Bibliometric Exploration of Workforce Skills: A Comprehensive Analysis from 1987 to 2023

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Abstract: The changing nature of labor skills has received more attention, but there is a lack of a complete bibliometric analysis that covers a long period of time in current scholarly discourses. Many existing studies have a limited scope, resulting in a significant vacuum in our understanding of research on workforce skill development. This study fills this gap by undertaking a thorough examination of literature from 1987 to 2023, utilizing 1580 papers. It reveals subtle trends, changes, and developing themes that have been overlooked in more focused investigations. The importance of this research resides in its capacity to inform policymakers, educators, and academics on the direction of studies on labor skills. This knowledge can facilitate well-informed decision-making and strategic planning in the ever-changing fields of education industry. This analysis attempts to provide comprehensive insights into the entire range of literature. Its purpose is to direct future research directions and offer practical strategies for developing a competent and flexible global workforce.

Keywords: Workforce, Skills, Changing technological landscape, Bibliometric analysis, Collaboration networks

1. Introduction

Automation, artificial intelligence, and digitalization are changing job requirements across industries. Thus, study on workforce skills has increased to understand, improve, and optimize them for success in the modern workplace. As we traverse the 21st-century employment, we must examine workforce skills in all its facets. This requires reviewing educational institutions that teach these skills, analyzing industry and employer expectations, and understanding the social and economic effects of a trained or inadequate workforce. This introduction prepares us to examine the employment skills landscape for trends, patterns, and research needs. By doing so, we contribute to the scholarly conversation about workforce skills and provide valuable insights for educators, policymakers, and businesses seeking to develop a workforce that is both technically proficient and equipped with the critical skills needed to navigate a rapidly changing world.

1.1 Research Gap and Study Significance

Despite the growing interest in labor skills, a complete bibliometric analysis encompassing a significant time range is conspicuously lacking in current scholarly discourse. Existing studies frequently focus on certain subdomains or short-term trends, creating a significant gap in our understanding of workforce skill development research. This study seeks to fill this void by providing a thorough evaluation of the complete spectrum of literature from 1987 to 2023, revealing patterns, shifts, and emerging themes that may have been overlooked in more narrowly focused investigations. This research is significant because it has the ability to enlighten policymakers, educators, and

academics on the trajectory of workforce skills studies, enabling for informed decision-making and strategic planning in the ever-changing world of education and employment. This thorough analysis is set to give useful insights that might guide future research paths and inform practical actions for developing a skilled and adaptive global workforce as workforce dynamics continue to shift.

2. Literature Review

Shenoy and v. T (2023) uses a systematic literature review to examine government, higher education, and industry skill training efforts. He also investigates the prior mismatch between industry requirements and academic practices that needed skill enhancement and how such training programmes affect graduates' job lives. Ra et al. (2019) study makes the case that improving learnability—the willingness and capacity of the present and future workforce to learn, unlearn, and relearn—is necessary to satisfy the skill demands of the fourth industrial revolution. Li (2022) centered conversation on the upskilling and reskilling of workers to prepare them for the workforce of Industry 4.0 and beyond. In order to implement Industry 4.0, the industry has identified the top talents that are needed, and we have provided a blueprint that can be used as a guide for learning and gaining new expertise. Following studies also helpful in understanding the workforce skills and lacking in the field (Acerbi et al., 2022; Brown & De Neve; Germain, 2021; Katiraee et al., 2021; Li et al., 2020; Xu et al., 2021).

Implementing AI in organizations incorporates several organizational tactics, according to this study, (Morandini et al., 2023). To reduce the workplace skills gap, workers' transversal talents must be mapped first. Subsequent, companies may help employees identify, enhance, and learn AI adoption abilities. The findings also suggest that organizations should provide ad hoc training and development to prepare workers' attitudes and mental models towards AI for the evolving job market and its problems. To assess technological advancements affecting various industry domains, the study of Johnson et al. (2021) team first did bibliometric research and generated word co-occurrence diagrams utilising BD&AI papers from high-impact publications. After collecting job posting data, the team summarised the skills needed to compete in BD&AI-driven businesses.

Ozyurt and Ayaz (2022) research employs bibliometrics and theme modelling. The study examines trends in publications, citations, significant countries, connections, author status, prominent themes, their thematic features, and research interests and trends. The findings classify articles into 21 topics. The most studied are "Technology acceptance", "Social network-based learning", "Teacher education", "E-learning satisfaction", and "E-learning". The most rapid issue within itself is "Gamification" and related to other topics is "Technology acceptance". Yubo et al. (2023) used scientific knowledge graphs and bibliometrics to analyze annual article publication changes, geographical distribution among countries, institutions, disciplines, and authors, keyword co-occurrence and clusters, and timezone view. To identify research hotspots, Padula et al. (2014) employed keywords, productive researchers, and journal analysis . Web of Science was utilized to conduct a comprehensive literature review. The United States, China, and the United Kingdom account for 31% of SDG-related research production, with an average of 15.06 citations per article. Over 45,345 writers from around the world have contributed to the SDGs, and collaboration is high. Kişi (2023) examined employee engagement. Bibliometric analysis was performed on 786 2002–2022 Web of Science employee engagement articles. Citation, co-citation, co-authorship, and co-occurrence analysis were done with VOSviewer. Top nations, institutions, authors, journals, and scientific publications were honored, along with current and future research trends. USA, Louisville, Brad Shuck, and Sustainability score highest in productivity. Corporate social responsibility, perceived organizational support, culture, work–family balance, and employee engagement outcomes (job satisfaction, commitment, performance, citizenship behavior) are being studied.

Aria and Cuccurullo (2017) bibliometric analysis platform for finding research tendencies and linkages, has been effectively employed in miscellaneous fields to plot the intellectual landscape. As established by Guo et al. (2020) in artificial intelligence (AI) in Healthcare, Luo et al. (2022) research in technology, Păduraru et al. (2022) management, El-Sherif and Abouzid (2022) technology and healthcare, Aagja et al. (2023) in digital technology and Yazdi et al. (2023) for analysis of fault tree improvements. These bibliometric analyses have clarified important relationships and directed future research efforts.

3. Methodology

A review study's main goal is to assess the state of the subject and examine recent developments in a particular discipline. The evaluation of the research's shortcomings and the provision of insightful viewpoints for scholars and engineers are further objectives. Scholars have devised techniques for organising literature reviews in a dependable

and resilient manner. Using a review methodology, Rowley and Slack (2004) scanned published literature, made a mental map, and generated a bibliography. According to Garza-Reyes (2015), there are five steps in this process: formulating questions, choosing sites for investigations, evaluating studies, analyzing and synthesising data, and presenting the results. Maditati et al. (2017) established a number of strategies, including content, metadata, bibliometric analysis, and systematic review, to help academics conduct thorough literature evaluations. As a result, the procedures of these research papers and other studies are followed in this review (Hou et al., 2021; Huang et al., 2022; Yazdi et al., 2023). The study creates a four-step methodology for carrying out a comprehensive review of the literature and bibliometric analysis of earlier studies on skill development and the skills gap in the workforce. The structure is shown in Figure 1, with three primary phases: (i) choosing the keywords, (ii) getting information from the database, and (iii) analyzing the metadata statistically and using bibliometrics.

3.1 Keywords and Data Collection

We searched Scopus using "workforce" and "skill" in this investigation. We also use "technology" and "skill development" to broaden the material. SCOPUS records cover 1987–2023. Exporting papers from WOS removed some important bibliographic and other information, but SCOPUS included all necessary information, including funding, citations, and bibliographies (see Figure 1). Article titles, abstracts, keywords, and complete texts are screened to eliminate repeats and irrelevant information. The advanced screening procedure in this work considers the following factors: (i) articles that proposed or reviewed the workforce; (ii) articles that used skill gap and development in a variety of application disciplines; (iii) articles that limited their explanation to a just sample illustration were disregarded; (iv) articles that focused on a general discussion of were considered irrelevant; and (v) the a Then, Scopus 1580 papers were thoroughly examined.
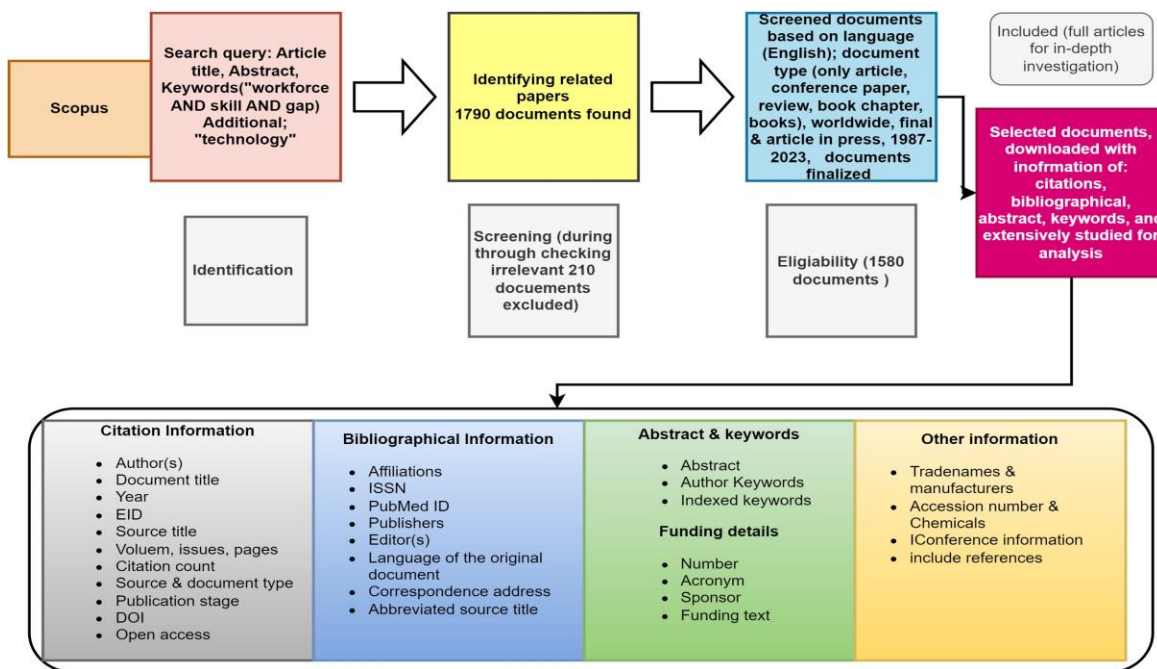

Figure 1: Literature review framework

3.2 Software and Tools

Bibliometric analysis helps evaluate publications and identify research gaps. Authors, citations, keywords, titles, journals, and publication years may be analyzed. Bibliometric analysis helps evaluators comprehend the issue's goals and results. Tsenguun et al. (2018). Bibliometric analysis tools VOSviewer by van Eck and Waltman (2010) and Biblioshiny by Aria and Cuccurullo (2017) are flexible and trustworthy. VOSviewer and R-packages are used for bibliometric analysis to find, analyse, and track research trends.

33 Meta Data and main Information

A bibliometric examination of 1,102 sources' 1,580 documents from 1987 to 2024 on labour and skill gap studies

uncovers interesting trends and patterns. An ongoing interest in the area is indicated by the 3.01% yearly growth rate, which also reflects the field's growing significance in the face of global economic changes. The average age of documents is 5.51 years, which is quite recent and emphasises modern issues. The research has been cited 9.855 times on average per document, indicating its significant scholarly impact. This research is clearly collaborative, as evidenced by the 292 single-authored documents that highlight individual contributions from the 5,326 writers involved. A document with 3.62 co-authors highlights the interdisciplinary approach in the collaboration index. International co-authorships, which make up 17.78% of the total, highlight the need to approach workforce issues from a global perspective. The frequency with which items (914), see Figure 2.
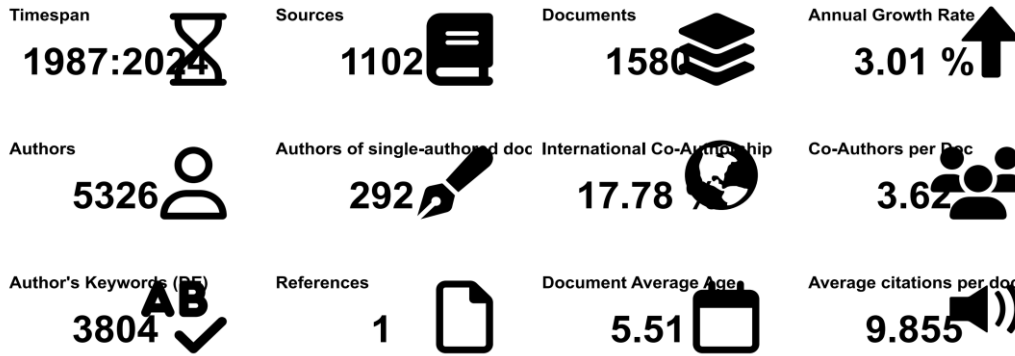

Figure 2: Main information summary

3.4 Scientific Production

The yearly scientific production chart gives a compelling picture of field research output, revealing trends, variations, and possible underlying variables. Notably, the data shows a large increase in publications over time, indicating an increasing interest and focus on the topic. Recent years, especially 2023 with 251 publications, 2022 with 202, and 2021 with 166, show a steady growth in scientific productivity. This spike may be due to changing global economies, technology, and society making labor and skill gap concerns more important. The growing amount of knowledge throughout these years may reflect the complexity and relevance of understanding and solving workforce concerns. The number of papers increased gradually from 2003 to 2014, demonstrating a growing recognition of the workforce and skill gap as a research subject. Early 2000s numbers may have been low due to fledgling interest or a sluggish reaction to labor dynamics developments. The data also shows periodic swings, like the 2018 drop and 2019 rebound. These changes may be caused by external forces, money, or research agendas. Understanding the causes of these oscillations requires a better understanding of these years' circumstances. The late 1990s and early 2000s had moderate production, showing the research area was maturing. The late 1980s and early 1990s saw little or no output, suggesting that labour dynamics research was only beginning, see Figure 3.
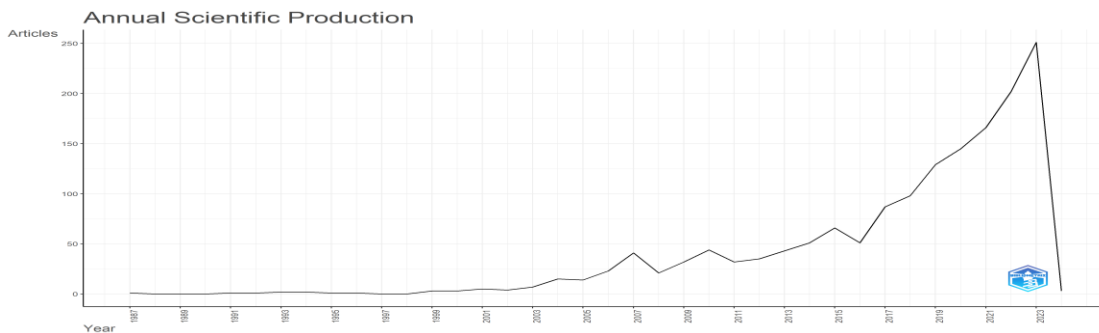

Figure 3: Depicting annual production on workforce skill research

3.5 Average Citation Per Year

The dataset's average citation per year fluctuates throughout time, showing research output's effect and influence. Citations per year have increased in recent years, indicating the field's expanding prominence and importance. The

average annual citations have increased from low in the early 2000s to high in the recent decade.
Total Citations=∑(Citations per Year)
Total Years=Number of Years
Average Citation per Year=Total Citations/Total Years
Let's calculate it:
Total Citations=251+202+166+145+129+98+87+51+66+51+43+35+32+44+32+21+41+23+14+15+7+4+5+3+3+1
+1+2+2+1+1Total Citations=251+202+166+145+129+98+87+51+66+51+43+35+32+44+32+21+41+23+14+15+7
+4+5+3+3+1+1+2+2+1+1
Total Years=2023−1987+1

The greater citation counts show that 2023, 2022, and 2021, with 251, 202, and 166 publications, had a significant influence. This implies that contemporary research is both comprehensive and prominent in the academic community, emphasising the growing importance of workforce and skill gap investigations. In the modern time, research in this topic has gained prominence and influence, resulting in greater average citations each year, see Figure 4.
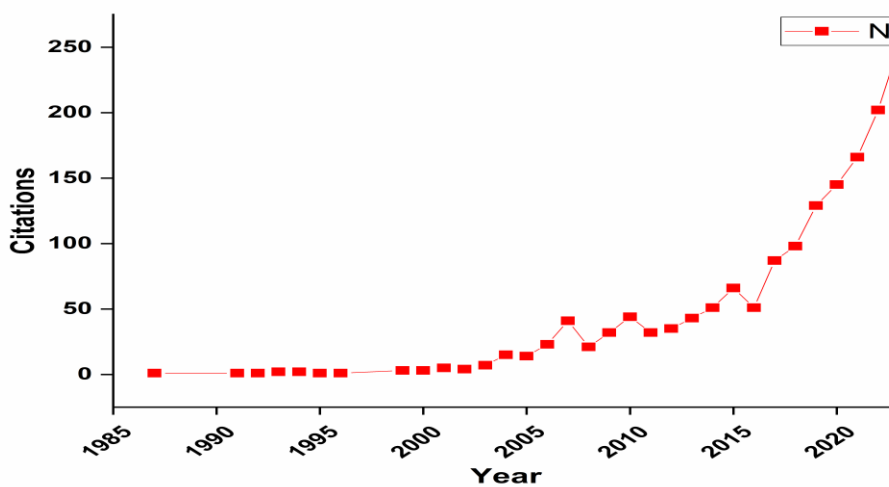

Figure 4: Showing citations year by year

4. Results and Discussion
4.1 Most Relevant Sources
4.1.1 Top Journals

Key workforce and skills research sources represent a broad intellectual landscape. The 72-article ASEE Annual Conference and Exposition Proceedings are crucial to engineering and technology education. 24 articles in the Journal of Public Health Management and Practice emphasise the importance of a professional public health staff. Human Resources for Health addresses health workforce issues with 22 articles. BMC Medical Education, BMC Health Services Research, and BMJ Open are vital to medical education and healthcare workforce dynamics. Higher Education, Skills and Work-Based Learning (10 papers) examines the evolution of skills and work-based education, whereas the ACM International Conference Proceeding Series (8 articles) covers technology and computing. Frontiers in Public Health and Industry and Higher Education, each containing 7 articles, demonstrate the interdisciplinary character of workforce research by addressing public health issues and industry-higher education collaborations. This selection shows the wealth of workforce and skills conversation across disciplines, see Figure 5.
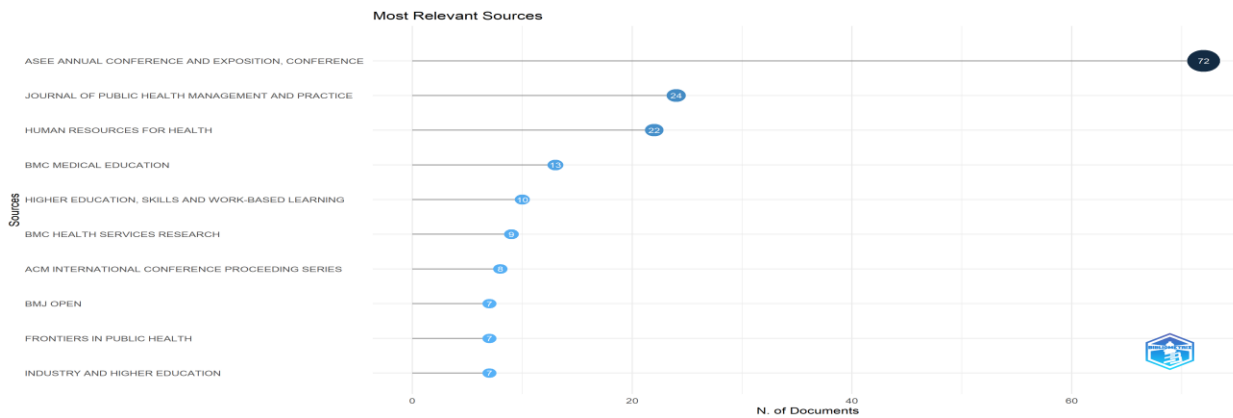
Figure 5: Illustrating most relevant sources in this field research

4.1.2 Authors Local Impact

The data shows numerous authors' local impact measures, including h-index, g-index, m-index, total citations (TC), number of publications (NP), and starting year of publishing records (PY_start). Interestingly, each author has a different academic impact. Example: BROWNSON RC has a higher h-index of 5, see Figure 6, indicating five publications with at least five citations. CASTRUCCI BC and WU W have h-indices of 4, indicating a strong impact, while ADAMS J has 3. AYKAZI T, BEKEMEIER B, FERNANDES FP, GERALDES CAS, GOTI A, and KHAN R have m-indices from 0.375 to 1 for the h-index relative to publications. The author's productivity may affect these m-index numbers. The quantity of citations and publications also reveal each author's influence and production. AYKAZI T and GOTI A, both starting in 2021, have 30 citations each, demonstrating early academic impact. This local impact study provides a nuanced view of each author's scholarly contributions and influence in their publication records.
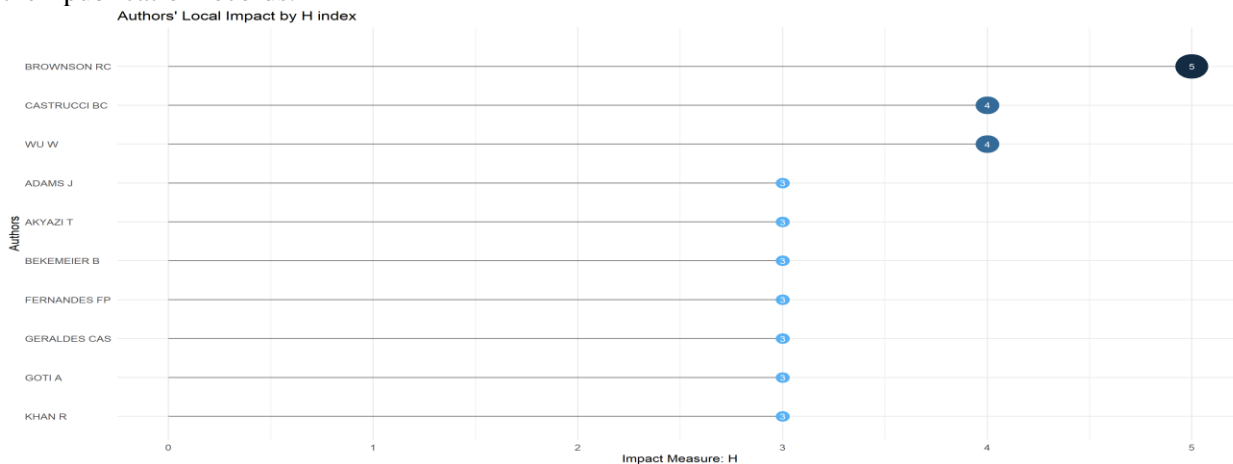

Figure 6: Showing relevant authors local impact

4.1.3 Sources local impact

Impact indicators for various sources show their academic influence. "Human Resources for Health" has a 12 h-index, 22 g-index, and 0.8 m-index, indicating persistent and strong influence from 22 publications since 2009. The "Journal of Public Health Management and Practice" has an h-index of 8, see Figure 7, g-index of 13, and m-index of 0.533 over 24 publications since 2009. Both "BMC Health Services Research" and "BMC Medical Education" have h-indices of 7 and 5, indicating their importance in health and medical education. With h-indices of 5, "Nurse Education Today" and "Rural and Remote Health" highlight their contributions to nursing education and rural health research. Although new, "Higher Education, Skills and Work-Based Learning" has made an impact with a g-index of 10 and an m-index of 0.571 since 2017. Since 2007, "International Journal of Environmental Research and Public Health" has had 307 citations, demonstrating its environmental health effect. "Journal of Clinical Nursing" and "Journal of Construction Engineering and Management" have h-indices of 4, indicating their nursing and construction engineering effect. This approach emphasizes the different degrees of impact these sources have on
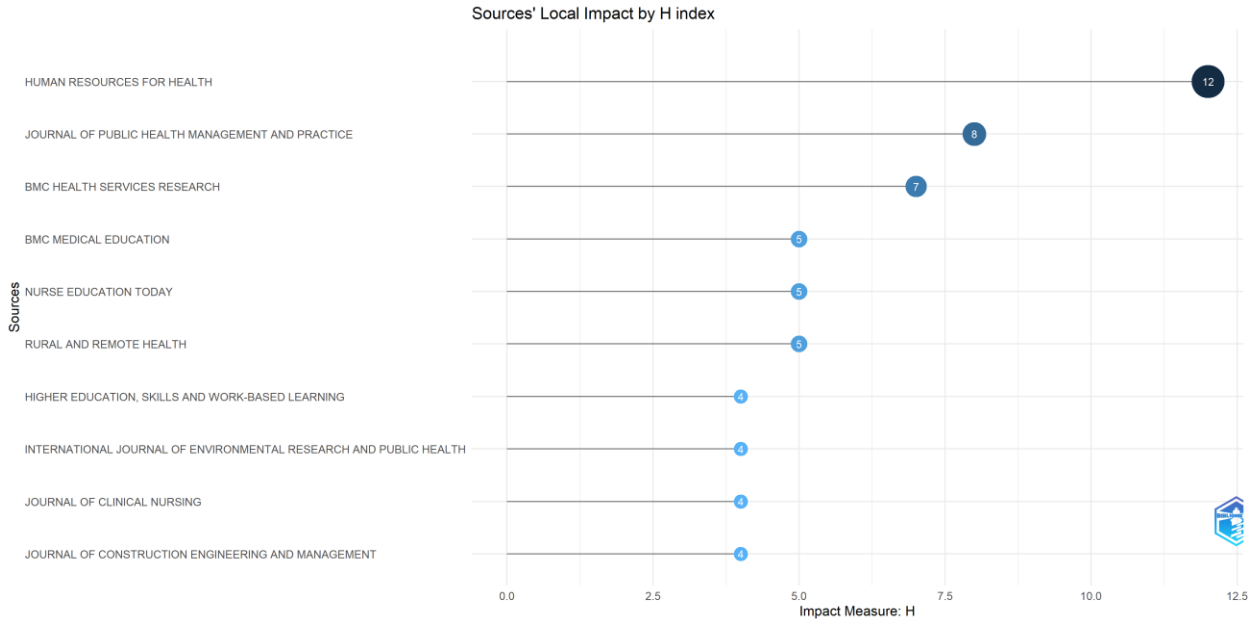
scholarly discourse in their disciplines.

Figure 7: Presenting sources local impact

4.1.4 Sources' Production over Time

The indicated sources' production trends over time show dynamic scholarly output. The "ASEE Annual Conference and Exposition, Conference Proceedings" reached 72 articles in 2023 after a steady increase. This growth indicates continued interest in engineering and technology education themes covered in this conference. The "Journal of Public Health Management and Practice" has steadily increased to 23 articles in 2023, demonstrating a dedication to public health, management, and practice research. "Human Resources for Health" publishes 22 papers in 2023, demonstrating its commitment to health sector human resource issues. With 13 and 10 papers in 2023, "BMC Medical Education" and "Higher Education, Skills and Work-Based Learning" show growth, demonstrating growing medical and higher education focus. This analysis reveals that these sources have developed with labour and education research, see Figure 8.
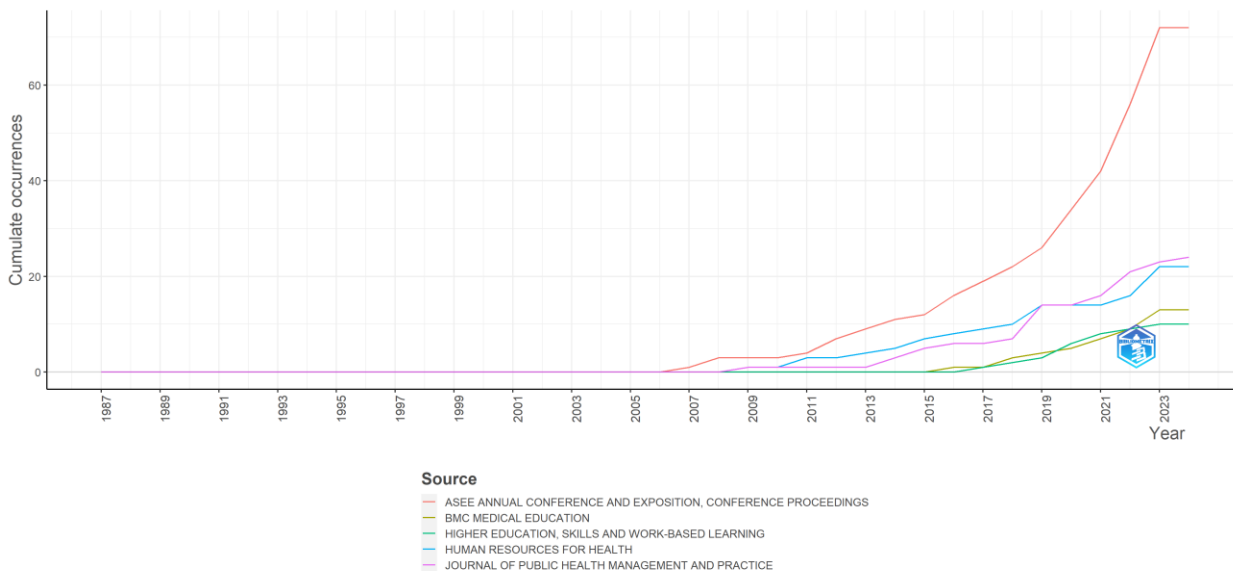

Figure 8: Showing sources production year by year

4.2 Authors Production over Time

Each author's production trends show different levels of intellectual effort and effect. From 2021 to 2022, Akyazi T's frequency and total citations (TC) increased, but in 2023, they decreased. This shows an early productivity boost followed by a focus or engagement shift. A 2016 publication and a 2021 increase in frequency and TC reveal Bekemeier B's more scattered production. The uneven pattern may reflect occasional yet significant contributions. Brownsone RC has consistently produced and had an impact, peaking in 2012, 2014, and 2018. Akyazi T and Bekemeier B have high Total Citations per Year (TCpY) scores, highlighting their efforts. This analysis shows that author productivity fluctuates over time, maybe due to research concentration, collaboration patterns, or career paths, see Figure 9.
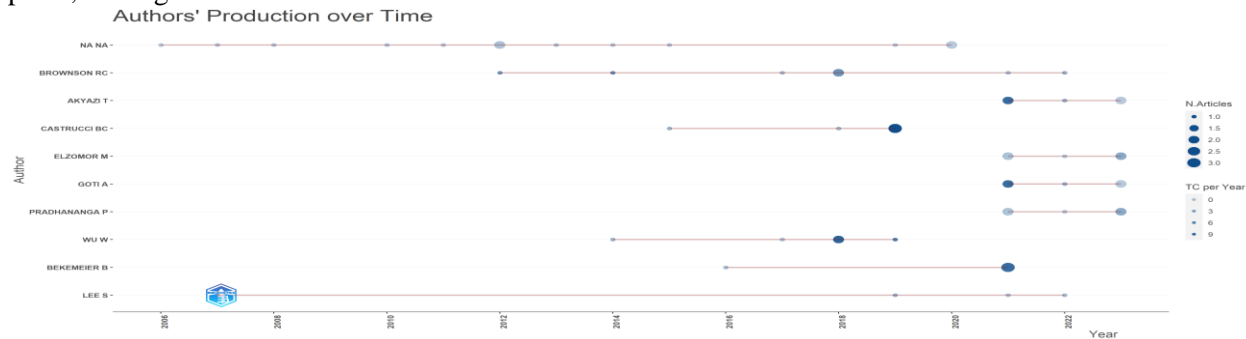

Figure 8: Presents authors' contribution timeline

4.2.1 Most relevant Affiliations

The top affiliations by publication count reflect the global workforce and skills research scene. Monash University leads with 24 articles, demonstrating its commitment to this field's scholarship. Purdue University follows with 22 papers, demonstrating its scientific achievements. Workforce and skills research is strong in Australia, with 21 and 20 articles from La Trobe University and the University of Melbourne, respectively. American universities like the University of California and University of Washington contribute 18 and 17 articles, respectively, emphasising worldwide collaboration and contributions. The University of Johannesburg, University of Michigan, University of Toronto, and University of Florida add diversity and international participation in workforce dynamics and skill gaps. This pattern of connections shows that workforce research is global, with universities on different continents contributing diverse viewpoints and techniques, see Figure 10.
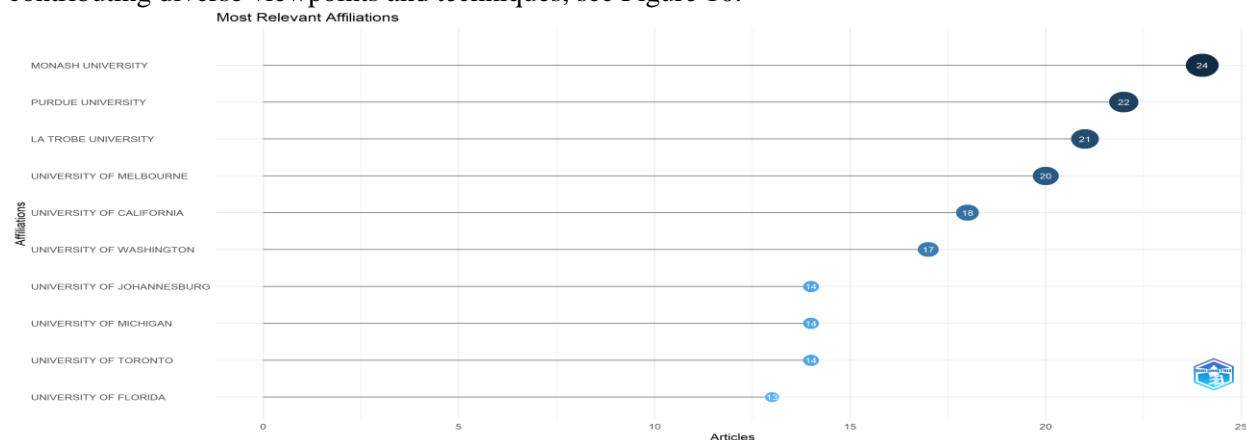

Figure 9: Shows most relevant affiliations

4.2.2 Corresponding Authors by Countries

The global distribution of scholarly contributions can be gleaned by analysing the most relevant countries by manpower and skills production. The generic category with 606 articles represents research without a country identity. The US leads with 369 articles, demonstrating its consistent research in this sector. The UK and Australia follow with 125 and 102 papers, respectively, demonstrating their major contributions to workforce dynamics and skill gaps scholarship. India, Canada, and Malaysia have 39, 29, and 21 articles, respectively, highlighting worldwide diversity. South Africa, Germany, and China provide 19, 17, and 13 publications, demonstrating the global aspect of workforce research. The ratio of multi-country articles to total publications is high for China, reflecting a trend of collaborative research. This analysis shows global engagement in understanding and addressing workforce concerns, with each country contributing distinct insights and contributions to the expanding
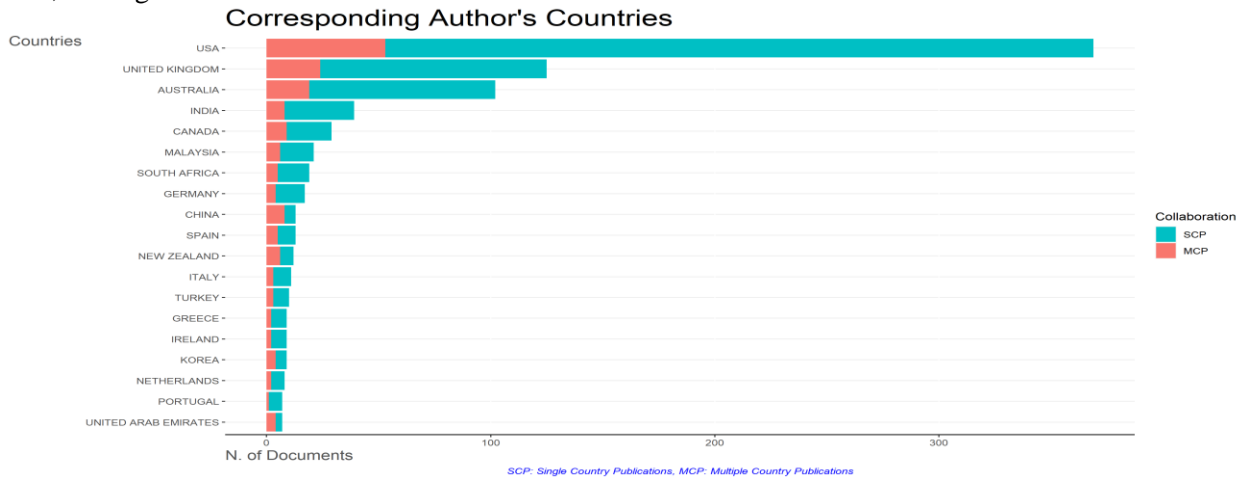
area, see Figure 11.

Figure 10: Demonstrates authors countries

4.2.3 Countries Scientific Production

The top 10 countries by workforce and skills production show the geographical spread of scholarly contributions, emphasising the worldwide importance of this topic. The US leads with 1499 articles, demonstrating its ongoing workforce research. The UK follows with 422 publications, showing a substantial influence on intellectual discourse. With 387 papers, Australia contributes significantly to workforce dynamics and skills research. India, Canada, Malaysia, and South Africa provide 136, 112, 77, and 60 articles, respectively, demonstrating the diversity of worldwide activity in this field. Germany, China, and Italy round out the top 10 with 56, 50, and 46 articles, respectively, demonstrating global interest in labour dynamics and skill shortages. This analysis confirms that workforce research is interdisciplinary and cross-cultural, with each country contributing unique and valuable knowledge to the field, see Figure 12.
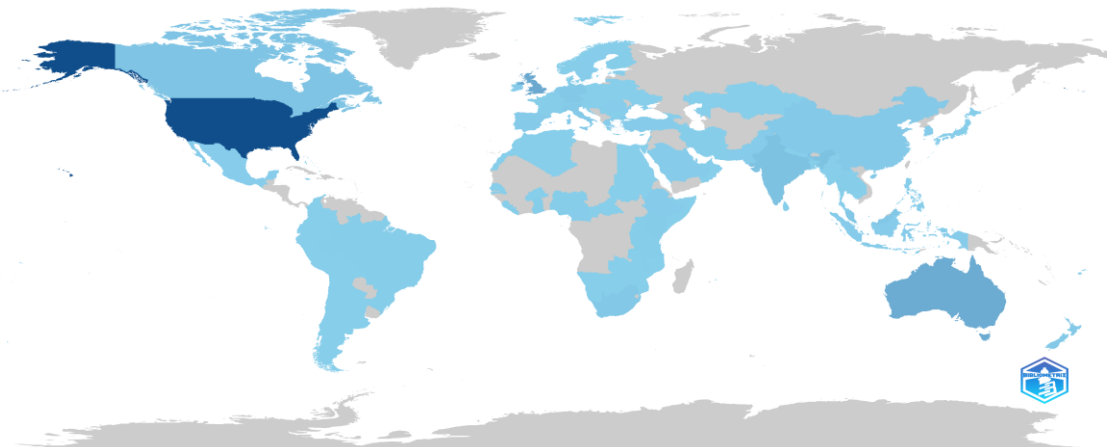
Figure 11: Map with dark colors of most producing countries

4.3 Most Cited Countries

The top countries in the workforce and skills category by total citations (TC) and average article citations reveal the importance and influence of regional research. With a TC of 4393, the US tops this field in impactful work. The UK follows with 2072 TC and a 16.6 average article citation, demonstrating article impact and recognition. Australia's 1415 TC and 13.9 average article citation imply a substantial workforce-related research presence and influence. Germany has a remarkable average article citation of 26.6, highlighting its publications' impact. India, Zambia, Canada, and Bangladesh also have high TC and average article citation values, reflecting the global impact of research. South Africa and Mexico complete the top 10, showing the transnational nature of workforce and skills research, see Table 1. Each country brings unique viewpoints and crucial contributions to the scholarly conversation. This analysis highlights the diverse and important contributions of different countries in expanding

our understanding of workforce dynamics and skill gaps.

Table 1: Countries role in workforce skill research

Country	TC	Average Article Citations
USA	4393	11.9
UNITED KINGDOM	2072	16.6
AUSTRALIA	1415	13.9
GERMANY	453	26.6
INDIA	349	8.9
ZAMBIA	283	283
CANADA	252	8.7
BANGLADESH	183	61
SOUTH AFRICA	132	6.9
MEXICO	114	28.5

4.4 Most Global Cited Documents

The most widely cited labour and skills documents show influential research that has affected scholarly debate. Rothwell's 2007 Personnel Review paper has 501 citations, making it the most cited. This work has had lasting impact and relevance with a remarkable TC per year of 29.47 and a normalised TC of 15.92. The 2013 DiPrete document on women and the education gender gap is the second most mentioned. The work has 485 citations and a 44.09 TC per year and 23.46 normalised TC despite not having a DOI. This shows its tremendous impact on academia, particularly gender dynamics in education. Fulton's 2011 Human Resources for Health paper ranks third with 346 citations. This study contributes to health sector human resources debate with a TC per year of 26.62 and a normalised TC of 11.31, see Table 2. Bag et al.'s 2021 Technological Forecasting and Social Change report has a high TC per year of 94.67 and a large normalized TC of 36.32. This shows that technology change predicting research has acquired popularity quickly. Hongoro, Anyangwe, Dickson, Mulligan, Ahmed, and Heimerl's remaining documents include healthcare, environmental health, and workforce economics, adding to the literature. These texts demonstrate their lasting significance and scholarly influence on workforce dynamics and skill gaps.

Table 2: Most cited documents between 1987-2023

Paper	DOI	Total Citations
ROTHWELL A, 2007, PERS REV	10.1108/00483480710716704	501
DI PRETE TA, 2013, THE RISE OF WOMEN: THE GROW GENDER GAP IN EDUC AND WHAT IT MEANS FOR AMER SCHOOLS	NA	485
FULTON BD, 2011, HUM RESOUR HEALTH	10.1186/1478-4491-9-1	346
HONGORO C, 2004, LANCET	10.1016/S0140-6736(04)17229-2	304
BAG S, 2021, TECHNOL FORECAST SOC CHANGE	10.1016/j.techfore.2020.120420	284
ANYANGWE SCE, 2007, INT J ENVIRON RES PUBLIC HEALTH	10.3390/ijerph2007040002	283
DICKSON KE, 2014, LANCET	10.1016/S0140-6736(14)60582-1	229
MULLIGAN CB, 2008, Q J ECON	10.1162/qjec.2008.123.3.1061	197
AHMED SM, 2011, HUM RESOUR HEALTH	10.1186/1478-4491-9-3	178
HEIMERL C, 2010, OR SPECTRUM	10.1007/s00291-009-0169-4	159

4.5 Most Relevant Keywords

The corpus's most common words reveal workforce and skills literature's main themes and key areas. The frequent use of "human" and "humans" suggests a broad and inclusive approach, emphasising the importance of human beings in the investigations. "Education" emphasises the importance of education in the employment and skills

area. The predominance of "female" and "male" suggests a focus on gender dynamics and inequities in many situations. The recurring use of "article" may indicate a dataset-wide reference to scholarly works, while "adult" suggests a workforce-related study focus on adults. The most common words, "workforce" and "skill", underscore the research's main topics of understanding and improving workforce capacities. The term "students" emphasises education and may indicate study on student workforce preparedness. The most common words indicate a thorough corpus analysis of human elements, education, gender dynamics, workforce characteristics, and skills development. The workforce and skills literature takes a multidisciplinary and inclusive approach to studying human employment and skill acquisition, see Figure 13.
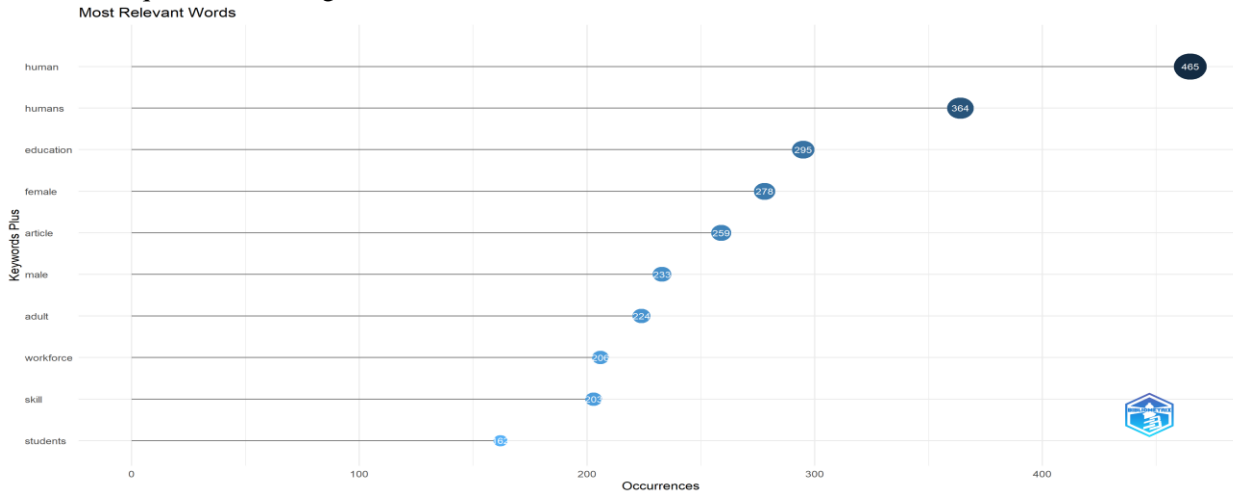
Figure 12: Showing most relevant keywords

4.5.1 Word cloud of frequent words

The corpus' phrase frequency analysis shows workforce skills research tendencies. With 273, "workforce" dominates, emphasising workforce comprehension and optimisation. "Health" follows 244, emphasising the link between workforce skills and healthcare. Repetition of "skills" at 215 shows a focus on technical and soft skills needed for workforce engagement. "Education" and "training" occurring 175 and 174 times show continued interest in skill acquisition techniques. The phrases "gap" (146) and "development" (140) emphasise practical issues like skill gaps and adapting to new needs. At 115 apiece, "care" and "study" show the healthcare sector's sophisticated exploration, while "industry" (109) emphasises different worker dynamics. This numerical summary of workforce skills study themes provides significant insights for future research and initiatives, the wordclouds presenting a summary picture, see Figure 14 &15.

Figure 13 Word cloud by frequently used words in abstracts

Figure 14: Word cloud by plotting frequently used words keywords

4.5.2 Trending Topics

Trending topics in the workforce skills corpus show changing key phrase frequencies. Terms like "human" and "humans" have dominated labour considerations since 2017, peaking in 2020 and 2022. "Education" has risen steadily, culminating in 2021, reflecting a continued focus on education in employment development. The terms "female" and "male" peak in 2017, 2019, and 2021, indicating a recurring focus on workplace gender issues. "Workforce" and "skill" have seen recent interest spikes in 2020, 2021, and 2022, indicating a renewed focus on the workforce and its skills. Due to an expanding examination of the student perspective in employment training, "students" has gained attention, peaking in 2022. Finally, "United States" has peaked in 2013, 2017, and 2020, suggesting changing attention to the U.S. workforce. This analysis shows how workforce skills research adapts to social and economic changes by highlighting changing issues, see Figure 16.

Figure 15: Trending topics in past 3 decades

4.6 Co-Occurrence network Analysis
4.6.1 Analyzing authors, keywords plus, abstract

The co-occurrence network by authors shown interesting outcomes, see Figure 17. Cluster 1, using phrases like "workforce development," "skills gap," and "higher education," emphasises current issues. High betweenness centrality of "workforce development" reflects its centrality in connecting cluster subtopics. The cluster's focus on "covid-19" and "digital transformation" shows its response to global events and its desire to adjust workforce capabilities. The term "capacity building" emphasises proactive workforce development, while "curriculum development" emphasises adapting educational content to current needs, particularly in public health.
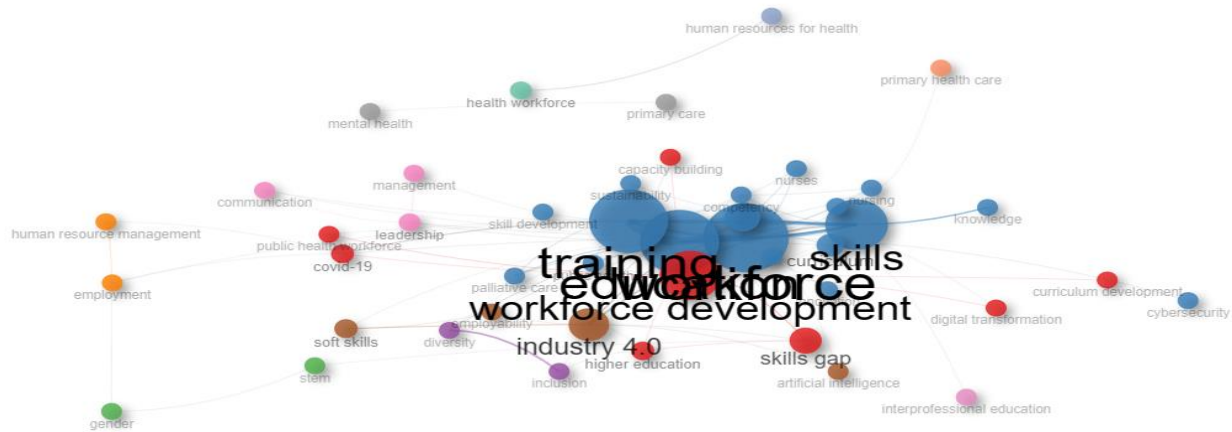
Figure 16: Co-occurrence networking by authors

Cluster 2, dominated by "workforce," "education," and "training," focuses on workforce success competencies. The strong betweenness centrality of "workforce" emphasises its integrative relevance in workforce research. The cluster emphasises "skills" and "competencies," emphasising the relevance of education and training in skill development. Having "public health" and "nursing" shows a focus on healthcare worker competencies and continual learning and development.

Cluster 3, centred on "gender" and "stem," examines gender dynamics in STEM professions. Low betweenness centrality values suggest this cluster is highly specialised. The terms "gender" and "stem" reflect a complex study of STEM gender representation and inclusion.

Cluster 4, "diversity" and "inclusion," explores varied and inclusive workplaces. This cluster's betweenness centrality ratings imply specialisation. "Diversity" and "inclusion" dominate research on workplace diversity and inclusivity.

Cluster 5, "human resource management" and "employment," focuses on workforce management organisation. The phrases "human resource management" and "employment" emphasise employee recruitment, development, and management. This cluster has a low betweenness centrality, suggesting an internal theme.

Cluster 6, "industry 4.0" and "soft skills," explores their confluence. Overall, the cluster by keywords and by abstact also presented, see Figure 18 & 19.
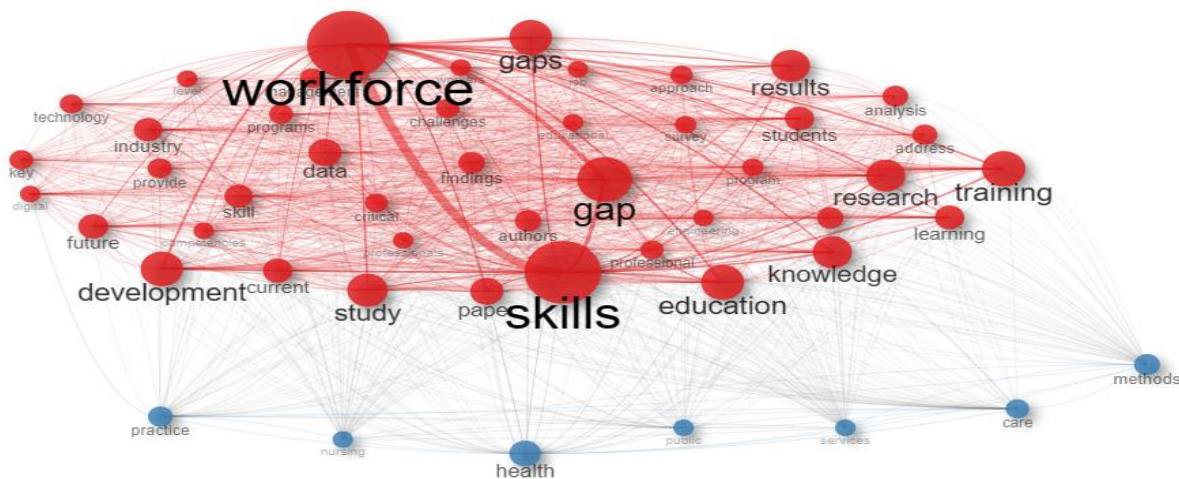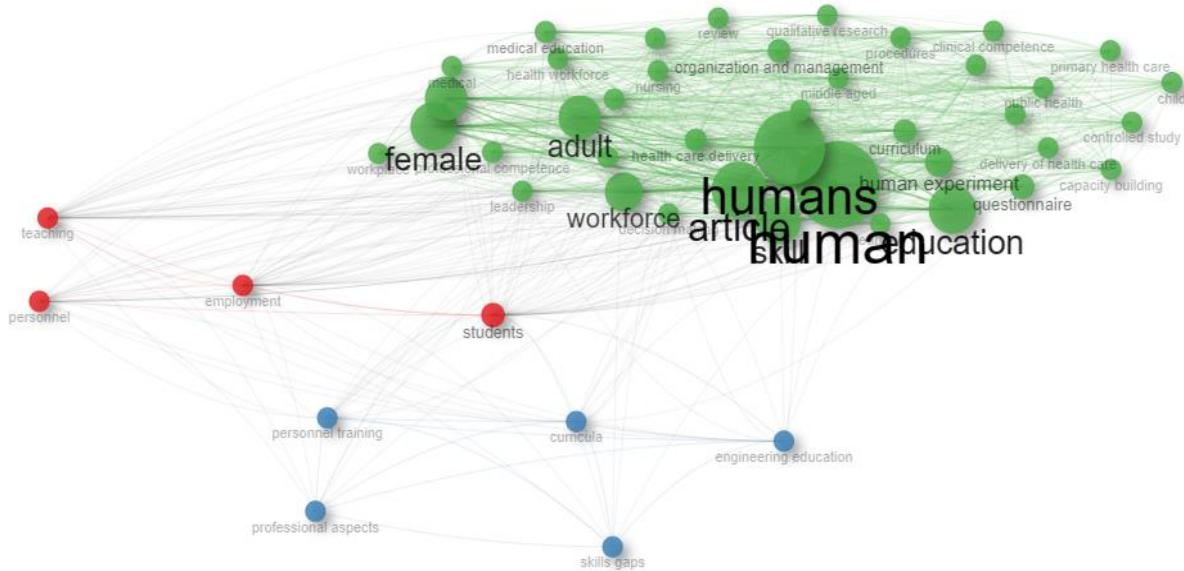

Figure 17: Co-occurrence network by abstracts

Figure 18: Co-occurrence network by keywords plus

4.7 Collaboration Networks
4.7.1 Networking by authors

Authors collaboration network study shows researcher clusters and collaboration tendencies. Network metrics reveal the collaboration dynamics of each cluster of writers who have worked closely together. Author clusters and collaboration dynamics in workforce skills research are revealed via collaboration network analysis. A cross-disciplinary network of Castrucci BC, Leider JP, Yeager VA, and Balio CP links numerous research topics in Cluster 1. Elzomor M and Pradhananga P lead Cluster 2, a close-knit intra-disciplinary group that collaborates on a specific topic. Cluster 3, including Bilgin B and Mischel CW, collaborates across scientific domains. Cluster 4 researchers Moencks M and Roth E collaborate across subfields without bridging. Cluster 5, coordinated by Salleh KM and Sulaiman NL, emphasises health sciences multidisciplinary collaboration. Cluster 6, represented by Hutchison N and Khan R, emphasises an education research collaboration. Multiple authors Akyazi T, Goti A, Alberdi E, and Oyarbide A collaborate in Cluster 7. Clusters 8, 9, and 10 represent health sciences and public health, multidisciplinary science and technology, and multi-disciplinary collaboration. Finally, Cluster 11, led by Bekemeier B and Welter CR, shows how research collaboration connects workforce skills research, see Figure 20.
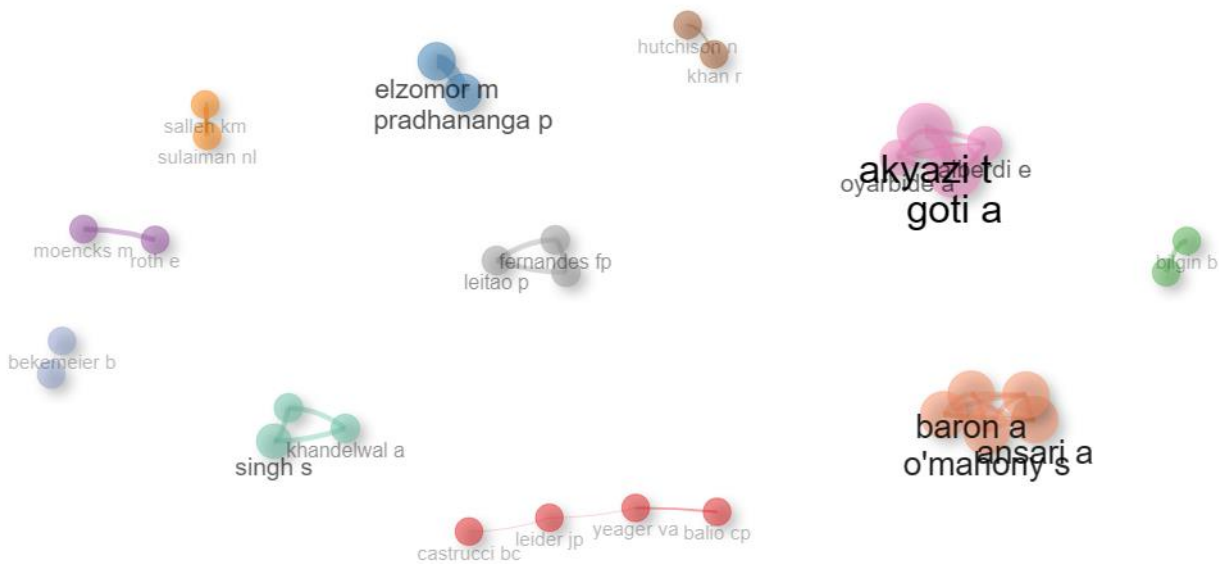

Figure 19 Collaboration network by authrs

4.7.2 Institution's Networking

Workforce skills research institutions' collaboration network highlights key participants and their significance. High betweenness ratings and PageRank values help Monash University, Melbourne University, and New South Wales University promote worldwide linkages in Cluster 1. Cluster 2 introduces Purdue University and the University of California as global research hubs. Cluster 3, which includes King's College London and the WHO, emphasises health-related workforce skills research. Cluster 4 shows how the University of Washington and University of Michigan influence worldwide collaboration. Cluster 5, which includes Southampton and Cambridge, forms a closer regional network. This collaborative environment emphasises workforce skills research's global and interdisciplinary nature, with institutions defining the field, see Figure 21.
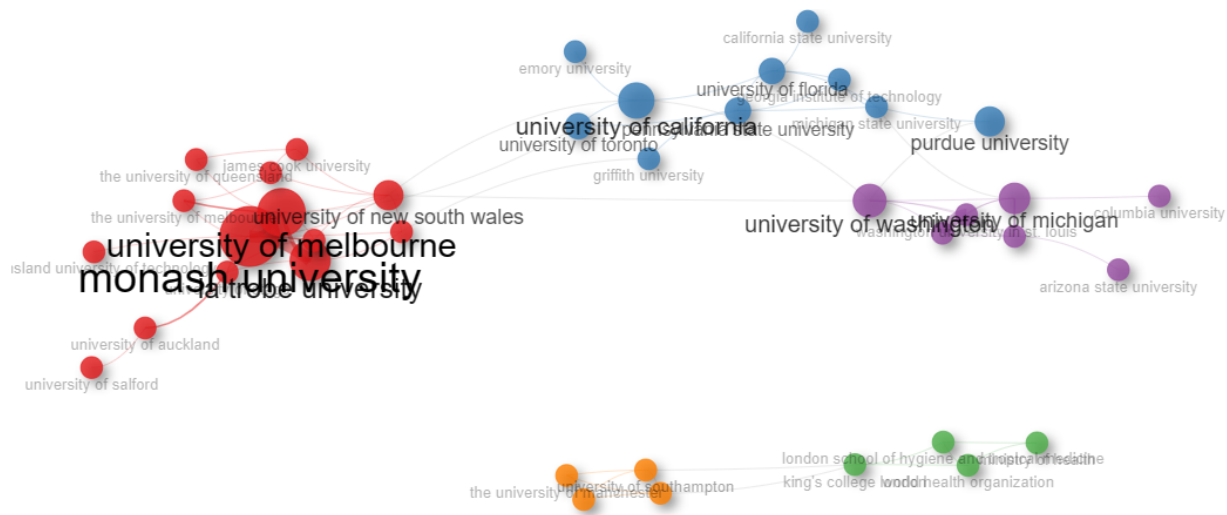

Figure 20: Collaboration network by institutes clusters

4.7.3 Countries networking

The country-specific author cooperation network illuminate's workforce skills research internationally. The US has a high betweenness score of 370.49 in Cluster 1, suggesting its important role in connecting scholars from other countries. Australia, India, Canada, Malaysia, South Africa, and China also contribute to this cluster, creating a global collaborative network. New Zealand, Kenya, and the UAE collaborate, while Korea, Indonesia, and Ethiopia are more local. Strong multinational collaboration in Nigeria and France shows workforce skills research's worldwide reach. The UK leads Cluster 2 with a betweenness score of 275.24. Germany, Italy, and the Netherlands also serve as vital links between cluster researchers. Belgium, Switzerland, and Spain show strong collaboration, highlighting this cluster's diverse international partnership environment. Cluster 3, represented by Lebanon, emphasises regional cooperation over global connection. Both global and regional research networks are shown in these country-specific clusters of international workforce skills research collaboration, see Figure 22.
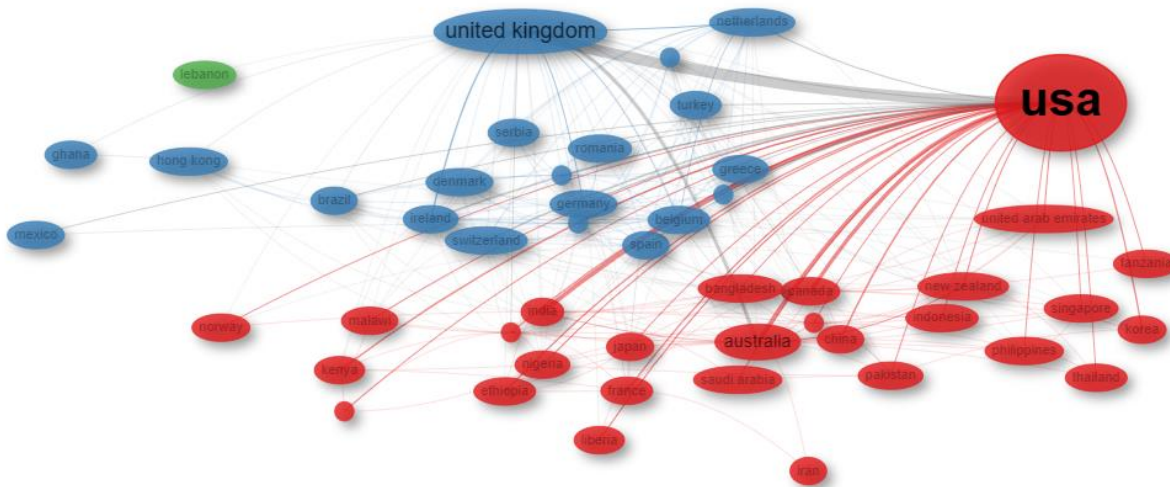
Figure 21: Countries by clusters of networking

4.8 Research Gaps and Future Opportunities
The detailed bibliometric analysis from 1987 to 2023 shows considerable advances in workforce skill comprehension, but major research gaps and attractive prospects remain, leading the way for future research.

4.8.1 Research Gaps
a) The study covers a long period, but a more detailed look at temporal trends could reveal changing labor skills research patterns due to technological advances, economic transformations, and global events.
b) Technology, education, and health intersect with workforce skills. More research on interdisciplinary collaboration and discourse shaping could help us grasp workforce skills' complexity.
c) The analysis highlights significant countries, but regional differences in labour skill development and research production may yield policy and educational insights.

4.8.2 Opportunities for Future Research
a) Future study on the effects of artificial intelligence, automation, and Industry 4.0 on worker capabilities and job market skill sets seems promising.
b) Workforce skills' adaptation in crisis conditions like the COVID-19 epidemic can reveal their resilience in dynamic and tough environments.
c) Considering workforce skills from an inclusion and diversity viewpoint can help create equitable workplaces. Research might examine how various skill sets boost organisational effectiveness and employee well-being.
d) Understanding how educational systems can adapt to teach future-ready skills is vital given the rapid speed of change. This research can inform educational policy and practices.
e) According to the prestigious "Journal of Public Health Management and Practice," worker skills and public health activities can improve community well-being.
f) This review of research gaps and opportunities intends to help researchers and practitioners focus on areas that can significantly impact worker capabilities.

5. Conclusion
In conclusion, our broad review and bibliometric analysis from 1987 to 2023 provided a data-driven and comprehensive understanding of workforce skills research. Publications have increased significantly on the annual scientific production chart, indicating greater interest and focus on the issue. Modern labour skills research is

having a greater influence, as the average citation per year has increased. Our findings have revealed the most important sources, prolific authors, influential affiliations, and key countries contributing to workforce research, demonstrating its worldwide nature. Co-occurrence networks have revealed dynamic shifts in study issues, demonstrating workforce skills studies' resilience to shifting socio-economic and technological contexts. Collaboration networks across authors and institutions have revealed complex patterns of cooperation, emphasising the interdisciplinary and cross-cultural nature of workforce skills research.

Looking at the most cited countries and documents shows how influential particular locations and key works are worldwide. The top 10 countries in labour and skills production contribute widely and diversely, with the US leading in article count. The most cited countries by total and average article citations also demonstrate the relevance of regional research. Impactful workforce study comes from the US, UK, and Australia. The study of research gaps and future opportunities guides scholars and practitioners. This study covers a long time span, however temporal trends can be more precisely analysed to reflect labour skills research pattern shifts. The convergence of technology, education, and health with workforce skills allows for interdisciplinary collaboration and a better understanding of skill development complexity. Regional disparities in labour skill development and research production may also inform policy and education. There are several study opportunities on how AI, automation, and Industry 4.0 affect worker skills and labor market skills. Understanding COVID-19-related labor skill adaptation.

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