strategies to achieve the objective. Planning is also a management tool. The study by Câmara et al. (2022) exemplifies that efficiency involves integration between peers, such as customers, partners, and suppliers. For Ferreira (2019), it exemplifies that high-technology strategies promote the computerization of manufacturing. The study by Pereira et al. exemplifies that there is flexibility and automation in the manufacturing industry. The study by Pisz (2021) defines design as technological trends as evolution in the manufacturing industry. The study by Jesus (2020) exemplifies that technology, through increasing digitalization, exchanges data that happens in real-time.

The fifth semantic group constructed was knowledge, which is the human capacity to understand, grasp, and comprehend things, in addition to applying, creating, and experiencing new things. The study by Reis (2021) exemplifies knowledge as an exchange of information and the possibility of communication between production processes and manufacturing. Bayram et al. (2022) discovered that information can be acquired from different sources when evaluating artificial intelligence in the decision-making process. Ferreira (2019) exemplifies knowledge such as high-performance technological strategies, which promote the computerization of the manufacturing production process. Reis (2021) shows that information exchange processes between production processes and manufacturing enable communication and exchange of information to form knowledge. Finally, the study by Keskin et al. (2022) describes knowledge as something a person can benefit from, adding value to what they produce through these technologies.

The sixth semantic group created was quality, which is the perfection of an organization's process, service, or product to its customers. The survey identified four attributes in this grouping. The first was an improvement (Amatani et al., 2021) due to integrating complex physical machines and devices with sensors and networked software. The second was monitoring (Checa et al., 2018), generally done through a cyber-physical technology set, generating intelligent factories. The third was agility (Bataglini, 2021), resulting from technological advances that increase efficiency, lower production costs, and mass standardize organizational processes when acting on the production line. The fourth and final attribute was modularity (Grabowska et al., 2022b), the sum of disruptive innovations across all value chains.

The seventh semantic group constructed was society, a broad structure in which subjects establish relationships, almost always impersonal but with collective aspects. The relationship between people and society is one of interdependence and mutual influence. The component attributes of this grouping found in the literature were a person (Keskin et al., 2022; Abubakar et al., 2022; Jesus, 2020; Sivanuja & Sandanayake, 2022; Gonçalves et al., 2022), which represents the human being who creates and is influenced by created technologies. Transparency was another term found in the study by Grabowska et al. (2022b), with the possibility of knowing the different states a product passes through, from its production in nature to its arrival in the hands of final consumers. Personalization (Bataglini, 2021) and customization (Steffens, 2020) were similar attributes, denoting the possibility of Industry 4.0 meeting specific, personalized needs. The paradigm attribute (Lakmali et al., 2020) denotes the transformation society is going through, in which changes (Jasiulewicz-Kaczmarek et al., 2020) seem to be one of its most striking attributes.

Processes was the eighth semantic group constructed to group a series of specificities and specific processes. The process attribute was found (Grabowska et al., 2022b; Mohammed & Trzcieliński, 2021) with the conception of logical sequencing of steps that constitute all production processes. However, several attributes of specific processes were found, all resulting from the influence of Industry 4.0, such as the decision-making process (Bayram & Ömer, 2022), manufacturing (Arucu, 2021; Cruzara et al., 2021; Jazzar et al., 2021; Omri, 2021), productive (Steffens, 2020; Turel & Elife, 2019); Reis, 2021), digital and physical (Carraro et al., 2019), intelligent (Sivanuja & Sandanayake, 2022), organizational (Ivascu, 2020) and virtual (Carraro et al., 2019). This entire variety of processes is aimed at the continuous improvement of manufacturing (Jazzar et al., 2021; Ferreira, 2019; Reis, 2021; Schneider, 2019; Wikström & Gedda, 2022; Verma et al., 2020), which is the central focus of the fourth revolution, whose most striking impacts are perceived in the form of cost reduction (Bataglini, 2021; Steffens, 2020).

The integration system was the ninth semantic group constructed, connecting the segments and subunits of an organization to collect relevant data and information aimed at suggesting continuous improvements throughout the production chain of which it is part. In this grouping, system attributes (Lemos et al., 2022; Jesus, 2020) and its variants, such as computational system (Gonçalves et al., 2022), cyberphysics (Jazzar et al., 2021; Gonçalves et al., 2022); Lakmali et al., 2020; Rawat & Purohit, 2019; Rawat et al., 2018), industrial (Abubakar et al., 2022; Karanina et al., 2022; Keskin et al., 2022), information (Abubakar et al. ., 2022; Rawat & Purohit, 2019; Rawat et al., 2020), production (Bigliardi et al., 2022; Čršnar et al., 2022; Lazzareschi et al., 2021). These variants account for the most prominent, noticeable systems on which Industry 4.0 acts. Specific attributes of how systems operate were also found in the form of network connection (Câmara, 2020), integration (Črešnar et al., 2022; Reis, 2021; Steffens, 2020; Verma, 2020; Bolz, 2022; Câmara, 2020), interaction (Carraro et al., 2019), interconnection (Jesus, 2020; Mohammed & Trzcieliński, 2021; Lazzareschi et al., 2021) and synchronization (Omri, 2021). These integrated and interconnected systems generate organizational intelligence (Abubakar et al., 2022; Arucu, 2021; Câmara, 2020; Jazzar et al., 2021; Bayram & Ömer, 2022) of contemporary production systems.

Information technologies are a striking reality, typical of Industry 4.0, and that is why they constituted the tenth semantic group, such as the number of attributes found in the literature review. Technology is a product of science and engineering involving instruments, methods, and techniques that aim to solve problems. It is a practical application of scientific knowledge in various areas of research. The technology attributes were found (Jazzar et al., 2021; Ferreira, 2019; Lazzareschi et al., 2021; Nwankwo, 2022; Arucu, 2021; Bajic et al., 2022; Checa & Alvarado, 2018; Ivascu, 2020; Reis, 2021), advanced technology (Sivanuja & Sandanayake, 2022; Črešnar et al., 2022; Lemos et al., 2022) and information and communication (Karanina et al., 2022; Turel & Elife, 2019). These informational technologies generate a series of realities whose attributes were found to be the internet of things (Jazzar et al., 2021; Gonçalves et al., 2022; Lakmali et al., 2020; Mohammed & Trzcieliński, 2021; Cruzara et al., 2021), which allows communication between objects, digitalization (Bajic et al., 2022; Črešnar et al., 2022; Gonçalves et al., 2022; Grabowska et al., 2022b; Schneider, 2019), as a reference to a world digital (Bigliardi et al., 2022) or virtual reality (Pató et al., 2022), as opposed to a real-world (Bigliardi et al., 2022). Information technologies generate new products and services (Turel & Elife, 2019), which are produced through increasingly intelligent factories.

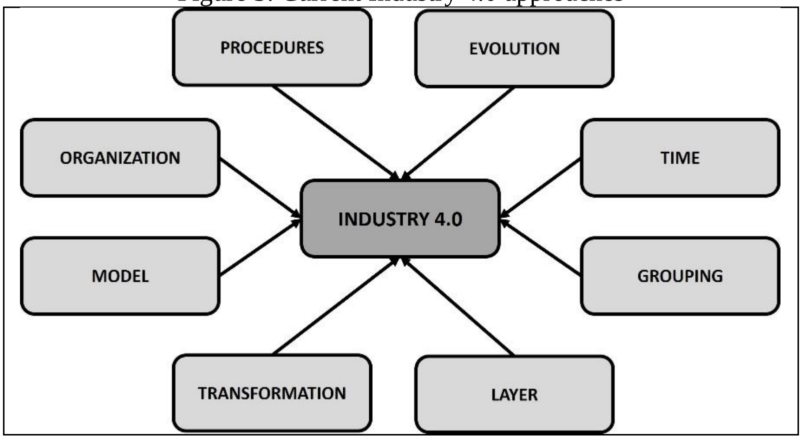
Industries are transformation organizations by nature. The literature review allowed this observation, given the high number of attributes focused on this nature, which led to the construction of this eleventh semantic group. Transformation technologies obtain, store, protect, process, access, manage, and use information and organization data. The attributes gathered in this group were production technology (Jazzar et al., 2021; Walentynowicz & Pienkowski, 2020), innovations (Grabowska et al., 2022b), innovative products (Carraro et al., 2019), physical reality of production (Pató et al., 2022; Checa & Alvarado, 2018), physical and virtual dimension of production (Lazzareschi et al., 2021), physical world (Checa & Alvarado, 2018) and mobility (Grabowska et al., 2022b). Transformation technologies are derived from information and communication technologies.

Industrialization was the last semantic group constructed, meaning socioeconomic expansion of creating industries and their improvements through technologies. Machines have started to replace man in the most strenuous and dangerous tasks, intensifying and perfecting the transformation of raw materials into goods. The attributes included in this group were transformation (Wikström & Gedda, 2022), a fundamental element of every contemporary industry (Sivanuja & Sandanayake, 2022; Pereira et al., 2022; Kazancoglu et al., 2021; Kazancoglu et al., 2021), to mark the innovative character of the fourth industrial revolution, operationalized with intelligent machines (Abubakar et al., 2022; Almatani, 2021; Gonçalves et al., 2022; Mohammed & Trzcieliński, 2021; Sivanuja & Sandanayake, 2022; Sarı et al., 2020) and which, for this reason, also generate innovative (Câmara, 2020; Gonçalves et al., 2022; Grabowska et al., 2022b; Mohammed & Trzcieliński, 2021) and sustainable (Grabowska et al., 2022a) products. The significant assets (Boltz, 2022) of these new organizations are knowledge, which structures the new industrial practices (Nwankwo, 2022; Cruzara et al., 2021), present in each of their production lines (Bataglini, 2021).

Discussion of Results

The results regarding equivalence terms concern the different approaches science has taken to explain the phenomenon of Industry 4.0. Figure 3 summarizes these findings. In general, Industry 4.0 is taken in its diachronic dimension; that is, it is explained from the point of view of its evolution over time. This is what the equivalence terms procedures (which means sequence of steps), evolution (which denotes growth), time (chronological evolutionary scheme), and transformation (in the sense of something becoming what it is not yet) mean. The other terms represent synchronic stages or specific photographs of a given moment in this evolutionary scheme. For example, a model is like a representation frozen during the evolution of Industry 4.0. The same happens with organization, grouping, and layering.

Figure 3. Current Industry 4.0 approaches

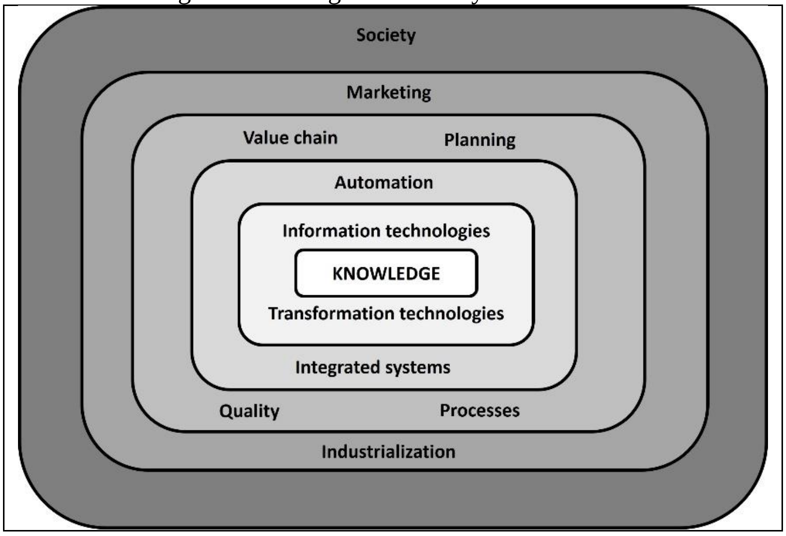


Source: Prepared by the authors.

The literature indicates that mixing diachronic and synchronic aspects is the most appropriate way to explain the Industry 4.0 phenomenon. In other words, it is necessary to consider the phenomenon's evolutionary dynamics, even when one intends to explain an aspect of reality statically as if one were trying to photograph it. Otherwise, diachronic studies, which focus their concern on explaining the phenomenon's evolution, need to consider synchronic aspects as if they were sequential portraits of a film. Thus, alternations of synchronicity and diachronicity are the predominant strategies in the literature to explain the behavior of the reality of Industry 4.0, whether one wants to make a static description or an explanation of its evolutionary dynamics.

The synchronic and diachronic nature pointed out by science is in line with the logic behind the attributes that characterize Industry 4.0, as shown in Figure 2. The starting point for understanding this phenomenon is knowledge, its driving force. This means that the stock of improved and accumulated knowledge is the raw material of Industry 4.0, which allows the generation of information and transformation technologies. In turn, these two groups of technologies structure the automation and integration of production systems, which are two visible, physical aspects. In contrast, knowledge information and transformation technologies are extra-physical immaterial. The planning and elaboration systems of value chains, quality systems, and increasingly improved processes result from what automation and systems integration make possible, depending on the operating environments in which the markets are contained. Where automation and system integration possibilities are more available, scientific-technological-based industrialization is more likely to be accentuated. This intensification characterizes modern societies and opens spaces, mainly for applying Industry 4.0 beyond the borders of factory production systems, entering the environments of citizenship, as is the case of so-called smart cities.

Figure 4. The logic of Industry 4.0 attributes

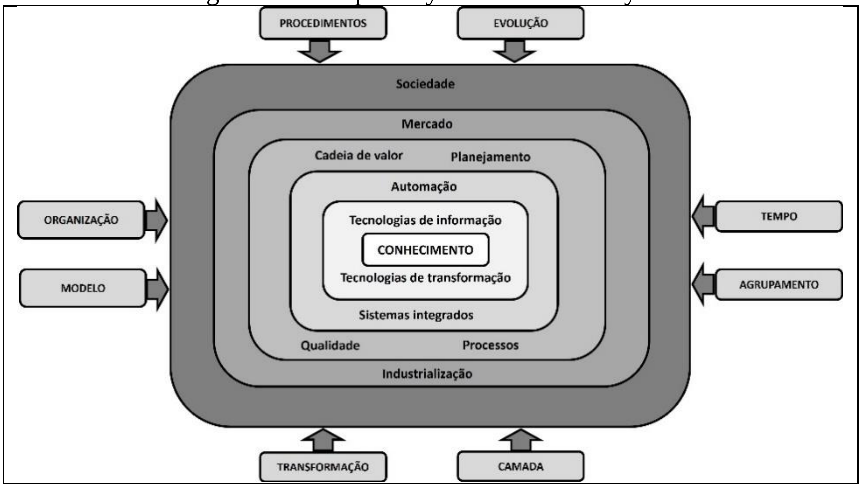


Source: Prepared by the authors.

These results indicate that the probability of introducing Industry 4.0 in organizations is closely related to the existing and available organizational knowledge. The existing knowledge is part of the organization's environment and aligns with its culture at that stage of evolution from a diachronic perspective. The available knowledge is that which already exists in your operating environments but which is not yet being used in your production systems. Therefore, It is necessary to incorporate them because it is this incorporation that will allow the generation of new information and transformation technologies and restart a new evolutionary stage, as shown in Figure 4. This means there is a diachronic scheme of introducing Industry 4.0, in which the acquisition or generation of knowledge is the first stage and incorporating its developments into organizational society is the last.

The phenomenon of Industry 4.0 shows that the great industrial revolutions are the synthesis of the interdependence of different spheres of life, mainly the social and economic ones (Ciasullo et al., 2023; Rusko & Kosonen, 2023), in which knowledge, to a greater or lesser extent, lower intensity, is the driving force. It can even be said that these revolutions are the consequences of what human beings know and can translate into technologies (Mhlanga & Salih, 2023; Nicoletti, 2023; Dadwal et al., 2023). From a synchronous perspective, knowledge and technologies act in specific corners of human activities, causing changes in aspects of the present reality that are intended to be eliminated (if understood as unwanted) or improved (in those cases considered positive). Thus, procedures, organizational forms, interpretative models, and even large groups of organizational and social aspects change, just as implementing a new industrial production system or a new learning methodology does. This is the synchronic nature of revolutions, understood as substantial changes that small organizations and large societies can undergo. If these localized revolutions multiply in other organizations and societies, such as through adopting organizational and social mimicry, the consequence is macroevolution, as with Industry 4.0.

Figure 5. Conceptual synthesis of Industry 4.0



Source: Prepared by the authors.

Revolutions, therefore, are diachronic phenomena. This means that they evolve, often layer by layer, causing small transformations, at first, until they are perceived as revolutions. It is this phenomenon, both diachronic and synchronic that Figure 3 represents. What happens inside organizations and societies, marked in the rectangular layers of the figure, causes micro-localized developments within an organization or part of a society. This is the case, for example, of replacing tiring human work with robots, freeing people for more noble activities. This introduction of technology also requires knowledge of how to operate the equipment. Transformation technologies (such as modern equipment) are based on information technologies, which connect with other organizational sectors, such as finance, legal, and marketing, promoting replacing old practices. Suppose the results are considered positive by most people and organizations (or those who have the decision-making power to continue the introduction or discontinue it). In that case, the tendency is for it to multiply and reach almost all the intricacies of associated human life.

CONCLUSION

This study took stock of the scientific literature on what Industry 4.0 is, with the help of the conceptual bibliographic method. The results showed the existence of eight groups of approaches (procedures, evolution, time, grouping, transformation, layer, organization, and model) and twelve groups of attributes (industrialization, transformation technologies, information technologies, integrated system, processes, society, quality, knowledge, planning, market, value chain, and automation). These discoveries made it possible to understand that Industry 4.0 has a driving force: knowledge, which spreads similarly in waves until it reaches the entire society and is not limited only to the interior of factories and economic organizations.

Two implications of these findings are noteworthy. The first is the dynamic nature of implementing Industry 4.0 in organizations, whether economic or not, which is done more quickly if knowledge and technologies are available or more slowly when knowledge and technologies are fragile or non-existent. The second is teleological since the purpose of Industry 4.0 and all industrial revolutions is to continually improve production processes, even though these benefits often generate unwanted externalities, such as environmental impacts. This means that the progress of knowledge and its developments cannot be stopped but can be directed towards other purposes.

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