Warehouse workforce preparedness in the wake of Industry 4.0: A systematic literature review

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Abstract

With the changing landscape, new job roles are created: data analysts, solution architects, and network professionals within manufacturing. Advanced technology can handle most jobs, such that the traditional workers are facing mass layoffs. However, training related research on how to improve warehouse workers' readiness remains scant. This literature review serves to help answer the question: how to prepare warehouse workers face the changes that Industry 4.0 causes. The authors analyzed 17 papers published from 2011-2019. The results show that future researchers can consider focusing on Latin America population. The literature review also reported the 17 papers into publication venues, Industry 4.0 focus, and research targeted industry.

Introduction

The rise of Industry 4.0 transforms the workplace [1]. New technology reduces production costs while increases the product quality with more efficient work processes [2]. While it is plausible that Industry 4.0 improves people's overall life satisfaction, at the meanwhile, this rapid change causes anxiety among employees because advanced technology may replace human workers, especially blue collar workers [1, 3]. For example, in a traditional warehouse, workers' job, which includes operations of pickup, delivery, and bookkeeping are highly repetitive [4]. Even for those who stayed, cooperating with machines or using new technologies bears negative psychological influences that may deteriorate the work environment for warehouse workers [5]. Thus, how to prepare warehouse workers with the skills they needed for the future seems like a critical matter.

Despite the warehouse workers are affected by introducing advanced technology and systems, less research has focused on the population of warehouse workers in the wake of Industry 4.0. Organizations need to develop skills and invest in training to embrace the change that Industry 4.0 has generated, and the College of Engineering ought to adapt the change and update teaching approaches. For engineering educators, it is propitious to shift the focus from warehouse systems improvement (Industry 4.0) to studying how to prepare the next generation warehouse workforce (human resources).

Studying the influence of Industry 4.0 on warehouse workers, in this systematic literature review the authors narrowed their search range from 2011 until late 2019 because the concept of Industry 4.0 was introduced in 2011 [6]. The authors also focused on warehouse workers as this population is heavily affected by Industry 4.0 in the supply chain management [7, 8].

This literature review tries to answer two main research questions:

1. What are effective means that warehouses use to prepare their employees for the change that Industry 4.0 has generated?
2. How are those training programs delivered?

Theoretical framework

The ADDIE model is a systematic approach to training and development [9]. According to Branson [2], ADDIE is short for Analysis, Design, Development, Implementation, and Evaluation. However, most training program designers follow a simplified ADE model [10]. Actually the ADDIE model was developed from Thiagarajan's [10] ADE model (Analysis, Design, and Evaluation). In this literature review, the authors employed the ADE model and coded articles based on the dimensions that Thiagarajan [10] suggested. To be specific, in the model, there are three main steps to follow for a training program. The first step is to conduct needs assessment which means to find the targeted training areas. Second, based on the assessment results, program designers analyze and develop and design the program. Third, program evaluation: it is important to measure the effectiveness of a learning program based on its original design at the outset and the execution of the program implementation. Thus, the authors coded the reviewed literature into three overarching categories: training needs assessment, training programs, and training evaluation. See the ADE model in Figure 1.

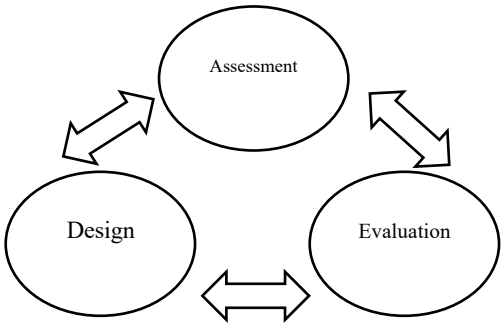

Figure 1. The ADE model

Methods

Following the steps in the Matrix Method for conducting systematic literature reviews [11], the authors used a three-step procedure to identify pertinent scholarly articles. First, the work uses four popular databases, ABI/Inform Complete, Business Search Ultimate/Business Search Complete, Web of Science, and EBSCO, to survey the literature, synthesize findings, and make suggestions for future research. Second, Boolean search techniques were used and Industry 4.0 related to key terms were also selected. To be specific, the authors employed an extensive list of search terms related to Industry 4.0. For example, the authors included: Industry 4.0, internet of things, blockchain, digital, connected, sensor, robotics, artificial intelligence, smart, and big data. In addition, this literature review focuses on how to prepare the next generation workforce at various venues, such as 2-year college, university, workplaces. Thus, the authors also included search terms such as: education, training, and talent development. An example of the search terms the authors used for Web of Science was TS=(warehouse OR "supply chain" OR "material handling") NOT TS=("data warehouse" OR "knowledge warehouse" OR “machine learning” OR “deep learning”) AND TS=(learning) AND TS=("industry 4.0" OR "internet of things" OR blockchain OR digital OR connected OR sensor OR robotics OR "artificial intelligence" OR smart OR "big data").

The authors only included peer-reviewed English publications in the initial attempt. And the authors have excluded conference proceedings because high quality studies tend to published in peer-reviewed journals [12]. The authors also ignored brief notes, introductions, editorials, professional commentaries and book reviews, which are common in the journals analyzed and which cannot be classified as published articles. Finally, the authors created a publication pool of

64 articles. The authors analyzed publications from 2011–2019 because although there are articles centering on this issue prior to 2011, it is really only after 2011 that the concept of Industry 4.0 itself becomes consolidated and there are publications on the workforce development side of warehouse published in high impact journals.

During the literature screening process, the authors used certain exclusion criteria: (1) studies that mentioned "connected" but not from a technological perspective, (2) studies mentioned learning, however, it's a combination of machine learning, algorithm learning, data learning, or deep learning. The authors also checked included articles' reference list, aiming to extend the literature pool.

After checking and deleting duplicate, a pool of 48 articles was generated and the authors moved to the literature coding process. The authors coded each paper into six categories and during the screening stage, the authors used stated exclusion/inclusion criteria and excluded 31 papers (see the PRISMA diagram below; Figure 2). The coded 17 papers were organized in these six categories: Publication trend, Research industry, Industry 4.0 focus, Training focus, Publication venues, and Research targeted regions.

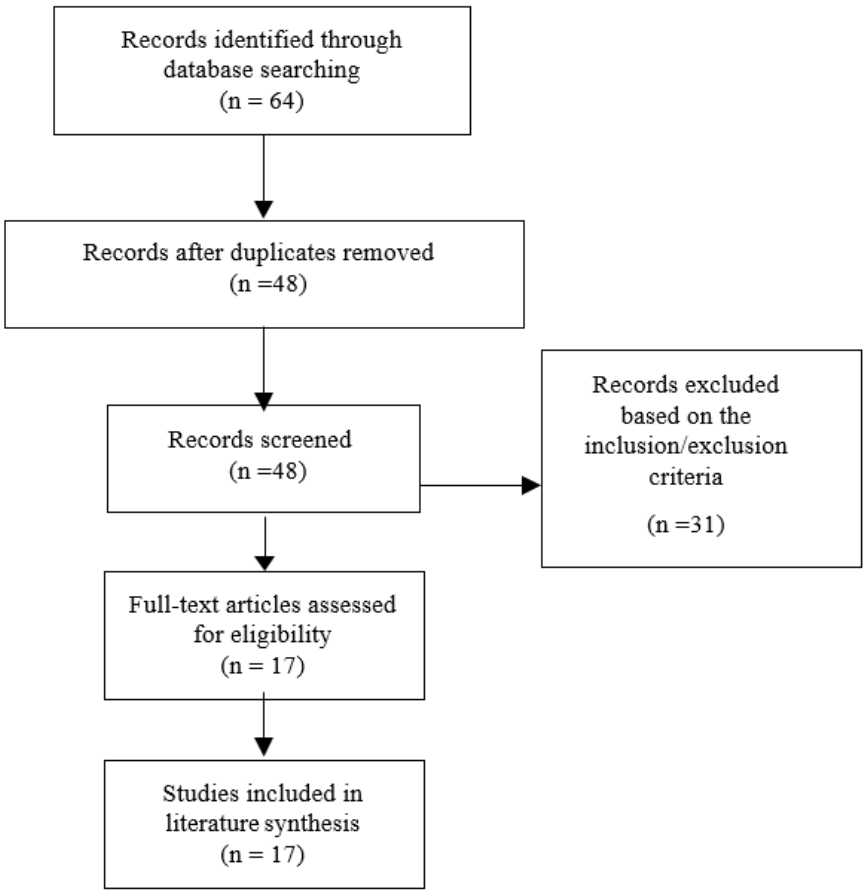

Figure 2. Search and review strategy using the PRISMA method

Results

Publication trend

The authors mapped each year's publication numbers on the bar chart below. The authors also created a trend line to assist readers to see the publication trend. As depicted from the bar chart (Figure 3), there is a slightly ascending publication trend from 2012 to 2019.

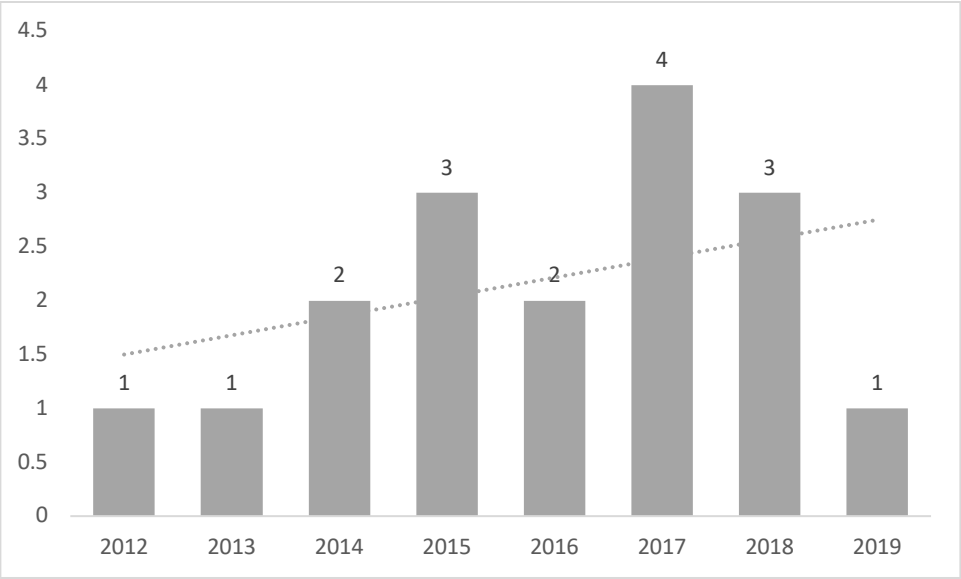

Figure 3. Publication Trend

Targeted region

The authors coded the targeted geographic region into continents: Asia (n=2), Europe (n=9), North America (n=2), Africa (n=3), Australia (n=1). It is worth noting that there is no published paper focused on the Latin America regions. See details in Figure 4.

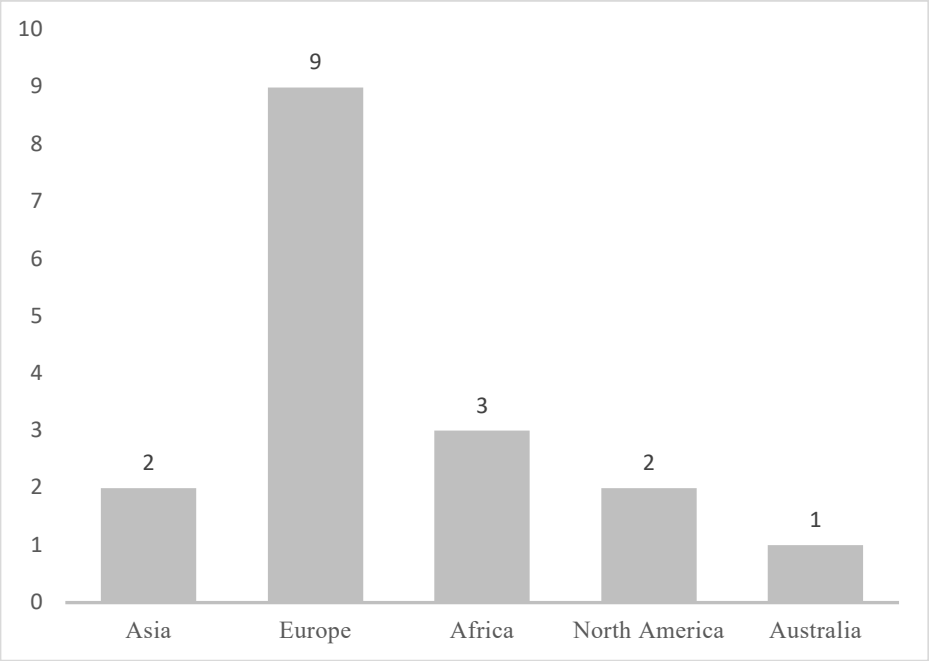

Figure 4. Targeted region

Publication venue

In order to render a picture of where to publish related work for future researchers, the authors also mapped the publication venues in Table 1. Seventeen articles were published in 16 different journals. Among these 16 journals, 10 can be searched in the Social Sciences Citation Index (SSCI). Their impact factors vary from 0.529 to 5.212.

Table 1. Journal titles and impact factors.

Journal title	Impact factor
The International Journal of Logistics Management	5.212
Process Safety and Environmental Protection	4.384
Journal of Field Robotics	4.345
Journal of Business Logistics	3.171
Computer Communications	2.766
Annals of Operations Research	2.284
Journal of Stored Products Research	1.954
Journal of Chemical Education	1.763
International Journal of Engineering Education (n=2)	0.611
Societies	0.529
Transport Problems	N/A
Vadyba Journal of Management	N/A
Journal of Operations and Supply Chain Management	N/A
Przegląd Elektrotechniczny	N/A
SA Journal of Human Resource Management	N/A
Mrev Management Revue	N/A

Training dimensions

Gustafson and Branch's (2002) instructional design model guided our decisions in coding papers into the three main training dimensions: training needs assessment (n=9), training program (n=11), and training evaluation (n=6). Figure 5 shows these three training dimensions in analyzed literature.

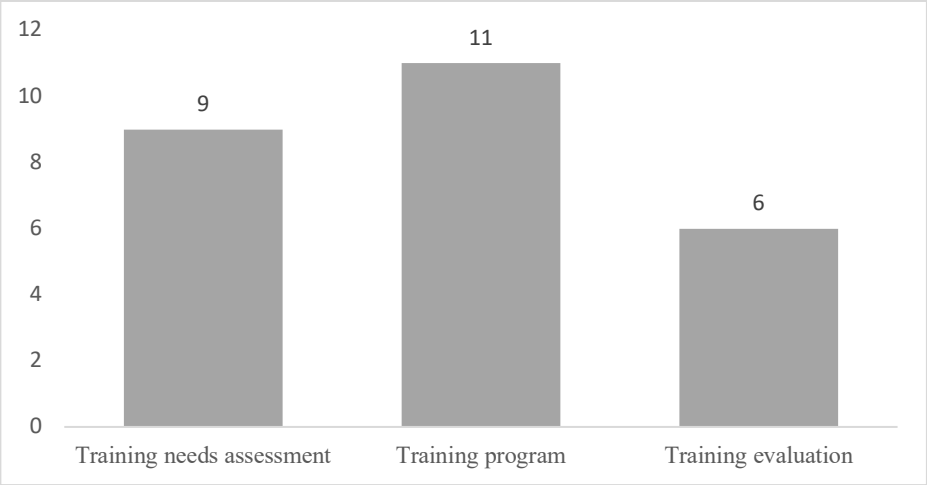

Figure 5. Training dimensions

Industry 4.0 focus

This category aimed to differentiate the foci of the reviewed papers (see Figure 6). Only three papers emphasized on the nature of Industry 4.0. For example, Walter et al. [13] mainly focused on the introduction of robots in the warehouse, and at the end of the paper they proposed the possible influence of using robots in the warehouse on the current workforce. The majority of the articles (n=14) zeroed in on the application of Industry 4.0 related tools in the warehouse, and how the application may help workforce develop. For example, Cvetkovski et al. [14] introduced how a university class used Virtual Reality to gain mechatronics knowledge.

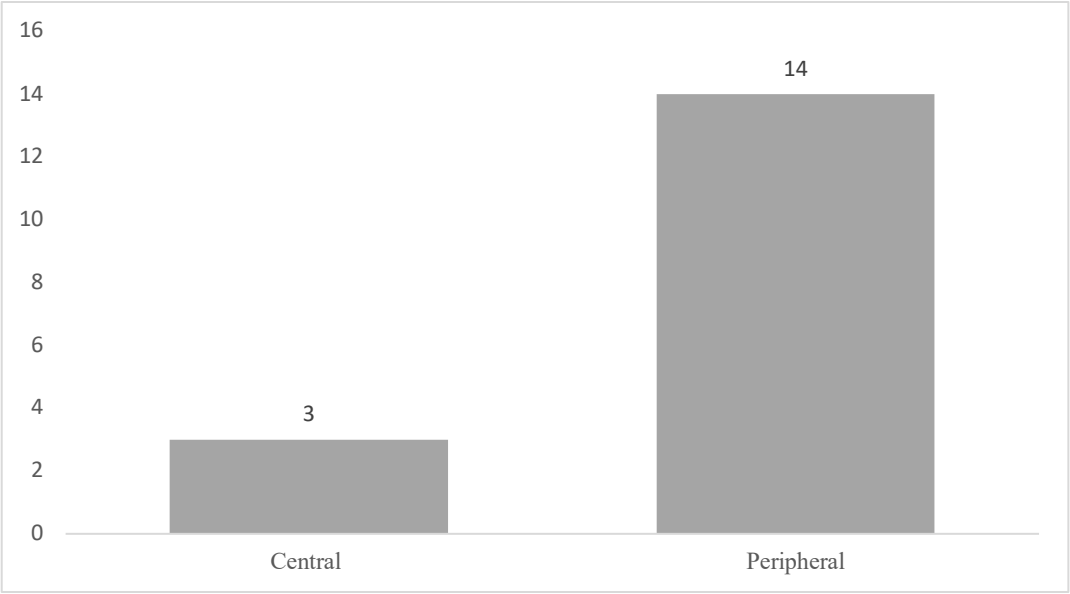

Figure 6. Industry 4.0 focus

Research industry

Categorizing the research industry helps researchers find some understudied industries (see details in Figure 7). Regarding the training/education programs provided for the future workforce, students from universities are the most focused populations (n=6). For example, Gromovs and Lammi [15] introduced their bachelor program framework which includes Blockchain and IoT related knowledge. Similarly, Erdelyi and Rajko [16] described a web-based interactive learning program teaching student how to use online psychometric charts.

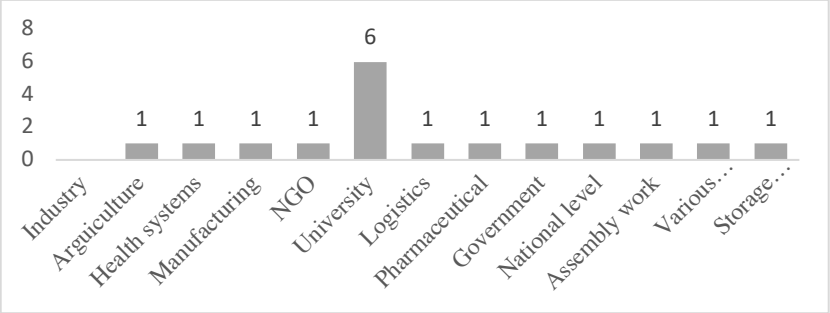

Figure 7. Research industry

Discussion and Future Directions

Based on the content analyses of the 17 included papers the authors synthesized the literature and answered two research questions. The authors aim to offer research suggestions for researchers who share a similar interest on the intersection of Industry 4.0 and future warehouse workers. The authors focus on future possible contributions to training program designs for the future workforce.

The first question sought to discover how current organizations/universities are preparing for future workforce for the warehouse workers (e.g., designers, common workers, and managers). Indeed, many advocate the need for training warehouse workers to perform new tasks (needs assessment) and more research regarding how to prepare the warehouse workers (program design). The authors also noted that the proposed training programs are often presented without evaluation results, which causes trouble in program comparisons. Overall, the synthesis of the literature indicates that most studies have focused on training program's designs, whereas the evaluation of those programs is lacking. However, evaluation is an integral component for an effective training program. Alvarez, Salas, and Garofano [17] pointed out that the evaluation stage of a training program is fundamental for its sustainability. That is to say, evaluations provide constructive feedback for the content of those training program. To be specific, the sector of organizations overlooked the importance of reporting the training effectiveness (evaluation); most of them reported the design of certain training programs. On the contrary, almost every educational program in the higher education sector reported the evaluation mechanisms. For example, Zhong and Huang [18] conducted a case study using a sample from a university in China. They found that a new smart pedagogical environment for students is conducive for students' learning-by-doing performance in engineering classes. They used hands-

on evaluation service explorer (an evaluation tool) to measure its effectiveness after every session.

From the research region perspective, the authors found that there are limited studies focused on the impact of Industry 4.0 on warehouse workers in certain regions (i.e., Latin America). These areas appear to have a concentration of employment with lower wages and low cost for human resources turnover [19, 20]. However, with the permeation of Industry 4.0 the whole world will be affected by its strong influence in the upcoming years [21]. This literature review may act as a learning source for those regions.

Regarding the training needs assessment, the authors synthesized the 17 papers and found that there are needs at the governmental level—tax-subsidy scheme helping SMEs with warehouses be ready for Industry 4.0, support in the educational system to teach the labor market new skills such as how to work with automated robots; at the organizational level—learning organization, the whole organization applies the Cyber-Physical Systems, in which contiguously exchange information between machine and humans; at the technological tool level—specialized training on information and communication technology for warehouse workers, RFID tracking systems for better communication and improvements in the use of warehouse space, operating Cobots in warehouses, general Industry 4.0 related trainings for farmers/NGO staff, training about the usage of Raspberry Pis and Arduino with sensors.

Most of the included papers introduced specific training programs, meaning that they provided detailed explanation of the program and offer future suggestions about how to adopt these programs in different contexts. The authors employed a multi-level analysis to categorize these training programs into different levels: programs at the technological tool level—voice commendable robotic forklift in the army warehouse, RFID tracking with IoT-based working

principles within the context of smart warehouse, the application of Big Data and IoT usage in helping truck drivers drive safely; at the higher educational level—the usage of data in warehouse as a practitioner route, teaching students about warehouse in a dosing system with sensors, focusing on the broader context of warehouse, training teachers first about the inclusion of blockchain and IoT in more warehouses, RFID and smart tags in warehouse, using VR to teach students about pneumatic actuator construction and learn how to master the fundamentals of PLC programming, and using digital interface about the effects of changing conditions on psychometric properties in warehouses (Table 2).

Table 2. Training needs assessment and training program designs

	Governmental level	Higher Educational level	Technological tools	Organizational level
Training needs assessment	Funding support in the educational system		Information and communication technology for warehouse workers RFID tracking systems Operating Cobots in warehouses Industry 4.0 related knowledge The usage of Raspberry Pis and Arduino with sensors	Learning organization
Training programs		how to use data in warehouse in a more practitioner route	voice commendable robotic forklift	

teaching students about warehouse in a dosing system with sensors	RFID tracking with IoT-based working principles
Teaching blockchain and IoT	The application of Big Data and IoT usage in helping truck drivers
Using VR to teach students about pneumatic actuator construction and learn how to master the fundamentals of PLC programming	
Using digital interface about the effects of changing conditions on psychrometric properties in warehouses	

Last but not least, the authors analyzed how those programs were being evaluated. The majority of those studies use both qualitative (open-ended questions) and quantitative methods (pre/post-survey) to evaluate the learning effectiveness.

Despite that advanced technologies are weakening the human factors in the workplace, for example, the introduction of Kiva robotic picking system reduces the needs for training for human workers given the majority of work can be finished by the robots [21], with the reported social impact of Industry 4.0 on workforce (mass layoffs), how to prepare warehouse workers are worth our attention. The application of Industry 4.0 in warehouses leads the future change of the workforce in warehouses.

It seems like more studies should consider the support from the governmental or national level. Only one paper discussed how a government may mitigate the negative impact of Industry 4.0 on SMEs, which are the backbone of any economy. The update of knowledge and skill at such a massive scale needs a tremendous investment from the national level. In terms of national human resource development, Waite, McDonald, and Kimberly [22] reported a wide recognition about the critical role of STEM professions in the 21st century, but they also expressed their deeply concerns about the lack of support from the government and industry level to handle the wake of change in this age. Focusing on two of the fastest growing emerging economies in the world, in a comparative study between China and India's educational challenges, Alagaraja and Wang [23] firmly stressed the role of government and educational institutions' role in advancing future workforce. The authors are expecting to see more publications about how the government and university is building the future warehouse workforce.

Conclusion

The paper applied a Matrix Method to collect and analyze current literature on workforce development in the context of warehouse. The authors found that there is an ascending trend in the past nine years since the introduction of Industry 4.0. However, most of the papers are focused on developed countries, such as countries in Europe or North America, whereas no publications were found focusing on Latin America. The authors also categorized the reviewed papers into publication venues, Industry 4.0 focus, and research targeted industry, aiming to offer guidance for future researchers on where to focus and in which journal to publish.

The authors mainly focused on the training needs, training design, and training evaluations for the development of warehouse workers. In terms of future directions, in the needs assessment, training needs at the higher educational level are missing. Future researchers may conduct literature review of training/education needs for the higher education sector in particular. Indeed, the educational system needs to catch up with the change in the "real world." With regard to training design, programs at the governmental level or the national level, and the organizational level are absent. For example, at the governmental level, researchers stated the needs for funding support on educational systems, and for future researchers, how to design and construct an updated educational system for future warehouse workers may be a research direction. At the organizational level, learning organization may provide a framework on how to update knowledge and store knowledge at the system level, and yet, no research has focused on a learning warehouse construction. These are some focused future directions, and our expectation is that future research will concentrate on those research gaps and impact the scholarship.

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