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Understanding and measuring skill gaps in Industry 4.0 — A review

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ABSTRACT

This study utilized a systematic-narrative hybrid strategy to overview the concept of skill gap and its measuring approaches. Using the PRISMA guidelines, we conducted a systematic search in January 2023 to retrieve English records from the ProQuest, ScienceDirect, Scopus, and Web of Science databases using the keywords "skill gap," "skill mismatch," "skill shortage," "identifying or measuring," and "Industry 4.0." In total, 40 articles met our predefined inclusion criteria, and we analyzed them descriptively and qualitatively using thematic analysis and constant comparisons. We found that skill gaps certainly exist, and that concerns about growing skill gaps have been raised worldwide. Our literature review also revealed the need for a common understanding of skill gaps. Considering this, we provided a skill gap definition. Skill gaps are an extremely nuanced phenomenon, so paying careful attention to their definition and interrelating social, environmental, and technological factors when measuring them is essential. Since we found very few studies that employed different methods and perspectives to research the concept, more research is needed to map actual skill gaps, which can only be done by considering different perspectives and measuring approaches.

1. Introduction

Today, industry relies heavily on interconnectivity, automation, artificial intelligence, machine learning, and real-time data. Underpinned by digital transformation, this industrial revolution is also known as Industry 4.0 (Ghobakhloo, 2020)—an umbrella term first coined in 2011 in Germany for production processes that are automated via technology and in which devices communicate with each other along the value chain activities (Karacay, 2018; Sung, 2018). next significant change emerging in the industrial sector is Industry 5.0, which focuses on the synergy between people and autonomous machines (Nahavandi, 2019). Despite the hype surrounding Industry 5.0, skill gaps pose a significant challenge for Industry 4.0 and, evidently, for Industry 5.0. Industries are confronted with the lack of right-skilled workers, which contributes to a slowdown in adopting key technologies and reaching key goals (Bokrantz et al., 2020; Di Battista et al., 2023; Stavropoulos et al., 2023). This mismatch between the skills required by employers and those possessed by employees is often called a skill gap or skills gap (Braun et al., 2022; Enders et al., 2019; McGuinness et al., 2018; Quintini, 2011). There are several causes for skill gaps. In a world gripped by severe environmental, economic, and social challenges and changes (Adepoju, 2022; European Center for the Development of Vocational Training, 2016; Felsberger et al., 2022; López Peláez et al., 2021; Organisation for Economic Co-operation and Development (OECD), 2017), workers in the industry sector are especially facing higher skill demands (Guo et al., 2022). Due to constant changes, industry sectors must make disruptive changes to their operating environments and workflows. These changes modify employees' tasks, which demand new skills at all value chain stages of Industry 4.0 (Di Battista et al., 2023; Moldovan, 2019). Hence, owing to the increased complexity of work environments and new operational structures, successfully implementing Industry 4.0 demands a wide range of skills (Karacay, 2018). Concerns about growing skill gaps have thus been raised worldwide (European Centre for the Development of Vocational Training, 2018; Korn Ferry, 2018; OECD, 2017; Quintini, 2011). Consequently, individuals must be prepared to continuously update their skills to meet evolving skill requirements (Clark, 2013).

Changes in working life, such as digital transformation, particularly in Industry 4.0, demand specific skills that are not necessarily taught by educational institutes or developed in the labor market. Fostering a work environment in which employees can continuously develop their potential is thus vital (Wallin et al., 2020). Moreover, workforce training/re-training should be considered a continuous process rather than an on-off activity (Felsberger et al., 2022). Regarding skill gaps, it has been

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argued that radically reforming education and training systems is neither needed nor required and is likely to be both costly and largely ineffective (Rathelot and van Rens, 2017). Instead, skill gaps can be utilized to assess the skills that are lacking and, depending on the organization and the employee, to set different goals and resources for upskilling/reskilling (Braun et al., 2022). Optimal training decisions require accurate information about training needs and, thus, skills and skill gaps (McGuinness and Ortiz, 2016). Hence, industries must understand the scope of the changes, the content of work requirements, and the skills needed from the workforce (Karacay, 2018).

Although the need to address skill gaps is evident and more topical than ever, an in-depth understanding of the concept is necessary. The concept has often been studied regionally or by sector, highlighting the skills employers seek (e.g., Chowdhury, 2020; Jayaram and Engmann, 2017). The relationship between the education system's performance and the labor market's demands has also been examined (e.g., Baqadir et al., 2011; Dimian, 2014). Furthermore, skill gaps have been considered as either resource-based—i.e., skilled employees as efficient resources—or more market-oriented and competence-based—i.e., skills linked to achieving business objectives (Schwalje, 2012). Thus, various stakeholders have different interests, which leads to disagreements about the exact skills that are needed and how skills issues should be addressed (OECD, 2016). Researchers, in turn, have struggled with the nuances of skill gaps, skill mismatches, and skill shortages, since they are broadly and commonly referred to in policy debates and documentation (McGuinness et al., 2018). Hence, the main challenge of identifying skill gaps is the blurred line between work–life needs, political recommendations, and empirical research results.

Since skill gaps can be defined in various ways, it makes it difficult to measure them (Schwalje, 2012). For instance, skills can refer to general cognitive and noncognitive abilities or the skill characteristic of a particular job, profession, or sector (OECD, 2017). These can thus be technical, cognitive, or soft skills. Previous studies on future skills have, for instance, identified 18 future skills (Enders et al., 2019). Gaps, in turn, have been described and captured in three commonly used terms: skill gaps, mismatches, and shortages. Skill gaps occur when employees do not have adequate skills to perform their tasks (McGuinness et al., 2018). They are also closely related to skill shortage—the mismatch between the demand for and supply of specific skills—which is often used to describe the lack of available and suitably skilled candidates for vacant job positions (McGuinness et al., 2018; Quintini, 2011). Skills mismatch, in turn, reflects the imbalance between an employee's skill level and the skill level demanded by the work (Brunello and Wruuck, 2021; OECD, 2017). Evidently, no clear definition of skill gaps exists. Essentially, skill gaps can be represented by the mathematical formula A–B = C, where A represents the skills needed for future tasks; B the skills needed for current tasks; and C the skill gap—the skills that should either be hired or developed and trained (Habash, 2019, p. 396).

Consequently, skill differences, and thus gaps, are typically measured by comparing the qualifications of employed workers with the required capabilities and, more broadly, the structure of vacancies with the qualifications or training of the working-age population (Brunello and Wruuck, 2021). However, qualifications alone may not effectively reflect the skills demanded by the labor market (Morris et al., 2020); and most significantly, they exclude the skills acquired through informal education and experience. This approach of prioritizing skills over qualifications is called skills-first approach (Di Battista et al., 2023). Moreover, surveys, focus groups, forecasting models, competency assessments, education levels, and labor market analytics are used to demonstrate the existence of skill gaps (e.g., Collins, 2021; International Labor Organization (ILO) et al., 2017). However, can, for example, a Likert scale or self-assessment objectively detect skill gaps? Many workers do not know their own skill levels or which skills are relevant, which makes it harder for them to find proper channels for upskilling/reskilling (Enders et al., 2019). Thus, there are some factors that weaken the reliability of measurement in surveys, such as subjectivity and peer positivity bias (Kimmell and Martin, 2015; Schwalje, 2012). On the other hand, skills themselves are very multidimensional, but their measurement focuses only on specific selected dimensions, mainly due to data limitations (Brunello and Wruuck, 2021). One can try to measure skills using standardized tests. However, it cannot be guaranteed that employees will be able to apply these skills outside standardized testing (McGunagle and Zizka, 2020). Furthermore, when utilizing only skill databases, the key variables are binary and may not offer detailed information on the quality of skills or upskilling/reskilling goals (Pedota et al., 2023). An ideal dataset would, therefore, explicate a wide range of factors and details about the skill requirements of a job and the skill set of an ideal worker (Rathelot and van Rens, 2017). Moreover, skill gap measurement should target identifiable skills (Clark, 2013). The Program for the International Assessment of Adult Competencies (PIAAC) has taken a step toward measuring and evaluating the proficiency of adults and how they use their skills (OECD, 2021). However, PIAAC does not directly focus on working life, because it measures proficiency in key information-processing skills and examines how adults use various skills at work, at home, and in the wider community (Hämäläinen et al., 2019). A more holistic approach to identify skill gaps in working life must be thus adopted.

Although adopting a holistic approach to measure skills gap is considered good practice, quantitative, qualitative, and other data sources such as forecasting models, competency assessments, education levels, and labor market analytics are rarely combined (OECD, 2016). To date, the literature has provided mainly descriptive evidence of the impact of skill gaps on company performance (McGuinness and Ortiz, 2016), but concepts related to skill gaps remain ambiguous and difficult to define and measure (Collins, 2021; Schwalje, 2012). The lack of a standard definition, the diversity of data collection methodologies (Centeno et al., 2022), and competing interests of employers, politicians and researchers (OECD, 2016) indicate the limitations of past research, particularly concerning validity and measurement issues. The lack of clear and objective results, in turn, may lead to false arguments based on biased interest or little or no evidence of actual skill gaps (Cappelli, 2015), resulting in misdirected training resources.

In our opinion, no studies have provided incontrovertible evidence of skill gaps and how to tackle them, as there is no consensus on what constitutes a skill gap. There thus exists a research gap on the skill gap concept and the related measurement approaches. For digital transformation to sustainably benefit employees and companies, it is essential to understand the skill gap phenomenon and its consequences. Only those employees with the necessary skills, knowledge, and qualifications will be able to adapt to the digital transition, production system changes, and new working methods (Akyazi et al., 2020a). Deeply understanding the skill gap phenomenon could thus help organizations effectively handle digital transformation by recruiting and retaining talent and providing them with necessary training. After reviewing the different definitions, measurements, and analytical approaches used in earlier policy and research papers, we were primarily interested in gaining a more comprehensive understanding of the skill gap phenomenon and the suitable approaches for identifying and measuring skill gaps in the digital era, especially for Industry 4.0, but also more generally for the globalizing, digitalizing, and changing world. We thus utilized a systematic-narrative hybrid approach (e.g., Turnbull et al., 2023) to review the skill gap studies between 2012 and 2022, aiming to shed light on the skill gap concept and the approaches taken to understand and measure it. The following questions anchored our review:

a) How has the skill gap concept been understood in the context of today's globalized, digitalized, and changing world?
b) What approaches can be used to measure skill gaps?

Based on the literature review, we propose a definition for skill gaps and offer recommendations for future research and practices to understand the importance of different stakeholders' roles in bridging skill

gaps.

2. Materials and methods

We conducted a literature review of the full-text articles published between 2012 and 2022. A literature review can shed light on the skill gap concept and the related understanding and measurement approaches. Future research and practice on the skill gaps in Industry 4.0 and in other contexts can benefit from a comprehensive conceptualization and synthesis of the existing skill gap literature. Moreover, a literature review can critically evaluate data and offer positive and valuable results (Knopf, 2006).

We adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines for systematic reviews. These guidelines help authors report transparently why the literature review was done, what was done, and what was found (Page et al., 2021). Furthermore, we adopted a hybrid approach: our literature review drew on the characteristics of both the narrative and systematic review traditions (Turnbull et al., 2023). The search protocols and inclusion/exclusion criteria were drawn from the elements of the PRISMA practice. However, we applied a more narrative approach to analyze and synthesize data (see Section 2.5), since we included qualitative, quantitative, and mixed-methods studies in our review. The systematic review approach requires the application of data analysis processes such as the meta-analysis of quantitative data (Magarey, 2001). Conducting a systematic-narrative hybrid literature review thus enabled us to employ qualitative and quantitative elements. Moreover, using thematic analysis (Braun and Clarke, 2006) and conducting constant comparisons (Whittemore and Knafl, 2005), we descriptively (Loeb et al., 2017) and qualitatively analyzed the data.

Generally, the procedure followed three phases—planning, doing, and writing—and included formulating the research questions, choosing and justifying the methodology, selecting the literature sources, planning the search parameters, cleaning and synthesizing the data, and writing (Turnbull et al., 2023). All the authors contributed to the study's conception and design. The first two authors planned the inclusion/exclusion criteria and search strategy. The first author conducted database searches and removed duplicates. The first three authors performed the selection process, including critical appraisals, data collection, and analysis. The first three authors wrote the first draft of the manuscript. All the authors read, reviewed, commented on, edited, and approved the manuscript. The literature review procedure is described in more detail in the following subsections following PRISMA guidelines.

2.1. Eligibility criteria

Table 1 presents the inclusion/exclusion criteria. The timeframe for the articles (2012–2022) was based on the concept of Industry 4.0—a term first coined in 2011 to refer to a phenomenon that began in Germany (Sung, 2018). The non-reputable journals were identified based on Elsevier's CiteScore rating, the impact factor, and/or the journal citation indicator calculated by Clarivate and the Finnish scientific community's Publication Forum (https://jfp.csc.fi/en/). We did not limit the studies to specific methodological approaches, as diverse sources of information can offer a holistic understanding of a topic (Whittemore and Knafl, 2005). However, we limited our review to relevant peer-reviewed, English-language, full-text articles published between 2012 and 2022. We are from two European universities, and the availability of academic journals, made possible by the university subscriptions of academic publication channels—book and journal publishers, conferences, and print and digital publication series specialized in publishing results of scientific research—is typically quite comprehensive with some exceptions. These channels have an editorial board of experts and follow a peer-review practice. We thus excluded full-text articles that were unavailable through the university subscriptions or other free channels and databases, such as Google Scholar, which also offer access to the content of academic publishing channels.

2.2. Information sources and search strategy

We conducted the systematic search in January 2023, applying the search strings shown in Table 2 to the ProQuest, ScienceDirect, Scopus, and Web of Science databases. These four databases, commonly used to conduct literature reviews (see Behl et al., 2022), were selected by the authors in the planning phase to achieve sufficient coverage. The search included three sets of keywords: 1) skill gap, skill mismatch, and skill shortage; 2) identifying or measuring: measure, scale, assessment, questionnaire, instrument, tool, evaluation, or analysis; and 3) context: Industry 4.0.

2.3. Selection process

After searching the four databases, we imported the search results, including titles and abstracts, to the Zotero reference management software. The primary search yielded 53 studies: ProQuest Central (n = 6), Scopus (n = 18), Web of Science (n = 31), and ScienceDirect (n = 5). Fig. 1 presents a PRISMA flow diagram of the study selection process. The duplicates (n = 2) and the full texts that were unavailable through the university subscriptions or other channels, such as Google Scholar (n = 5), were removed. Skimming the abstracts of these five articles, we found that their themes were beyond the focus of our review (aircraft incidents and skill mismatch issues, institutional changes, employability, and the effectiveness of teaching or programs). However, because we could not access the full text of these articles and thus could not determine whether their focus was ultimately relevant, we acknowledge that we might have excluded some relevant studies.

The first three authors screened the titles and abstracts independently using the abovementioned criteria (see Table 1). The authors read the title and abstract of each article and decided on inclusion using a "no," a "maybe," or a "yes." "No" meant that a source did not meet the inclusion criteria and that it should not be included in the systematic review; "maybe" signaled that there is not much information to be gleaned from the title and abstract and that the full-text is worth screening; and "yes" meant that the source met the inclusion criteria and should be moved to the full-text screening stage. After screening the titles and abstracts, 41 studies remained.

That an article was published in a non-reputable journal—journals published in channels other than academic publication channels and,

Table 1
Inclusion/exclusion criteria.

Inclusion	Exclusion
Peer-reviewed articles with their full texts written in English and published between 2012 and 2022. Studies that covered skill gaps, skills shortages, skill mismatches, skills gaps, or Industry 4.0-related training, skill upgrading, or development and Industry 4.0, or digitalization- and globalization-driven changes in skills in the labor market or labor force. Studies that focused on identifying, understanding, measuring, or tackling skill gaps.	Studies covering irrelevant topics and foci. Dissertations, theses, conference abstracts, books, editorial letters, policy reports, and book reviews. Non-English articles. Articles published in non-reputable journals. Duplicate results. Articles whose full texts are unavailable through the available subscriptions or free channels.

Table 2
Search strategy.

Data sources	Keywords
ProQuest Central	Title ("skill* gap*" OR "skill* mismatch*" OR "skill* shortage*") AND (measure OR scale OR assessment OR questionnaire OR instrument OR tool OR evaluation OR analysis) AND "Industry 4.0" AND PEER (yes). Date: from January 2012 to December 2022; full text
Scopus	TITLE-ABS-KEY ("skill* gap*" OR "skill* mismatch*" OR "skill* shortage*" AND measure OR scale OR assessment OR questionnaire OR instrument OR tool OR evaluation OR analysis AND "industry 4.0") PUBYEAR >2012 AND (LIMIT-TO (DOCTYPE, "ar"))
Web of Science	Results for "skill* gap*" OR "skill* mismatch*" OR "skill* shortage*" (Title) AND measure OR scale OR assessment OR questionnaire OR instrument OR tool OR evaluation OR analysis (all fields) AND "Industry" (all fields) Timespan: 2012-01-01 to 2022-12-31 (publication date)
ScienceDirect	Title, abstract, or author-specified keywords ("skills gaps" OR "skills mismatches" OR "skills shortages") AND (measure OR scale OR assessment OR evaluation OR analysis) AND ("Industry 4.0") Year(s) 2012–2022

thus, do not follow the peer-review practice and or do not have an editorial board—was the most frequent reason for exclusion during the title and abstract screening phase. The exclusion was based on ratings and indicators (i.e., the CiteScore metric, impact factor, journal citation indicator, and Publication Forum rating). After the ratings and metrics were considered, the final decision was made according to the Publication Forum classification (level 1, 2, or 3). The Publication Forum, a rating and classification system based on the quality assessment of research outputs, aims to recognize non-reputable journals by defining their classifications. Only academic publication channels are eligible for classification. A panel of 23 discipline-specific experts and 300 distinguished researchers evaluate publication channels using several impact indicators and by indexing data (Publication Forum, 2021). The Publication Forum's procedure for ensuring scientific quality is thus trustworthy.

We then assessed the remaining 41 studies for which full texts were available to determine their eligibility. The full texts of all the eligible articles (i.e., "yes" and "maybe") were retrieved, and the first three authors independently performed full-text assessments to decide whether the articles should be included or excluded. Any disagreement regarding eligibility based on the title, abstract, and full-text screening was resolved by consensus. Any discrepancies were resolved according to the authors' notes or discussions. There were no significant conflicts of opinion, and the authors' estimates were quite similar. Sixteen research papers raised concerns, but only four contradicted each other. The first author made the final decision by carefully reviewing the authors' notes and the article titles, abstracts, and/or full texts against the inclusion and exclusion criteria. Of these 41 papers, one was not eligible

Fig. 1. Flow diagram showing the PRISMA review process.
(Adapted from Page et al. (2021).)

for inclusion. Finally, 40 full-text articles were included in the synthesis (listed in Table 4). The electronic database from which the articles were extracted (ProQuest = P, ScienceDirect = SD, Scopus = S, and Web of Science = W) and the coding number (issued by alphabetical order) of the articles are provided and used to identify specific papers in the result tables (Tables 4, 5, and 6).

2.4. Risk of bias assessment

The first three authors performed critical appraisals using a modified version of the Critical Appraisal Skills Program (CASP, 2022) systematic review, qualitative research, and cohort study checklists. The assessment scale was "yes," "no," or "cannot say." The questions were as follows: Was the purpose of the study clear? Was the methodology/design described and suitable for the study? Can the target group of the study be identified? Are the analysis and findings sufficiently described? Are the results of the study clear and plausible? These CASP assessment scales were chosen because the included studies were diverse.

The quality assessment turned out to be slightly challenging, as we did not filter or limit the methodological approach of the studies or exclude conference papers. For example, compared to conference papers, journal papers often contain more essential information, as they do not have page limits, whereas content-centered literature reviews could describe researchers' choices such as selection criteria more accurately. The included articles were of good or fair quality, probably because the articles published in non-reputable journals were excluded during the screening phase. The quality of one article was poor, but we decided to include it because of its highly relevant content: the article defined skill gaps and presented a competency model. The challenges regarding fair and poor articles were mostly due to the lack of coherence and clarity in the articles. The quality assessment results are detailed in the supplementary material (Appendix A, Table A.1).

2.5. Data collection, processing, and analysis

We collected data regarding the purpose of each study, how the skill gap concept was understood, how skill gaps were identified and/or measured, and other interesting observations and highlights (e.g., ways of tackling skill gaps) for further analysis. Although we collected diverse information, our review focused on the skill gap concept and approaches to measuring skill gaps. The additional extracted variables included the authors' names, year of publication, methodology, study region, and title of the paper, which we used to obtain an overview of the included studies.

We analyzed the data descriptively and qualitatively using thematic analysis, and we made constant comparisons to identify the themes and subthemes related to the research questions and summarize the particulars. We chose descriptive analysis because it helps answer questions concerning who, when, where, and to what extent (Loeb et al., 2017). We chose thematic analysis because it is a flexible and relatively quick way to highlight the similarities and differences in texts and summarize the most important features of a dataset (Braun and Clarke, 2006). In addition, we used a constant comparison approach to iteratively identify and compare important and accurate patterns and themes (Whittemore and Knafl, 2005). The constant comparative method, typically associated with grounded theory, can be extended to other qualitative research to produce higher levels of abstraction (Pawluch, 2005). Thus, our study applied a more narrative approach to analyze and synthesize data, which can be considered a systematic-narrative hybrid approach (see Turnbull et al., 2023). Thematic analysis emphasizes identifying, organizing, and interpreting the themes discovered from the extracted data (Braun and Clarke, 2006). Creativity and criticality, in turn, are key elements in constant comparisons for visualizing and comparing data and clarify the empirical and/or theoretical support that emerges from interpretations (Whittemore and Knafl, 2005). We combined these two approaches, beginning with thematic analysis and then conducting constant comparisons to draw final interpretations and create visualizations.

The first three authors conducted the thematic analysis by following the steps of Braun and Clarke (2006): 1) becoming familiar with the data, 2) generating codes, 3) generating themes, 4) reviewing themes, 5) defining and naming themes, and 6) summarizing data (i.e., writing up). The third author coded and analyzed the skill gap concept and understanding, and the second author coded and analyzed the measurement approaches. The first author coded and analyzed both the definitions of skill gap and its measurement approaches. The generated themes were then compared and organized, and the final themes were decided through consultation. This iterative consensus process ensured interrater consistency and reliability (Hemmler et al., 2022). Table 3 shows how authors applied specific codes and themes to one paper and how they combined themes through consensus to determine the final themes. Disagreements concerning the generated themes or subthemes were discussed to reach a consensus.

We interpreted the generated themes through constant comparisons, iteratively examining the patterns we began to discern. We considered the similarities and differences among the themes, made comparisons, and started to identify common patterns with the aim of organizing particulars into a general concept. We considered the different factors and relationships between the various factors and tried to build logical links between them. Finally, we created data visualizations with different programs (see Figs. 2, 3, and 4).

3. Results

This section presents insights into the literature on the skill gap. We begin with an overview of the basic descriptive statistics typical of systematic reviews, followed by subsections where we answer our research questions more narratively.

3.1. Overview of the included studies

The selected literature (Table 4) revealed that concerns about skill gaps have increased across the world, especially in the past few years, as reflected in the research conducted. Most of the articles were published in 2020 (n = 8), 2021 (n = 10), and 2022 (n = 10). Most of the studies were from Europe (n = 15), followed by North America (n = 6), West Africa (n = 4), Southeast Asia (n = 4), and Oceania (n = 3). Regarding industry sectors, most research focused on manufacturing (n = 6), followed by information technology (IT; n = 4), Industry 4.0 (n = 3), finance (n = 3), construction (n = 3), and e-business (n = 3). However, gaps in the labor market have also been examined more generally. Overall, the studies examined skill gaps from the perspectives of working life and education, current and future knowledge and skill demands, requirements, profiles, and statuses, with the aim of identifying strategies, tools, models, and databases to narrow skill gaps. Moreover, different methods, such as reviews (n = 3), case studies (n = 2), pilot studies (n = 2), mixed-methods studies (n = 6), and qualitative approaches (n = 6), were used. However, the methods were largely quantitative, such as surveys (n = 14).

3.2. Skill gap

The first research question was: How has the skill gap concept been understood in the context of today's globalized, digitalized, and changing world?

Skill gap, the studies showed, is a very nuanced phenomenon that lacks a clear definition. Generally, it can be understood as the difficulty of providing the right skills to the right people at the right time (Anshari and Hamdan, 2022) to enhance employee productivity and innovation, improve and advance organizational performance, create value (Horbach and Rammer, 2022; Ayodele et al., 2021), support digital transformation (Akyazi et al., 2020a; Li et al., 2021), and narrow reduce gaps

Table 3
An example of a coding application, how the skill gap was understood, and the themes derived from the coding application.

[P2]	Coder 1 codes	Coder 2 codes	Coder 1 themes	Coder 2 themes	Finalized themes
	Lack of talent	Lack of talent	Skill mismatch between employers and graduates/ higher education	Gaps between the employees' competencies and those demanded by employers	Gaps between the employees' competencies and those demanded by employers/ industry
	Skilled workforce shortage	Skilled workforce shortage	Mismatches/skill gaps between employer/ industry demands and employee skills	Labor market challenge	Skill gaps as a labor market challenge/gap (e.g., workforce shortages, unfilled jobs, lack of talent)
	No ability to work in the digital future	Employees do not have the right skills (i.e., to work in the digital future)	Skilled workforce shortage/lack of talent		
	Mismatch between unfilled jobs and candidates, and employers' challenges in identifying qualified employees with the right skills	Unfilled jobs			
	Undergraduates' lack of important skills	The gap between knowledge, skills, and abilities and what is crucial for companies			

Fig. 2. Skill gap with a complex combination of causes and consequences.

and shortages in the constantly changing business environment and labor market (Sharma et al., 2016; Li et al., 2021). Skill discrepancies make it increasingly difficult to align skilled people and processes with an organization's goals (Arthur-Mensah, 2020; Francalanza et al., 2021). Though employees and employers play a major role in these rapidly changing business realities (Abbasi et al., 2018; Ayodele et al., 2020; Arthur-Mensah, 2020; Ho, 2016), training providers are equally important as well (Adepoju and Aigbavboa, 2021; Akyazi et al., 2020b), as they can instill the necessary skills (see Fig. 2). The figure below illustrates our main findings, including our proposed skill gap definition.

Hence, a skill gap can be understood as a gap between the demand for and supply of skills (all the articles shared this view at some level; see Table 5). In other words, there is a gap, lack, shortage, or mismatch between the knowledge, skills, and abilities employees possess and those that employers expect, require, and demand. It is a gulf between the current and future industry requirements and the ability of the workforce to satisfactorily meet the industry needs (Arcelay et al., 2021). Employers' expectations, opinions, and ways of thinking can deepen a company's skill gap (e.g., through discrimination, preferences for who is hired, or unrealistic expectations; Abbasi et al., 2018; Ayodele et al., 2020; Cohen and Eyal, 2021; Cukier, 2019; Mori, 2021). However, a skill gap can also widen because of employee factors (e.g., lack of

Fig. 3. Approaches to measuring skill gaps clustered by data sources and methods.

Fig. 4. The steps of the most-often-used approach for measuring skill gaps.

interest, resistance to change, occupational preferences, personal preferences, and familial, professional, and identity considerations; Arthur-Mensah, 2020; Ho, 2016). Moreover, it should be noted that rapidly changing businesses and working environments and skill requirements lead to formerly useful skills becoming outdated or the quality of skills gradually deteriorating (Anshari and Hamdan, 2022; Cohen and Eyal, 2021; Novakova, 2020; Viganego et al., 2022). Employees are expected to evolve; hence, the challenge is not only to attract and retain talented people with the required skills but also to develop the skills of the existing workforce (Butt, 2020; Adepoju and Aigbavboa, 2021). Without skill development, there exists the risk of a skill obsolescence gap emerging; therefore, one could argue that a skill gap results from an education/training gap (Adepoju and Aigbavboa, 2021; Novakova, 2020; Viganego et al., 2022)—a misalignment between the skills needed by the industry and those developed by the education/training providers (Akdur, 2021). In other words, education and training providers struggle to adapt to the changing industry demands and business realities. The reviewed studies highlighted the need to address/tackle such skill gaps by developing curricula, education, and training that can better prepare the workforce for the future (Akyazi et al., 2020b; Oladokun and Olaleye, 2018). Thus, a skill gap is a gap between education and training outcomes and industry-specific skill needs and/or a gap between the skills employees possess and those the industry identifies as important (Carlisle et al., 2021).

There are various reasons for skills becoming obsolete and for a demand for new skills emerging. A skill gap can also thus be seen as a combination of complex causes and consequences (see Table 5). Megatrends such as digitalization, globalization, green transformation, and demographic changes, as well as constantly changing operating environments—in terms of economic, financial, sociopolitical, physical, and time factors—may cause an imbalance between skill supply and demand (Arthur-Mensah, 2020; Carlisle et al., 2021; Chang-Richards et al., 2017;

Table 4
Publications selected for the systematic literature review.

Paper code	Author(s)	Year	Study region	Industry/sector	Methodology	Research perspective
W1	Abbasi et al.	2018	Pakistan	Financial services	Quantitative	The gap between the demand for and supply of skills
W2	Adepoju and Aigbavboa	2021	Nigeria	Construction	Quantitative	The gap between the demand for and supply of skills
W3	Akdur	2021	Turkey	IT sector	Quantitative	The potential education/training gap
S1	Akyazi, Goti, Oyarbide et al.	2020	Europe	Food	Desk research	The gap between the demand for and supply of skills
S2	Akyazi, Goti, Oyarbide-Zubillaga, et al.	2020	Europe	Manufacturing	Desk research	The current and future skill needs
S3	Albizu et al.	2022	Basque Country	Business	Mixed methods	Mismatch approaches
S4	Anshari and Hamdan	2022	–	Industry 4.0	Qualitative	The current and future skill needs
S5	Arcelay et al.	2021	Europe/Spain	Energy	Desk research	The current and future skill needs
W4	Arthur-Mensah	2020	US	Manufacturing	Qualitative	An education/training approach
W5	Ayodele et al.	2021	Nigeria	Real estate	Quantitative	The gap between the demand for and supply of skills.
W6	Ayodele et al.	2020	Nigeria	Real estate	Quantitative	The gap between the demand for and supply of skills
SD1	Babic et al.	2022	US	Manufacturing	Content analysis	The potential education/training gap
S6	Butt	2020	–	Manufacturing	Literature review	A process management approach
W7	Carlisle et al.	2021	United Kingdom (UK)	Tourism	Quantitative	The gap between the demand for and supply of skills
W8	Chang-Richards et al.	2017	New Zealand	Construction	Quantitative	A human resources management approach
W9	Cohen and Eyal	2021	Israel	Life sciences	Qualitative	Mismatch approaches
P1	Cukier	2019	Canada	Labor markets in general	Literature review	The current and future skill needs
W10	Do et al.	2023 (online 2022)	Taiwan	Robotics	Mixed methods	The gap between the demand for and supply of skills
S7	Francalanza et al.	2021	Europe	Industry 4.0	Mixed methods	The gap between the demand for and supply of skills
W11	Ho	2016	Hong Kong	Construction	Mixed methods	Labor and skill shortages
W12	Horbach and Rammer	2022	Germany	Labor markets in general	Quantitative	Skill shortages
S8	Husin et al.	2022	Malaysia	IT-sector	Mixed methods	The current and future skill needs
SD2	Li et al.	2021	US	Manufacturing	Desk research	The current and future skill needs
SD3	Maheso et al.	2019	South Africa	Manufacturing	Concept design	An education/training approach
SD4	Moldovan	2019	Europe	Industry 4.0	Quantitative	The gap between the demand for and supply of skills
W13	Moore and Morton	2017	Australia	Labor markets in general	Qualitative	The gap between the demand for and supply of skills
W14	Mori	2021	Vietnam	Manufacturing	Mixed methods	The employers' perceptions
W15	Morris et al.	2020	UK	Labor markets in general	Desk research	Skill shortages
SD5	Novakova	2020	Slovakia	Industry 4.0	Literature review	The potential threats of automation
W16	Oladokun and Olaleye	2018	Nigeria	Real estate	Quantitative	The employers' perceptions
W17	Oldford et al.	2022	Canada	Financial services	Content analysis and Case study	The potential education/training gap
P2	Qiu et al.	2020	US	E-business	Case study	The gap between the demand for and supply of skills
S9	Romero-Gázquez et al.	2022	Europe	Industry 4.0	Quantitative	The gap between the demand for and supply of skills
S10	Romero Gázquez et al.	2021	Europe	Industry 4.0	Pilot case study	The status of Industry 4.0 adoption
W18	Royle and Laing	2014	UK	E-business	Qualitative	The gap between the demand for and supply of skills
W19	Sharma et al.	2016	Australia	Agriculture, forestry, and fisheries	Quantitative	Skill shortages
W20	Singh Dubey et al.	2022	India	IT-sector	Quantitative	The gap between the demand for and supply of skills
W21	van Romburgh and van der Merwe	2015	South Africa	Financial services	Pilot case study	The gap between the demand for and supply of skills
P3	Viganego et al.	2022	Spain	Labor markets in general	Qualitative	The gap between the demand for and supply of skills
W22	Zheng and Shi	2021	China	E-business	Quantitative	An education/training approach

Horbach and Rammer, 2022; Moore and Morton, 2017; Novakova, 2020). These different skill problems, in turn, are reflected in business realities. Skill gaps may hinder the development of a company, sector, industry, and, more broadly, a country, thus generating business gaps. For instance, in some countries, manufacturing sectors rely mainly on low-skilled foreign workers, preventing them from investing in automation and technology upgrades (Husin et al., 2022), meaning that industries and sectors struggle to support their new business models. Because of skill gaps, industries struggle to ensure the value creation necessary to remain competitive and productive and to take advantage of new technologies and practices in their rapidly evolving operations (Akyazi et al., 2020a; Francalanza et al., 2021; Maheso et al., 2019). For example, green skills are vital for maintaining a competitive edge (Akyazi et al., 2020b). Hence, a suitable set of such skills may ensure clients' satisfaction, optimize returns, increase firms' competitiveness, and maintain employees' professional relevance (Ayodele et al., 2020).

Furthermore, skill gaps and outdated skills can make it challenging to find and recruit adequately trained workers to fill vacancies and properly conduct work—in other words, skill gaps cause labor market challenges and skill shortages (Chang-Richards et al., 2017; Horbach

Table 5
The various concepts, complex causes, and consequences of skill gaps.

Paper code	Central concept(s) in article	Brief description of the concept(s)	Causes of skill gaps	Consequences of skill gap
P1	Skill gap and skills mismatch (skill shortage)	The gap/mismatch between the competencies employees possess and those demanded by employers	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation, demographic change, and global outsourcing), political economy, education/training gap, employer expectations/opinions, time-space gap (future is difficult to forecast), and obsolescence of existing skills (re-training is needed)	Business gap (economic success) and labor market challenges
P2	Skill gap (skilled workforce shortage/ lack)	The gap between companies' expectations and graduates' knowledge, skills, and abilities	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, lack of university–industry collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (business success) and labor market challenges (unfilled jobs)
P3	Skill gap	The gap between young workers' skills and those that companies consider critical for success	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, obsolescence of existing skills (people are expected to evolve)	Business gap
SD1	Skill shortage	Shortage of skilled workforce	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (how to ensure future curriculum), and obsolescence of existing skills (people are expected to evolve)	Business gap (digital technology adoption and business processes) and labor market challenges (shortage of a skilled workforce)
SD2	Skill gap	Mismatch between employers' needs and workforce's skills.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and aging workforce), management gap (outdated workforce planning), education/training gap (lack of training effectiveness), time-space gap (future trends), worker preferences (poor perception of the industry), and obsolescence of existing skills (people are expected to evolve; re-training is needed)	Business gap (digital transformation challenges) and labor market challenges
SD3	Skills shortage	Skills shortage	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, and time-space gap (how to learn future methods)	Labor market challenges (skill-related challenges) and business gap (digital technologies adoption and business processes)
SD4	Skill gap	Skills and knowledge gaps	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (how to nurture the necessary skills in future employees), management gap (organization culture), and obsolescence of existing skills (re-training is needed)	Business gap (digital technology adoption, business processes, and value creation)
SD5	Skill gap	Multidimensional gaps in labor markets and businesses	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (all job positions will look different in the future), political choices, and obsolescence of existing skills (people are expected to evolve, re-training is needed)	Labor market challenges and business gap (digital technologies adoption)
S1	Skill gap and skills mismatch (skills shortage)	The gap between what the industry expects and what the workforce delivers. Mismatch between job profiles and labor force.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, management gap, time-space gap (how to predict foreseen skills requirements), lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (production processes, business models, value creation, and technology adoption)
S2	Skill gap and skills mismatch (skills shortage)	The gap between what is expected by the industry and what is delivered by the workforce. Mismatch between job profiles and labor force.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and green transition), education/training gap, management gap, time-space gap (how to predict foreseen skills requirements), lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (technology adoption, business processes, and competitive edge)
S3	Skills mismatch and skill gap	Levels of education or skill are either higher or lower than required, or education disciplines are unrelated to jobs. Employers believe that	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), employer	Business gap (productivity)

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Table 5 (*continued*)

Paper code	Central concept(s) in article	Brief description of the concept(s)	Causes of skill gaps	Consequences of skill gap
		employees do not have sufficient skills to successfully conduct their duties.	expectations/opinions, management gap, and obsolescence of existing skills (people are expected to evolve)	
S4	Skill gap	Definite shortage of certain skills/knowledge/ capabilities	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, management gap, lack of technology preparedness, global issues (crises such as pandemics), and obsolescence of existing skills (re-training is needed)	Business gap (competitiveness, innovativeness, relevance, and business processes)
S5	Skill gap and skills shortage	The gap between industry needs and employees' capabilities	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, management gap, worker preference gap (resistance to change), time-space gap (how to identify future skill requirements), and obsolescence of existing skills (re-training is needed)	Business gap (technology adoption, business processes, and relevance)
S6	Skill gap	The gap between the existing workforce skills and the required skills	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), management gap, time-space gap (how to anticipate future change), lack of strategic roadmaps, and obsolescence of existing skills (people are expected to evolve; re-training is needed)	Business gap (technology adoption, business processes, competitiveness, and value creation)
S7	Skill gap and skill mismatches	Skill and knowledge gaps	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (how to be ready for future demands), lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (technology adoption and business processes)
S8	Skills shortage (skill gap)	Specific skill shortages. The mismatch between employers' expectations and future graduates' skills.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (how to prepare next generation for jobs), management gap, employer expectations/opinions, worker preferences (resistance to change), lack of policies, changing needs of the sector, and obsolescence of existing skills (re-training is needed)	Business gap (business processes and economy)
S9	Skill gap	The gap between the skills acquired by workers and those required by the industry	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and globalization), education/training gap, time-space gap (how to prepare for future), management gap, worker preferences (lack of interest), lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (technology adoption, business processes, and competitiveness)
S10	Skill gap	The gap between the skills required by the industry and the skills of employees	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, time-space gap (how to prepare for future), management gap, lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (technology adoption and competitiveness)
W1	Skill gap	The gap between the skills expected by managers and the skills possessed by graduates	*Gaps between the competencies employees possess and those demanded by employers/industry*, education/training gap, employer expectations/ opinions, management gap, student expectations, and lack of stakeholder collaborations	Business gap (economy)
W2	Skill gap	The difference between the current skill level and the expected skill level. The difference between the needs of employers for skilled talent and the skills possessed by the existing labor force.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, management gap, political economy, time-space gap (how to predict future required skills), and obsolescence of existing skills (re-training is needed)	Labor market challenges and business gap (economy, technological adaptability, and business profitability)
W3	Skill gap	The gap between the necessary skills and gap between the expectations of industry and academia. The misalignment of the skills learned at university with the skills required at workplace.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/ training gap, management gap, lack of stakeholder collaborations, worker preferences	Labor market challenges (employability) and business gap (efficiency)

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Table 5 (*continued*)

Paper code	Central concept(s) in article	Brief description of the concept(s)	Causes of skill gaps	Consequences of skill gap
			(profiles), and obsolescence of existing skills (people are expected to evolve)	
W4	Skill gap (skills mismatch)	The gap between the skills required and the skills offered by schools to young people	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation, socio-economic workforce changes, and globalization), education/training gap, management gap, lack of stakeholder collaborations, worker preferences (lack of interest), time-space gap (how to develop relevant skills for future workforce), and obsolescence of existing skills (people are expected to evolve, re-training is needed)	Labor market challenges and business gap (organizational performance and competitiveness)
W5	Skill gap	The gap between the required skills and the observed skills	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and globalization), education/training gap, employer expectations/opinions, worker preferences (focus), political economy, and obsolescence of existing skills (people are expected to evolve)	Business gap (productivity, business processes, and organizational success)
W6	Skill gap (skills mismatch)	The gap between the skills possessed by graduate employees and the skills required by the industry	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation, globalization, and industrialization), education/training gap, employer expectations/opinions, and lack of stakeholder collaborations	Business gap (business processes, productivity, competitiveness, and value creation)
W7	Skill gap and skills shortage	The gap between education and training outcomes and industry-based skills needs as well as the gap between the skills employees possess and those that the industry considers important.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (sustainability), education/training gap, political economy, worker preferences, economic cyclic gap, management gap, time-space gap (how to guarantee future proficiency levels), and obsolescence of existing skills (re-training is needed)	Business gap (competitiveness)
W8	Skills shortage	Skill shortages due to the demand for skills	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation, green transition), education/training gap, management gap, worker preferences (lack of interest), economic cyclic gap, political economy, lack of technical capability, and time-space gap (forecasting of skills needs is difficult)	Labor market challenges and business gap (productivity and sector's success)
W9	Skills mismatch, skill gap, skill shortage, and skill obsolescence	The difference in the type or level of skills from what is required to properly perform a job	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (globalization), employer expectations/opinions, worker preferences (identities, biographies), lack of stakeholder collaborations, time-space gap (which skills are valuable in the future), difficulty of transferability of skills, and obsolescence of existing skills (re-training is needed)	Labor market challenges
W10	Skill gap and talent shortage	The gap between industry's expectations and graduates' skill sets. The difference in an employee's type or level of abilities from what is required to properly perform a job.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education training gap, employer expectations/opinions, worker preferences (attitudes), lack of stakeholder collaborations, and obsolescence of existing skills (re-training is needed)	Business gap (economy)
W11	Skills shortage, labor shortage, and skills mismatch	Employers struggle to find suitable workers to fill available vacancies due to the full capacity of employment. Insufficient number of employees with the qualifications, skills, or experience required to perform a particular job.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (aging workforce), education/training gap, worker preferences (interests and perceptions), employer expectations/opinions, management gap, lack of stakeholder collaborations, economic cyclic gap, lack of geographic-specific strategies, and obsolescence of existing skills (re-training is needed)	Labor market challenges
W12	Skills shortage and skill gap	Demand for workers in a certain profession is greater than the supply of qualified, available, and willing workers. The gap between the supply and demand of skills.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and demographic change), economic cyclic gap, political economy, education/training gap, regional labor market disparities, worker preferences (willingness to work), and obsolescence of existing skills (re-training is needed)	Labor market challenges Business gap (economy, innovation, and productivity)

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Table 5 (*continued*)

Paper code	Central concept(s) in article	Brief description of the concept(s)	Causes of skill gaps	Consequences of skill gap
W13	Skill gap and skills shortage	The gap between employer demands and job-ready graduates	*Gaps between the competencies employees possess and those demanded by employers/industry*, education/training gap, employer expectations/opinions, workplace geography, structure, and culture	Labor market challenges (employability)
W14	Skills mismatch, skills shortage, and skill gaps	Skill mismatch or skill deficit (i.e., demand for skills exceeds supply). Skill problems not only to the supply side but also to the demand side. Employees' levels of education or skills are either more or less than what is required.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education training gap, economic cyclic gap, employer expectations/opinions, political economy, lack of stakeholder collaborations, and sector demands	Business gap (economy and industrialization)
W15	Skill gap, skills shortage, and skill deficiencies	Skill deficiencies refer to skill-shortage vacancies. Skill gaps, in turn, represent skill issues, where current employees do not have the necessary skills to skillfully perform a job	*Gaps between the competencies employees possess and those demanded by employers/industry*, political economy, education/training gap, employer expectations/opinion gap, and place-specific needs	Labor market challenges and business gap (economy and productivity)
W16	Skill gap, labor shortage,	The gap between the skills possessed and the skills required by the industry	*Gaps between the competencies employees possess and those demanded by employers/industry*, political economy, education/training gap, lack of stakeholder collaborations, employer expectations/opinion gap, management gap, and obsolescence of existing skills (re-training is needed)	Labor market challenges and business gap (economy)
W17	Skill gap	The gap between industry's demand for and supply of skills	*Gaps between the competencies employees possess and those demanded by employers/industry*, education training gap, and employer expectations/opinions	Business gap (value creation)
W18	Skill gap, skills shortages, skills shortfalls	The gap between the skills needed for jobs and those that graduates possess. The perceived gap between industry and academia.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), political economy, education/training gap, management gap, and obsolescence of existing skills (re-training is needed)	Business gap (business processes and progress)
W19	Skills shortage	A state of imbalance in which the demand for a certain type of skill exceeds its supply	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and aging population), political economy, management gap, time-space gap (predicting needs is difficult), and obsolescence of existing skills (re-training is needed)	Labor market challenges and business gap (productivity and competitiveness)
W20	Skill gap (skills shortage)	The gap between students' perception and practitioners' expectations regarding desired skills. The difference between the desired and required levels of skills among new entrants.	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation and globalization), lack of stakeholder collaborations, management gap, worker preference gap (job-seeking behavior), employer preferences/opinions, emerging economy's needs, and time-space gap (how to supply of talent for the future pool)	Business gap (competitiveness) and labor market challenges (employability)
W21	Skills shortage and skill gap	The gap between what the employers expect and what the universities deliver. Skill shortages (students do not have enough skills to succeed in practice)	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (demographic change), education/training gap, lack of stakeholder collaborations, and employer preferences/opinions	Business gap (economy)
W22	Skill gap and shortage of talent	The gap between the expected level of skills in the workplace and the existing skill level of the employees	*Gaps between the competencies employees possess and those demanded by employers/industry*, megatrends (digital transformation), education/training gap, lack of stakeholder collaborations, employer expectations/opinions, worker preferences (expectations), management gap, and different needs of sectors	Business gap (competitiveness and business processes)

and Rammer, 2022; Sharma et al., 2016), and disequilibrium occurs when the demand for a certain type of skill exceeds its supply (Sharma et al., 2016). Therefore, skill gaps can be equated to labor market gaps/skill shortages (see Table 5). According to recent forecasts, millions of manufacturing and production positions will remain unfilled by 2028, resulting in long-term labor shortages in the manufacturing sector (Li et al., 2021).

In summary, a skill gap results from the discrepancies between the preferences, expectations, and supply of three actors: employees, employers, and education providers. More broadly, these preferences and expectations are influenced by various megatrends and operating environments, which constantly change business realities. To bridge skill gaps, effective workforce planning must consider a wide range of factors. According to the studies we included, the skill gaps phenomenon is extremely multifaceted and nuanced and has no clear definition (see Table 5). Creating a holistic view of skill gaps is thus challenging—however, it is necessary for a methodologically sound and transparent research. In light of this, we proposed the following definition: *skill gaps are gaps between training outcomes and industry-specific skill needs and, therefore, gaps between the skills that employees possess*

and those that industry players consider necessary. Consequently, a skill gap can be understood as a difficulty in providing the right skills to the right people at the right time to enhance employee productivity, improve and advance organizational performance, create value, support digital transformation, and narrow gaps in business realities and labor markets.

3.3. Approaches to measure skill gaps

The second research question was this: What approaches can be used to measure skill gaps?

As the reviewed literature revealed, many approaches can be utilized to measure skill gaps. Fig. 3 summarizes these approaches. The included studies applied different data collection methods and data sources, measuring skill gaps by collecting data from employers, employees, students, education providers, literature, databases of job profiles, and professional social networks. The methods the researchers used were surveys, interviews, focus groups, data analysis, and the creation of skill frameworks (see Table 6). However, studies that combined several approaches and different actors' assessments were scarce. Since the reviewed literature highlighted that the skill gap is an extremely multifaceted and nuanced phenomenon, we considered single approach/actor studies to have minor potential in highlighting the actual skill gap.

Most often, the approach taken by the examined studies was as follows: 1) Create a skill framework for the field in which the study was to be conducted; 2) use the framework to design one or two different surveys to a) ask employers about employees' performance regarding each skill, their importance for the company, and/or the need for specific skills, and/or b) ask employees about their alignment with the skill framework, and, finally, 3) analyze the collected data, identify skill development, recruitment, or education curriculum gaps, and formulate the needs. The studies that used this approach were considered to have minor or fair potential to highlight the actual skill gap depending on whether different perspectives were considered. The studies that employed this approach are briefly described below and visualized in Fig. 4.

For instance, literature reviews were conducted to create skill sets and then send the surveys to 1) employers, asking them about the importance of these skills and employees' performance relative to these skills (Abbasi et al., 2018; Ayodele et al., 2021); 2) employees, asking them to self-assess their performance regarding these skills (Adepoju and Aigbavboa, 2021; Ayodele et al., 2020; Zheng and Shi, 2021); or 3) students or student employees, asking them about the importance of these skills and employees' performance regarding these skills (Akdur, 2021; Singh et al., 2022). A skill set was utilized to also conduct a performance–importance analysis, asking employers about the skills (Do et al., 2023) or asking employers to rate the trainees' level of skills (van Romburgh and van der Merwe, 2015). Furthermore, using skill sets, employers were asked about employees' performance and their future needs regarding these skills (Carlisle et al., 2021). The Industry 4.0 concept, in turn, was used to ask employers about the performance of employees regarding the associated skills (Husin et al., 2022), and key enabling technology skills were utilized to ask teachers, students, and industry representatives about these skills (Romero-Gázquez et al., 2021a, 2021b). Moreover, a list of occupations was used to create a skill set to ask employers about employees' performance and conduct field visits, interviews, and focus groups/workshops to capture feedback on skill gaps (Chang-Richards et al., 2017). Some researchers only took the first step in the abovementioned approach and created skill frameworks based on literature reviews, interviews, or focus groups (Babic et al., 2022; Romero-Gázquez et al., 2021a; Royle and Laing, 2014; Viganego et al., 2022).

The researchers also performed data analysis. Several researchers used professional databases—such as the Economic Modeling Specialist International (EMSI), European Skills, Competences, Qualifications and Occupations (ESCO), and International Classification of Occupations (ISCO)—to create skill frameworks, create skill and job profiles, update job profiles in terms of skills, and analyze the education levels of people who held those jobs (Akdur, 2021; Akyazi et al., 2020a; Akyazi et al., 2020b; Husin et al., 2022). The UK region-industry skill data was employed to calculate the effects of skills shortages, followed by surveys and interviews (Morris et al., 2020). These approaches were considered to have minor or fair potential to highlight the actual skill gap depending on whether different perspectives were considered. Surveys were also conducted to ask employers about unfilled job vacancies and how many qualified candidates they had (Ho, 2016) or to understand different firms' perceptions and extent of skill shortages (Royle and Laing, 2014). Interviews, in turn, were conducted to understand employers' impressions of graduates' work readiness and the demand for and supply of skills (Moldovan, 2019; Moore and Morton, 2017). The researchers also analyzed study programs, courses, and content to assess skills coverage—for instance, to examine how well an education curriculum covered certain skills (Oldford et al., 2022). Competency clusters were created by analyzing data from the Accreditation Board for Engineering and Technology (ABET)-accredited industrial engineering programs (Babic et al., 2022). In addition, learning factories and how they could be used to capture skill needs and improve course curricula was assessed (Maheso et al., 2019). Usually, these approaches were considered to have minor potential to highlight the actual skill gap, as they typically considered only one perspective (e.g., employers' impressions).

Only a few of the included studies used several approaches and compared the results of or validated the identified skill gaps. However, when this was done, the researchers included several data sources in their analyses to gain insights from employers, employees, and education providers (e.g., Albizu et al., 2022). Such approaches might have the potential to reveal actual skill gaps. Furthermore, skill gaps were mainly presented using text or tables; however, Do et al. (2023) used a two-dimensional coordinate system with importance and performance/satisfaction axes, and Zheng and Shi (2021) used spider net diagrams to visualize skill gaps. Thus, multi-method/level and innovative approaches could reveal the actual skill gap. On the other hand, different presentation methods could make it easier to detect a problem and make it visible. However, according to the results, multi-method/level approaches were scarce.

In summary, skill gaps have been and can be studied in several ways. This is, of course, understandable, as skill gap is a multifaceted phenomenon. What is worth noting, though, is that researchers did not utilize multifaceted data. Instead, they collected data mainly using surveys, which might leave some unanswered questions. For instance, in many cases, the samples were small or purposively selected. Moreover, the development, validation, and reliability of the survey instrument were unreported. Research limitations were also rarely pointed out. Thus, no validated proof exists that a measured skill gap is an actual skill gap.

We believe that multimodal methods involving multiple modes and/or methods of data collection and analysis could offer a more comprehensive understanding of this multifaceted phenomenon. For example, in vision-intensive professions, where visual attention and pattern recognition are critical for decision-making, eye tracking technology could provide better indicators of skill gaps and craft a better picture than questionnaire data. Past research has, for instance, indicated that skill gaps may be observable in the eye movement data via eye movement metrics and movement patterns (Deitelhoff, 2020). Furthermore, literature has demonstrated the eye tracking methodology's ability to improve the reliability of data and the generalizability of findings (Antonenko, 2019).

4. Discussion

In this study, we used a systematic-narrative hybrid literature review to clarify the concept of skill gaps and identify its measurement approaches based on skill gap studies published between 2012 and 2022.

Our review illustrates that a skill gap is a nuanced phenomenon with a complex combination of causes and consequences, and the approaches used to identify and measure it are diverse. In the following subsections, we discuss this multifaceted concept and its measurement approaches in more detail.

4.1. A clear skill gap definition

What does a skill gap really mean? It has no clear definition; based on the literature, it is multifaceted and diverse, and most of the studies reviewed did not clearly define it (Table 5). Its descriptions, although they formed the basis of the studies, were rather general. Different terms (i.e., gaps, mismatches, and shortages) were often interchangeably used. Other similar overlapping and intersecting terms (e.g., skill deficits, skill-related challenges or problems, skill differences, breaches between skill demands and supplies, lack of talent, skill deficiencies, and skill misalignment) were also common. Struggling with skill gap-related concepts and terms is not new: researchers have always struggled to define closely linked concepts (McGuinness et al., 2018). However, the findings supported by previous research—i.e., the lack of a standard definition (Centeno et al., 2022; Schwalje, 2012) and different economic, political, and research interests (OECD, 2016)—indicate that skill gap research has fundamental limitations (Centeno et al., 2022). Though the literature has explicitly acknowledged skill gaps, it has not

Table 6
The approaches utilized to measure skill gaps (1 = YES, when the criterion was applicable; 0 = NO; N/A = not assessed. Minor (score ranging from 0 to 1); fair (score 2); potential (score 3); N/A (shaded with gray).

Paper code	Based on skills map/framework/cluster/database	Different actors	Several approaches	Potential to highlight actual skill gap	Approaches
P1	N/A	N/A	N/A	N/A	Literature review
P2	No	No	No	Minor	Students, (hands-on exercises), Likert scale survey, and learning experiences
P3	Yes	No	No	Minor	Skills framework, experts, interviews, and perceptions
SD1	Yes	No	No	Minor	Topics clusters, study programs, and courses
SD2	Yes	Yes	No	Fair	EMSI job posting and profile data, sector and job seekers, data analytics, skills and domain knowledge
SD3	N/A	N/A	N/A	N/A	Developing learning factory concepts
SD4	No	Yes	No	Minor	Survey, SMEs representatives, VET providers, and knowledge and skill gap
SD5	Yes	N/A	No	Minor	Literature review, Cobb-Douglas production function, and potential scenarios
S1	Yes	No	No	Minor	Literature review, ESCO database, data analytics, sector, and current and near-future skills needs
S2	Yes	No	No	Minor	Literature review, ESCO database, data analytics, sector, and current and near-future skills needs
S3	Yes	Yes	Yes	Potential	Spanish labor force survey (LFS), ISCED, ISCO and NACE classifications, data analytics, surveys (qualitative and quantitative), employees, employers, and skills mismatch
S4	Yes	No	No	Minor	Skills framework, focus group discussion, and skills and capabilities
S5	Yes	No	No	Minor	Literature review, ESCO database, data analytics, sector, and current and forthcoming skills
S6	N/A	N/A	N/A	N/A	Literature review
S7	N/A	N/A	N/A	N/A	Training toolbox development
S8	No	No	No	Minor	Survey, employers (SMEs), and current and future hiring needs
S9	Yes	Yes	No	Fair	Skills framework, surveys, students and employees, and lack of skills, knowledge, and competencies
S10	Yes	No	No	Minor	Skills framework and training tool development
W1	Yes	Yes	No	Fair	Skills framework, survey (Likert-type scale), managers and graduates, and skill gap
W2	Yes	No	No	Minor	Skills framework, self-assessment survey (Likert scale), employees, and skill gap
W3	Yes	No	No	Minor	Skills framework, survey, practitioners, and industry-academia gap
W4	N/A	N/A	N/A	N/A	Case study, interviews, organization members, and the opportunities and challenges they faced while addressing their skills needs
W5	No	Yes	No	Minor	Surveys (Likert scale), employers and employees (self-assessment), and skill gap
W6	No	Yes	No	Minor	Surveys (Likert scale), employers and employees, and skill gap

Table 6. cont.

W7	Yes	No	No	Minor	Skills framework, survey (Likert le), employees, skill gap, sustainably skill gap
W8	No	No	Yes	Minor	Survey, field visits (observations and interviews) as a follow up, focus groups and secondary data to gain further insights, sector, and skill challenges
W9	N/A	N/A	N/A	N/A	Links between skills mismatch and international mobility
W10	Yes	No	No	Minor	Skills framework, interviews (semi-structured), experts, importance-performance analysis, and technical skill gap
W11	N/A	N/A	N/A	N/A	Conceptual labor supply framework
W12	Yes	Yes	No	Fair	Data analytics, Community Innovation Survey (CIS), job openings and qualifications, and skill shortages and innovation
W13	No	Yes	No	Minor	Interviews, managers, supervisors, perceptions, and attitudes about graduates' writing skills
W14	No	No	No	Minor	Interviews, employers, and perceptions of skill demand and mismatch
W15	Yes	Yes	No	Fair	Data analytics, ESS, and ABS data (UK region-industry data), and regional skill gaps
W16	N/A	N/A	N/A	N/A	Mid-school internship as a skill-gap-bridging scheme
W17	No	No	No	Minor	Content analysis, undergraduate course textbooks and instructor materials, and the current state of environmental, social, and governance pedagogy
W18	Yes	No	No	Minor	Skills framework, focus group, industry professionals, key competencies, and skills mode
W19	No	No	No	Minor	Surveys, firms, and skill shortage issues
W20	Yes	Yes	No	Fair	Skills framework, surveys, IT-professionals and students, and gaps in soft skills traits and factors
W21	Yes	No	No	Minor	Skills framework, surveys (Likert-type), firm representatives, and skills shortage
W22	Yes	Yes	No	Fair	Skills framework, surveys, students (self-evaluation) and employers, and skill gap

clarified what constitutes them (Royle and Laing, 2014)—a significant research gap we aimed to fill through this study.

We thus propose the following definition: *a skill gap can be understood as a difficulty in providing the right skills to the right people at the right time to enhance employee productivity, improve and advance organizational performance, create value, support digital transformation, and narrow gaps in business realities and labor markets* (Fig. 5). The reviewed literature reinforced the view that a skill gap is a gap between employers' demands for specific skills and the skills that employees possess (McGuinness et al., 2018; Quintini, 2011). Furthermore, a skill gap can occur between education and training outcomes and industry-based skill needs (Carlisle et al., 2021). Our findings also highlighted that, in today's constantly changing world, it is becoming increasingly tricky to align skilled people and processes with organizational goals due to skill discrepancies. It was even emphasized that skill gaps result from poor collaboration between trainers, employers, employees, and graduates (Abbasi et al., 2018). Thus, according to the reviewed articles, skill development is a specific area in which companies and education providers should allocate the necessary resources. Especially in industry, employees must become familiar with new working methods involving continuous learning to ensure that they remain valuable to their organizations and society (Braun et al., 2022). It is necessary to start training employees so that they can gain the skills needed to adapt to the constantly changing work environment (Albizu et al., 2022). However, it takes time and effort to plan and implement effective training (Qiu et al., 2020). Therefore, optimal training decisions and tools require accurate information about skill gaps (McGuinness and Ortiz, 2016). Hence, industries must understand the scope of the changes, and the work and skills needed from the workforce to deal with the changes (Karacay, 2018).

4.2. Measuring skill gaps

What approaches can be used to measure skill gaps? Though multiple approaches have been used, a holistic and validated approach is still lacking. Although earlier research has highlighted that adopting a holistic approach for skill gap measurement is considered good practice (OECD, 2016), quantitative, qualitative, and other data sources such as forecasting models, competency assessments, education levels, and labor market analytics are rarely combined. Despite fact that the concept of a skill gap is multifaceted, there seem to be some generally accepted ways of measuring it (e.g., by creating a skill framework and using it to design surveys). Nonetheless, there are some weaknesses regarding the reliability of measurement in surveys, such as subjectivity and peer positivity bias (Kimmell and Martin, 2015; Schwalje, 2012). Many workers do not know their own level of skills or even do not know which skills are relevant, making it harder to find proper channels for upskilling/reskilling (Enders et al., 2019). Can a Likert scale or self-assessment objectively describe a skill gap? This is a relevant question since these were the most utilized ways to measure skill gaps. Furthermore, as the reviewed literature showed, these approaches have not been validated or involve the "time-space gap"—researchers examined and measured skills only at specific times and thus failed to monitor changes in skill gaps over time. We thus believe that converging data from multimodal and multiple approaches, systems, and sources with

Fig. 5. A skill gap is a difficulty in providing the right skills to the right people at the right time in changing business realities.

more traditional measures, such as surveys, could offer a more comprehensive understanding of the skill gap phenomenon. Eye tracking, for example, is a versatile, accurate, and reliable methodology (Antonenko, 2019).

We agree with the previous literature that an ideal dataset should explicate a wide range of factors and details about the skill requirements of a job and the skill set of an ideal worker (Rathelot and van Rens, 2017). Hence, a more holistic approach is needed to identify and measure skill gaps. First, it is important to know what companies want and need (Maheso et al., 2019). Second, exploring the skill gaps among employees is important (Adepoju and Aigbavboa, 2021). Understanding the coverage of these necessary skill sets in education and training is critical (Akdur, 2021). One reviewed paper, for instance, suggested that technology-enabled talent-matching platforms could be one way to bridge the skill gap (Cukier, 2019). Thus, at best, the idea of a skill gap can be utilized to assess the skills someone lacks and, depending on the organization and the employee, to set different goals and resources for upskilling/reskilling (Braun et al., 2022). After our database searches (i.e., January 2023), some interesting and more holistic skill gap approaches emerged, such as Fareri et al. (2023), whose data-driven evaluation tool is user-friendly and whose methodology is easily adaptable to different contexts and goals.

5. Study limitations and strengths

Our review has some clear strengths. First, it was not limited to a specific research area or method. Diverse sources of information can offer a holistic understanding of a topic (Whittemore and Knafl, 2005). We were interested in gaining a clearer understanding of skill gaps and its measurement approaches in the digital era, especially for Industry 4.0, but also for the increasingly globalizing, digitalizing, and changing world. Therefore, the skill gap may manifest similarly in other work environments as well, although skill requirements may differ. However, a multi-approach perspective also limited the systematic evaluation of the evidence related to measurement approaches, which might have been possible if the study had focused only on, for example, quantitative studies. Because of data heterogeneity and the different research approaches, we did not conduct a meta-analysis but aimed to provide a narrative overview of the existing empirical evidence on skill gap measurement.

The second strength of the review is the effort we made to reduce bias in selecting relevant publications by having three researchers participate in the selection and analysis processes. We employed thematic analysis and constant comparison approaches to organize the particulars into a general concept. These analysis methods clarified the interpretations that emerged flexibly and creatively from the data (Braun and Clarke, 2006; Whittemore and Knafl, 2005). Any disagreements during the review and analysis processes were discussed to reach a consensus.

The review was limited to the ProQuest Central, Scopus, Web of Science, and ScienceDirect databases. Researchers who want to examine skill gaps more thoroughly, especially in different contexts, should expand the search to include, for example, the PsycINFO, ERIC, and Google Scholar databases. In addition, clarity could be increased if the search terms focused only on skill gaps, although that might involve a risk of excluding relevant studies with different search terms. In addition, this review may have excluded other relevant information contained in books or theses. We recognize that we did exclude some relevant studies when we excluded the full texts that were unavailable through university subscriptions or other channels, such as Google Scholar. We thus missed five papers that should have been screened, though their abstracts indicated that their focus might not have been relevant for our review.

6. Conclusions, implications of the study and directions for future research and practice

Our literature review revealed the need for a common understanding of skill gaps and provided a definition for this multifaceted phenomenon (see Section 4.1). Understanding skill gaps is important because, in recent years, industrial changes have often overtaken workers' learning speed, leading to delays and failures in technology adoption and sustainable development. However, providing the right skills to the right people at the right time in a constantly changing world is difficult. Skill gaps stem from the preferences, expectations, and supply of three actors—employees, employers, and education providers—that are broadly influenced by megatrends, operating environments, and business realities. Therefore, an actual skill gap may be hard to grasp using the existing measurement methods and good-practice approaches.

Throughout our review, we identified the existing gaps in skill gap measurement (e.g., focus, effects, and/or objectivity). Moreover, we found that previous research did not define (Table 5) or map the actual skill gaps (Table 6). This calls for more studies to evaluate the long-term effects of skill gaps, consider social, environmental, and technological factors from different perspectives, and combine different approaches—i.e., a holistic validated perspective.

6.1. *Recommendations for future practice*

Solving skill gaps, which are very nuanced phenomena, is a challenge—no single and clear solution exists. We thus suggest that educators, employers, employees, students, and political decision-makers should understand the importance of specific skills and recognize their roles in bridging skill gaps in today's digitalizing, globalizing, and changing world. Collaboration must be done at many different levels, and long-term and effective cooperation with various stakeholders is needed. Collaboration helps understand the different needs and expectations to avoid disagreements and lays the groundwork for approaches to bridge skill gaps. In addition, individuals must have the desire and readiness to develop their own skills, as skill gaps largely depend on employees and their skills and preferences. At the same time, employers' support is essential as well. The employers, educators, and policymakers should clearly define responsibilities—i.e., whose responsibility it is to provide, finance, and determine upskilling/reskilling so that employees can develop their potential.

The future is difficult to predict. However, the goal should be to utilize research and evidence-based data from different perspectives to make effective recruiting, re-training, and training investments. Stronger university–industry cooperation may help establish different ways to

identify and bridge the skill gap (e.g., skill frameworks, tools to adapt and create learning modules and curricula, and customized learning opportunities to meet individuals' needs). Therefore, deep, research-based knowledge and evidence-based understanding could help organizations thrive in digital transformation and constantly changing operating environments. Knowledge mining, learning analytics, and artificial intelligence may open new opportunities for utilizing information from human resources management systems, educational databases, job posting data, and other databases and create skill frameworks to identify and visualize actual skill gaps. Furthermore, recommender systems could be developed and utilized to offer personal and recruiting recommendations and bridge the skill gap. Only with such human-centered means can robots and intelligent machines work successfully alongside people, which can increase resilience and help achieve the goals of sustainable development.

6.2. Suggestions for future research

Future skill gaps researchers must have a coherent understanding of the phenomenon. They must clearly define the concept, the measurement dimensions, and the associated scales—only then it can be guaranteed that a study would offer clear evidence of skill gaps and how to address them. Since the literature does not offer enough data to clearly map the skill gap concept and develop a validated approach for measuring it, we suggest empirical data collection to understand how skill gaps are perceived by different stakeholders. In addition, skill gaps are often assessed and judged using multiple-choice questionnaires rather than proficiency and performance tests or observations. Tested and validated approaches are needed to explore the ideal state of skills and measure skill gaps. Furthermore, combining several approaches—such as observations, analysis of evidence of performance, interviews, multifaceted feedback, case studies, and simulations—might lead to a better understanding of actual skill gaps.

It is also essential to research the links between the effectiveness of training approaches and skill gaps from the point of view of different actors, such as education providers, employees, and employers. Furthermore, based on the reviewed literature, skill gaps have mainly been viewed at the macro (i.e., organizational) and meso (i.e., general labor market) levels, with only few studies considering the micro level (i.e., individual employees). Future researchers should measure individuals' skill gaps to help them set goals and prepare for new working environments. Thus, the development of individual skills should be incorporated into future research. In addition, cross-sectional longitudinal studies should be conducted to identify the short- and long-term effects of training and skill gaps. Future research may also consider the team dimension—the ways in which a team's skills complement each other, and the skills that contribute to its success.

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CRediT authorship contribution statement

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Declaration of competing interest

None.

Data availability

Data will be made available on request.

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