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LITERATURE REVIEW

Training for Industry 4.0: a systematic literature review and directions for future research

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ABSTRACT

Goal: This study aims to identify, synthesize and classify the main features explored by current research encompassing training for Industry 4.0 and propose directions for future research.

Design / Methodology / Approach: The methodological procedure was oriented by a systematic literature review (PRISMA) methodology and followed by content analysis. After a review of academic databases, 78 papers dealing with training for Industry 4.0 were included and classified based on topics related to the science of training and Industry 4.0.

Results: Most of the studies in training for Industry 4.0 are oriented to undergraduate and graduate students (in an educational approach) or industrial employees (in an enterprise approach) and, in general, they explore technical, technological, and human-oriented subjects. There is a lack concerning studies targeting managers who deal with Industry 4.0 and few studies consider content related to Industry 4.0 impact on business models, sustainability, corporate social responsibility, and other related concepts.

Limitations of the investigation: The main limitation is related to the database selection criteria. Search in non-indexed databases, book chapters, and non-English language are not included in this study.

Practical Implications: The findings presented in this paper are relevant for researchers and academics as they can serve as a guide for future research work. Consultants, professionals, and trainers can enhance their courses by including currently less explored content or target audiences.

Originality/Value: No similar papers were found in scientific databases and this reinforces this manuscript's originality and contribution.

Keywords: Industry 4.0; Training; Human Resource Management; Knowledge transfer.

1. INTRODUCTION

There is a new stage in developing production systems which presents as one of its pillars the digitalization of processes in the manufacturing environment designated as "Industry 4.0" at Hannover Fair in 2011. It is related to different terms as "Internet of Things", "Cyber-physical systems", "Smart Manufacturing", "Big Data" and "Smart Factory" (Benitez et al., 2019; Ghobakhloo, 2018; Trotta and Garengo, 2018). The relevance of Industry 4.0 and its implementation is based mainly on the possibility of increasing profitability in industrial production and, consequently, raising organizational performance (Brunheroto et al., 2021;

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Rojko, 2017). In addition to favoring cost reduction, Rojko (2017) also mentions other benefits associated with the adoption of Industry 4.0 concepts, such as, shorter time-to-market for the new products, more flexible and friendlier working environment, custom mass production without significantly increasing overall production costs, more efficient use of natural resources and energy, and others (Bai et al., 2020; Brozzi et al., 2020; Masood and Sonntag, 2020; Oztemel and Gursev, 2020; Zhong et al., 2017).

Due to these potential benefits, the implementation of Industry 4.0 concepts is being pursued by companies, especially in the manufacturing sector. According to Sony and Naik (2019), understanding Critical Success Factors is essential for this endeavor and three of them are linked to people: aligning Industry 4.0 initiatives with organizational strategy; unconditional support from senior management for Industry 4.0 initiatives, and the importance of employees for the success of Industry 4.0. Regarding the importance of employees for the success of Industry 4.0, Cerezo-Narváez et al. (2017); Dos Santos and Benneworth (2019); Schallock et al. (2018) highlight the relevance of training to provide the necessary competencies to the projects to be carried out.

According to Salas et al. (2012), "there is a science of training that shows that there is a right way and a wrong way to design, deliver, and implement a training program". It has a long tradition dating back to the early 1900s and it is a science with a legacy of evolution and with significant studies capable of promoting effective learning and positive results (Bell et al., 2017). According to the science of training, there are some key characteristics with a marked influence on the knowledge transfer that have to be considered when designing and delivering a training program, including: target audience, organizational conditions in which the training is offered, training content, pedagogical approach, learning methodology, and use of techniques to motivate participants (Kodwani, 2017; Massenberg et al., 2016, 2015; Salas et al., 2012, 2015; Sanna Junior and Goshorn, 2017; Tews and Noe, 2019).

In the training's plan phase, it is important to collect information about participants and analyze the profile of the group considering issues related to diversity, expectations, and requirements (Cheng et al., 2019; Li et al., 2019; Yang et al., 2018a). In addition, the training content is an important key characteristic as it influences the participant's motivation and, consequently, the knowledge transfer. The training content must be based both on the main theme to be learned by the participants and also based on the participant's profile (Salas and Cannon-bowers, 2001; Taylor and Bisson, 2019; Tian et al., 2015).

Despite the relevance of training for Industry 4.0 (Cerezo-Narváez et al., 2017; Schallock et al., 2018; Sony and Naik, 2019) and the growing number of papers that have been published about Industry 4.0 since 2011 (Pereira et al., 2018), it is still unclear within academia what the main characteristics explored by the researches dealing with training for Industry 4.0. We found no research paper that provides a review of this topic, specifically. Thus, this paper provides a literature review for a better understanding of the state of the art regarding the subject "training for Industry 4.0" and aims to answer the following three specific research questions: 1) As the target audience is a key characteristic on the knowledge transfer, does current research explore every target audience on training for Industry 4.0?; 2) As content is a key characteristic in knowledge transfer, does current research explore all the content on training for Industry 4.0?; and 3) What are the training approaches currently being explored?

Besides this introduction, this paper has five additional sections. Section 2. Theoretical Background details the theoretical basis regarding Industry 4.0 training and the science of training. Section 3. Methodological Procedures presents the details to allow the replicability of this research, Section 4. Results details the results obtained considering the application of methodological procedures, Section 5. Discussions discusses the results presented in Section 4, while Section 6. Conclusion presents the main conclusions and suggests some future research.

2. THEORETICAL BACKGROUND

Industry 4.0 and Training

Industry 4.0 aims to combine production agents (machines, robots, and operators) through a network of connections and information management based on three main factors: technology, organization, and human factors (Ardito et al., 2019; Dregger et al., 2016; Ghobakhloo, 2018, 2020; Hermann et al., 2016; Oztemel and Gursev, 2020; Reuter et al., 2017).

Considering specifically the human factor, the biggest threat to the implementation of Industry 4.0 is related to the resistance of workers to adopt new technologies and the need for training presents itself as the biggest weakness (Jain et al., 2021). Thus, training and continuous professional development deserve special attention and importance for Industry 4.0 (Kaya et al., 2020; Schallock et al., 2018). Especially for manufacturing companies, Bakhtari et al. (2021) present the lack of leadership from the management, lack of skills for training and education programs, and lack of qualified workforce as the main challenges in implementing Industry 4.0.

Nowadays, learning factories are effective for developing theoretical and practical training in a real production environment for undergraduates, graduate students, and workers (Abele et al., 2017; Baena et al., 2017). Learning factories can train technical and social skills; for example, installing and operating IT devices such as RFID tags, tablets, automatic guided vehicles, and others, proposing and realizing changes in all stages of the production system, practicing teamwork, knowledge transfer, knowledge acquiring, collaboration for synchronization of processes, and others. Specifically for undergraduate and graduate students, it is important to prepare them for real situations they will face in the future in both the technical and social aspects. (Baena et al., 2017; Schallock et al., 2018; Wienbruch et al., 2018).

Kim et al. (2020) proposes a cyber learning factory for operations management developed by applying 3D factory simulation software which can be used to train both operations managers of manufacturing companies and information systems architects of Information Technologies companies in a technical approach. According to Helming et al. *(*2019), managers play a crucial role in leading the implementation and development of Industry 4.0 in a company. Sony and Naik (2019) consider the performance of managers as one of the ten critical success factors in implementing Industry 4.0.

In addition to the technical and social skills developed in the training provided by the learning factories, several authors reinforce the importance of discussing the impact of Industry 4.0 on business models and other related concepts such as sustainability, CSR, lean, and others. Machado et al. (2020) presents opportunities for sustainable manufacturing in Industry 4.0 on the reduction of waste, energy consumption, and overproduction; creating job opportunities related to Information Technologies competencies and improving quality of working environment reducing routine jobs; Stock and Seliger (2016) presents a practical case of manufacturing equipment retrofitting as a specific opportunity for sustainable manufacturing in Industry 4.0; Nascimento et al. (2019) explore how rising technologies from Industry 4.0 can be integrated with circular economy (CE) practices to establish a business model that reuses and recycles wasted material such as scrap metal or e-waste and Potočan et al. (2021) reports about research on how Society 5.0 balances Industry 4.0, responsible economic development and resolution of social problems by the advancement of corporate social responsibility (CSR) in organizations.

Finally, the digital aspect of Industry 4.0 has been introduced in training with the use of technologies such as virtual simulations and gamification. Vidal-Balea et al. (2020a) proposes an augmented reality framework to facilitate, support, and optimize production and assembly tasks through training and assistance; Carretero et al. (2021) presents a methodology to develop virtual reality tutorials and training courses for professional preparation in industrial jobs, and Ulmer et al. (2020) proposes a novel concept and evaluation system combining gamification and virtual reality practice for flexible assembly tasks. These virtual simulations and gamification consider learning based on the presentation and discussion of situations experienced in practice and, due to this characteristic, it is considered a practical training approach. It is important to mention that introduction of the digital aspect in Industry 4.0 training aims to optimize knowledge transfer and improve training participants' learning.

Science of Training

On the other hand, there is a science of training that studies the best practices to be adopted in training to optimize the transfer of knowledge and participants' learning. Based on Bell et al. (2017); Cheng et al. *(*2019); Salas et al. (2012, 2015) and Yang et al. *(*2018a), target audience, training content, and training approach are key factors that should be considered when planning and designing training.

Information and data about the target audience must be collected and made known before the training is applied, that is, in the pre-training phase. According to Salas et al., (2012, 2015) and Yang et al. (2018a), in the pre-training phase a diagnosis is made of what needs to be trained (content) and for whom the training is intended (target audience) to enable the preparation of the next training phases (training and post-training) properly as guiding training design, presenting expected learning outcomes, and guiding training evaluation.

The training approach focuses on applying appropriate instructional strategies and outlining content and should be considered during the training phase (Salas et al., 2012, 2015; Sanna Junior and Goshorn, 2017). Regarding instructional strategies, it considers the following basic principles: (a) inform: present information or relevant concepts to be learned; (b) demonstrate: demonstrate knowledge, skills, and attitudes (KSAs) to be learned; (c) practice: create opportunities for participants to practice skills and; (d) provide feedback: reporting to participants during the training phase and in the post-training phase (Bell and Kozlowski, 2008; Salas and Cannon-bowers, 2001; Taylor and Bisson, 2019; Tian et al., 2015). In connection with these basic principles, an active learning methodology such as Project or Problem-based Learning (PBL) presents two main characteristics: (a) it provides the participant with responsibility for important decisions regarding the learning process, such as the choice of learning activities and monitoring and judging the progress of their own learning; (b) promote an inductive learning process, in which participants explore and experience a given task in order to infer its rules, principles and strategies for effective performance. Specifically, in relation to PBL, it should be considered that scientific research and psychological theory demonstrate that training participants simultaneously learn content and thinking strategies by learning from problem-solving experiences (Bell et al., 2017; Piñol et al., 2017; Salas et al., 2012, 2015; Stankunas et al., 2016; Werth, 2011)

Figure 1 presents an analytical framework organizing key topics related to the science of training and Industry 4.0, thus guiding the research questions of this study and the systematic literature review that will be presented in the next sections.

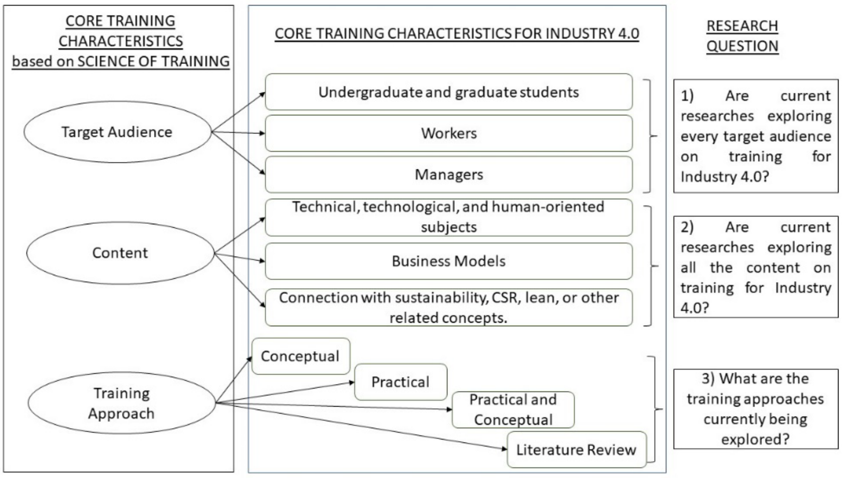

Figure 1. Analytical Framework.
Source: The authors themselves

3. METHODOLOGICAL PROCEDURES

In order to answer the three research questions mentioned above, a methodological procedure was elaborated based on three stages and followed step-by-step to allow the replicability of this research. Figure 2 presents a methodological framework to facilitate the presentation and understanding of the stages developed.

In stage 1, the preferred reporting items for systematic review and meta-analysis (PRISMA) methodology (Moher et al., 2009) oriented the research to ensure a replicable and robust systematic literature review. This methodology is widely used to guide the development of systematic literature reviews in various research fields, including the Industry 4.0 subject (Bueno et al., 2020; Liao et al., 2017; de Paula Ferreira et al., 2020).

The PRISMA methodology consists of a four-phase flow diagram (identification, screening, eligibility, inclusion), and the input data and results obtained in each phase are shown in Figure 1. The PRISMA methodology also presents a 27-item checklist to report a systematic literature review (title, abstract, introduction, methods, results, discussion, and funding) and it supported the development of all sections of this research.

Stage 2 consisted of qualitative content analysis based on Elo and Kyngäs (2008). According to them, a content analysis must be performed in three phases: (a) preparation phase; (b) organizing phase; and (c) reporting the results. This last item is presented in stage 3.

During the preparation phase (a), the unit of analysis must be defined. Specific for this research, the unit of analysis was defined as a theme: "main characteristics explored by researches on training for Industry 4.0". The organizing phase (b) was composed of five steps: open coding, coding sheets, grouping, categorization, and abstraction. Open coding means taking notes and headings to describe all aspects of the content. After this, the notes and headings are collected onto coding sheets and grouped and classified. The purpose is to provide a means of describing the phenomenon, to increase understanding, and to generate knowledge about it. Abstraction considers the formulation of a general description of the research topic through generated categories. Finally, in the (c) reporting the review process and results, an attempt is made to create an overview of the topic studied.

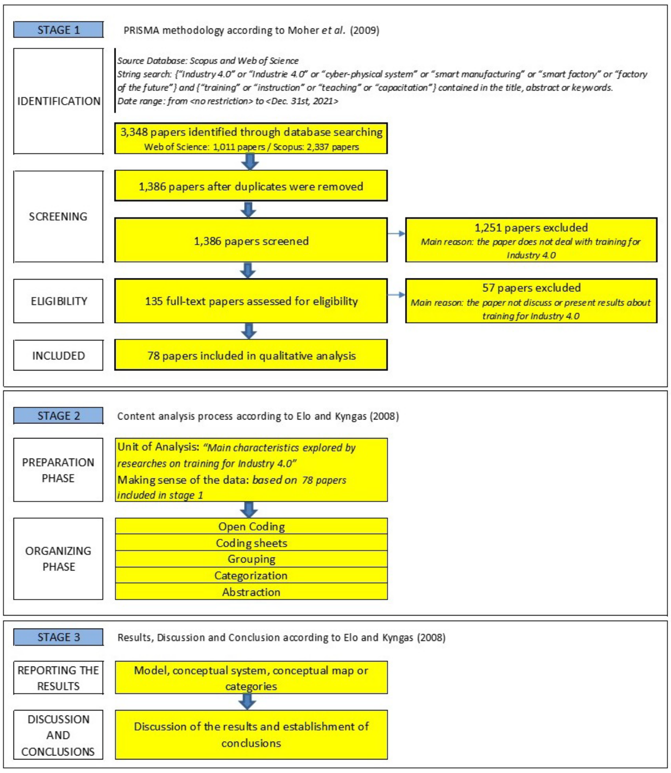

Figure 2. Methodological Framework.
Source: The authors themselves

Based on the above-mentioned procedures, the following (3) three categories were created based on the science of training (Cheng et al., 2019; Kodwani, 2017; Salas et al., 2012, 2015; Yang et al., 2018b) to group and categorize the 78 papers included in stage 1 of the methodological framework (see Figure 1): target audience, training content, and training approach.

Concerning target audience classification, Table 1 shows the categories used to group the analyzed papers. As mentioned previously, the main characteristics of participants must be known by the trainer and it is essential to prepare good content and, consequently, obtain success in knowledge transfer (Bell et al., 2017; Salas et al., 2012, 2015).

Table 1. Categories used to classify papers based on the target audience

Target Audience	Description
Undergraduate and graduate students	Industry 4.0 training aimed at students in graduation or postgraduation;
Workers	Industry 4.0 training aimed at employees in different stages of company production;
Managers	Industry 4.0 training aimed at employers, managers, or executive officers.

Source: The authors themselves

Regarding training content, papers were grouped into categories presented in Table 2.

Table 2. Categories used to classify papers based on training content

Training Content	Description
Industry 4.0 technical, technological, and human-oriented subjects	Discuss training content related to Industry 4.0 aspects as pillars and principles, robotics, robots, smart factory, production planning, a new way of production, maturity, cases of success, new competencies, and others;
Industry 4.0 and Business Models	Discuss training content related to new business models generated by Industry 4.0 or current business models impacted by Industry 4.0;
Industry 4.0 and other concepts connection	Discuss training content related to the impact or connection between Industry 4.0 and sustainability, CSR, lean, or other related concepts.

Source: The authors themselves

Finally, the papers were classified according to training approach. Table 3 shows the categories used for training approach classification and presents a description of each category.

Table 3. Categories used to classify papers based on training approach

Research Type	Description
1. Conceptual	Discuss training approach theoretically;
2. Practical and Conceptual	Discuss training approach theoretically and present applications and practical examples related to theory;
3. Practical	Discuss training approach with only applications or practical examples;
4. Literature Review	Perform a literature review on training for Industry 4.0 theme.

Source: The authors themselves

After the description of the results, discussions were done and conclusions were established.

4. RESULTS

The 78 published papers included in stage 1 of the methodological framework (see Figure 1) were sorted by date and Figure 3 shows the results. It is important to mention that no restriction was considered for the initial date of the published papers, so the first paper available in the Web of Science and Scopus database is from the year 2015. The expressive growth of the number of published papers in the last years compared to previous years is consonant with the growing search for the implementation of Industry 4.0 (Cordeiro et al., 2019; Frank et al., 2019; Ghobakhloo, 2018).

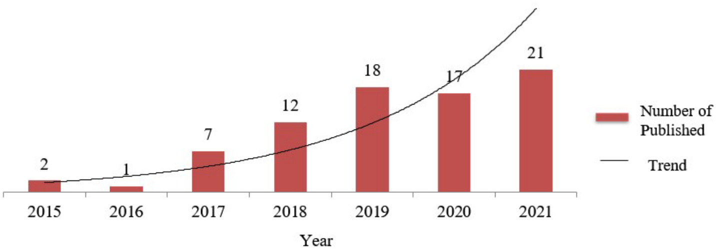

Figure 3. Distribution of published papers per year.
Source: The authors themselves

In the sequence, these 78 published papers were classified according to Table 1, Table 2, and Table 3 and the result is presented in Figure 4, Figure 5, and Figure 6, respectively. The Appendix A presents the classification individualized by paper.

Based on Figure 4, it can be noted that almost all research on training for Industry 4.0 focuses on students and workers as their target audience and a gap is observed about managers as their target audience. Figure 5 presents research on training for Industry 4.0 focusing essentially on the technical, technological, and/or human-oriented subjects and a gap in addressing content about the impact of Industry 4.0 in business models and the relationship of Industry 4.0 with sustainability, CSR, and other concepts.

Figure 6 shows the larger amount of research deals with the conceptual and practical application of Industry 4.0 concepts, that is, discusses training approach theoretically and presents applications and practical examples related to theory. On the other hand, no papers considered literature review on training for Industry 4.0.

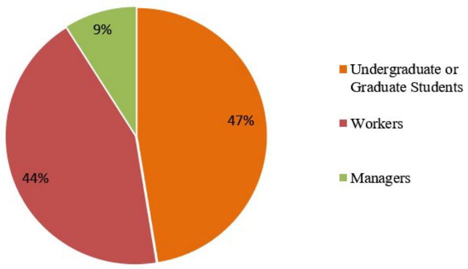

Figure 4. Distribution of papers according to the target audience.
Source: The authors themselves

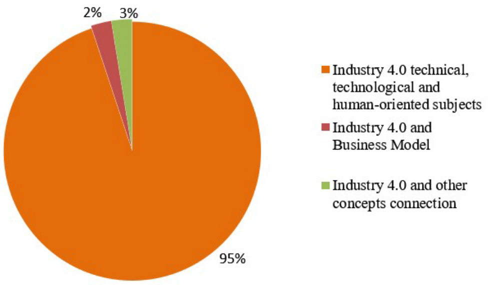

Figure 5. Distribution of papers according to training content.
Source: The authors themselves

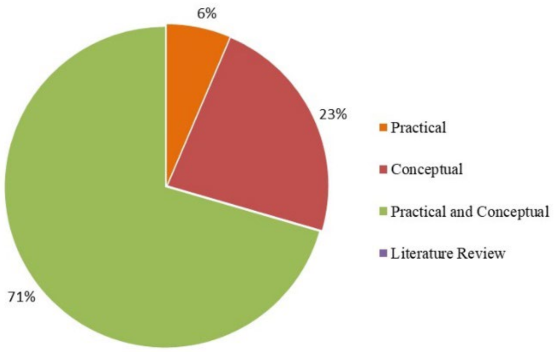

Figure 6. Distribution of papers according to training approach.
Source: The authors themselves

Figure 7 presents the results in a consolidated form. The majority of research is focused on undergraduate, graduate students, and workers with technical, technological, and human-oriented content. Research gaps are for research in management training including content related to the impact of Industry 4.0 on business models, sustainability, CSR, lean, and other related concepts. The conceptual and practical approach is the most applied in research and there is a gap related to literature review.

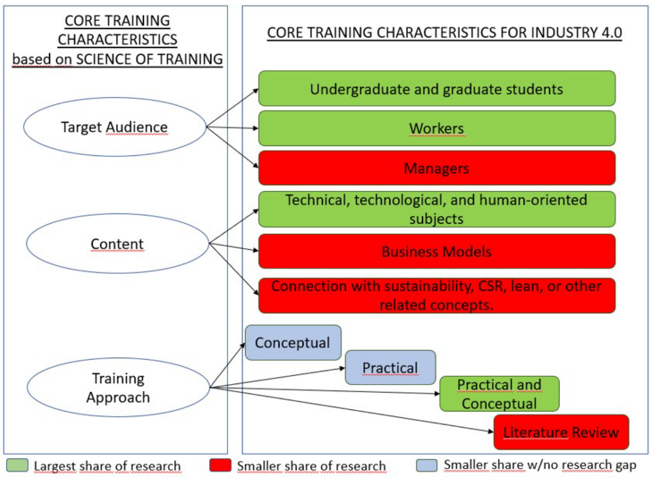

Figure 7. Share of research regarding training for Industry 4.0.
Source: The authors themselves

5. DISCUSSION

Given that the majority of research in training for Industry 4.0 has students and workers as their target audience, it is possible to notice the effort that educational institutions and companies have been making to prepare students and the current workforce for future professional challenges.

However, a gap can be observed about managers as the target audience. Based on Helming et al. (2019) and Moeuf et al. *(*2018), managers are one major component for Industry 4.0 implementation and they have a prominent role in the success and/or failure of an Industry 4.0 project; Sony and Naik (2019) consider managers as the seventh critical factor for Industry 4.0 implementation. Thus, managers are an important target audience that should be included in research about training for Industry 4.0.

Considering the training content, research on training for Industry 4.0 focuses essentially on the technical, technological, and/or human-oriented subjects. It is a relevant topic considering the new hard and soft skills required by Industry 4.0, especially for students and workers (Cerezo-Narváez et al., 2017; Dos Santos and Benneworth, 2019; Schallock et al., 2018; Sony and Naik, 2019).

Nevertheless, there is a gap in addressing content about the impact of Industry 4.0 in business models and the relationship of Industry 4.0 with sustainability, CSR, and other concepts. The importance of this theme is presented by several researchers, among them Müller et al. (2018) that analyses how Industry 4.0 triggers changes in the business models of small and medium German manufacturing enterprises; Wagire et al. (2020) concludes that innovative business models are one of the main pillars of Industry 4.0 and have a notable function in digital transformation and Arnold et al. (2016) and Ibarra et al. (2018) present a literature review on how Industry 4.0 affects business models. De Sousa Jabbour et al. (2018) argues that Industry 4.0 has the special potential to unlock environmentally-sustainable manufacturing; Ghobakhloo (2020) identifies the sustainability functions of Industry 4.0 and Sony and Naik (2019) consider sustainability the tenth critical success factor for Industry 4.0 implementation.

Taking into account the training approach, the majority of the research deals with the conceptual and practical application of Industry 4.0 concepts and it is aligned with an active learning methodology such as Project or Problem-based Learning (PBL) (Bell et al., 2017; Piñol et al., 2017; Salas et al., 2012, 2015) and with the application of new technologies such as virtual reality, augmented reality, insertion of robots in the production line, insertion of technology for planning production lines, and others (Carretero et al., 2021; Ulmer et al., 2020; Vidal-Balea et al., 2020b). In contrast, literature review papers take an essential role on an emergent and unexplored subject like training for Industry 4.0, showing an up-to-date scenario, identifying gaps, and proposing directions for future research.

Based on the combination of the results presented in Figure 4 and Figure 5, it can be noted that undergraduate students, graduate students, and workers receive essentially technical, technological, and human-oriented knowledge in training for Industry 4.0. On the other hand, it is necessary to explore Industry 4.0 training aimed at managers and consequently, explore training content regarding Industry 4.0 impact on business models and other concepts such as sustainability and CSR, once knowledge about its content is essential for the performance of the managerial role.

6. CONCLUSIONS

The general purpose of this study is to identify, synthesize, and classify the main features explored by current research encompassing training for Industry 4.0 and propose directions for further research. Based on the results, it was possible to answer the three specific research questions.

The search on academic bases has enabled the finding of seventy-eight papers, which were analyzed and classified into the target audience, training content, and research type. Most of the papers are directed to undergraduate students, graduate students, and workers and deal with technical, technological, and human-oriented subjects related to Industry 4.0. The majority of the papers present conceptual and practical or only conceptual approaches and no paper performed a literature review about training for Industry 4.0.

There is a gap concerning managers as the target audience according to our findings. Managers are required to be capable of guiding the change to Industry 4.0 by handing over the correct vision, creating the proper culture, and making the proper alliances within the organization. Industry 4.0 requires prepared leadership capable of leading and motivating employees towards a common goal (Helming et al., 2019; Moeuf et al., 2018; Sony and Naik, 2019). Thus, future research agenda on training for Industry 4.0 can focus on managers as target audience as well a future research avenue can explore the disposal and availability of managers to engage in training for Industry 4.0 compared to the training availability. Such surveys may even consider case studies and industry surveys.

Regarding the training content, there is a need to explore a holistic view of Industry 4.0 considering aspects of business models, sustainability, CSR, among others. Rojko (2017) cites the efficient use of natural resources and energy as an example of benefit associated with

Industry 4.0 implementation and connected with sustainability. Business models are impacted by Industry 4.0 and innovative ones are necessary for Industry 4.0 implementation (Arnold et al., 2016; Ibarra et al., 2018; Müller et al., 2018; Wagire et al., 2020). Thus, content related to business models and sustainability must be included in a research agenda proposal for Industry 4.0 training. It is noteworthy that literature review research should follow the development of Industry 4.0 training subject and this paper intends to make a first contribution to this topic.

It is important to notice that papers about Industry 4.0 managers training which is performed and reported in non-academic databases, namely "grey literature", are not included in this study and it is a limitation of the investigation. An analysis including these additional databases may lead to different results and it is a proposal for future research about Industry 4.0 managers' training.

It is expected that the above findings contribute to the improvement of the current state of knowledge about training for Industry 4.0 and they become used by researchers or trainers to boost their courses.

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APPENDIX A. CLASSIFICATION INDIVIDUALIZED BY PAPER

Item	Reference	Classification acc. Table 1 (target audience)	Classification acc. Table 2 (training content)	Classification acc. Table 3 (research type)
1	(Faller and Feldmúller, 2015)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
2	(Lin et al., 2015)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
3	(Abed et al., 2016)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
4	(Bueno-Delgado et al., 2017)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
5	(Gorecky et al., 2017)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
6	(Perini et al., 2017b)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
7	(Perini et al., 2017a)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
8	(Piñol et al., 2017)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
9	(Schroeder et al., 2017)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
10	(Vila et al., 2017)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
11	(Ahmad et al., 2018)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
12	(Büth et al., 2018)	Workers	Industry 4.0 and other concepts connection	Practical and Conceptual
13	(ElMoaqet et al., 2018)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
14	(Horrillo Tello and Triado Aymerich, 2018)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
15	(Huang, 2018)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
16	(Koleva and Andreev, 2018)	Managers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
17	(Mortensen and Madsen, 2018)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
18	(Mourtzis et al., 2018)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
19	(Schallock et al., 2018)	Managers	Industry 4.0 and other concepts connection	Practical and Conceptual
20	(Schrack, 2018)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
21	(Yang et al., 2018a)	Managers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
22	(Żywicki et al., 2018)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
23	(Abidi et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
24	(Bayes and Iglesias, 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
25	(Bogoviz et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
26	(Buligina and Sloka, 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
27	(Gerasimova et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
28	(Heinz et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
29	(Helming et al., 2019)	Managers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
30	(Longo et al., 2019)	Managers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual

APPENDIX A. CONTINUED...

Item	Reference	Classification acc. Table 1 (target audience)	Classification acc. Table 2 (training content)	Classification acc. Table 3 (research type)
31	(Moica et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
32	(Myznikova et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 and Business Model	Conceptual
33	(Pérez et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
34	(Roldán et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
35	(Saorín et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
36	(Segura et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
37	(Strubelt et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
38	(Tosello et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical
39	(Tran et al., 2019)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
40	(Tsourma et al., 2019)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
41	(Beloglazov et al., 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
42	(Cardillo and Chacon, 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
43	(Casillo et al., 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
44	(Jovanovic et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
45	(Kans et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
46	(Karbach et al., 2020)	Managers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
47	(Malaga and Ulrych, 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
48	(Mingaleva and Vukovic, 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
49	(Molino et al., 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
50	(Oleskow-Szlapka et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
51	(Segura et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical
52	(Silva et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
53	(Tovar et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
54	(Ulmer et al., 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
55	(Vidal-Balea et al., 2020a)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
56	(Yuanlong et al., 2020)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Conceptual
57	(Zawadzki et al., 2020)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
58	(Azevedo and Almeida, 2021)	Managers	Industry 4.0 and Business Model	Practical and Conceptual
59	(Benis et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
60	(Caño de las Heras et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
61	(Carretero et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
62	(de Giorgio et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual

APPENDIX A. CONTINUED...

Item	Reference	Classification acc. Table 1 (target audience)	Classification acc. Table 2 (training content)	Classification acc. Table 3 (research type)
63	(Dhalmahapatra et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
64	(Dobrilovic et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
65	(Gutiérrez-Martínez et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
66	(Hernández-Chávez et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
67	(Matulis and Harvey, 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
68	(Paszkiewicz et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
69	(Wang et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
70	(Židek et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
71	(Kliment et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical
72	(Mäkiö et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
73	(Simões et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical
74	(Tihinen et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical
75	(Lopez et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
76	(Romero-Gazquez et al., 2021)	Workers	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
77	(Hernández-Chávez et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual
78	(Muthukumar et al., 2021)	Undergraduate or Graduate Students	Industry 4.0 technical, technological and human-oriented subjects	Practical and Conceptual

Source: The authors themselves