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## THE IMPACT OF IT EVOLUTION ON INDUSTRIES AND WORKFORCE SKILLS: A SYSTEMATIC LITERATURE REVIEW

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### ABSTRACT

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Aim/Purpose	To investigate the impact of the evolution of Information Technology on global workforce skills and explore emerging approaches that address the IT talent shortage faced by diverse companies in finding skilled IT workers.
Background	This paper explores diverse approaches to bridge the skilled IT workers shortage gap, especially in the context of the widening gap following the impact of the COVID-19 pandemic. The study emphasizes the need to consistently leverage business and information technology strategies for competitive advantage.
Methodology	This study followed the systematic literature review methodology on 809 articles from ACM, IEEE Xplore, and Scopus digital libraries by utilizing an integrative mixed methods approach with topic modeling and manual content analysis.
Contribution	This paper aims to understand and describe the impact of the evolution of the IT industry on its workforce. It contributes additional evidence to our understanding of IT workforce development to support researchers and educators working towards developing effective strategies to bridge the IT talent gap.
Findings	On the one hand, the study finds that the evolution of the IT industry produces a shift in required skills and knowledge, resulting in workers needing to adapt and embrace lifelong learning. On the other hand, the evolution of IT creates

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	new opportunities for workers and results in a more globalized and interconnected workforce.
Recommendations for Practitioners	Practitioners are recommended to adapt to the shifting skills landscape, encourage lifelong learning, explore new opportunities for workers, and embrace a more globalized workforce.
Recommendations for Researchers	Researchers are encouraged to further explore the identified themes and delve into the nuances of the evolving impact of information technology on workforce skills.
Impact on Society	The findings have implications for industry growth, emphasizing the importance of aligning business and IT strategies to address the shortage of skilled IT workers on a global scale.
Future Research	Future research should focus on the continuous evolution of information technology and its impact on workforce skills, considering the identified themes as a foundation for further exploration.
Keywords	information technology, workforce skills, thematic analysis, BERTopic, globalized workforce, lifelong learning, COVID-19 impact

## INTRODUCTION AND BACKGROUND

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The definition of Information Technology (IT) is derived from the context in which it is used. In the industrial context, IT typically refers to computing applications. In the United States, many organizations have a dedicated IT department responsible for managing computing operations (Said et al., 2021). This discipline has become more widespread and applicable in various industries and roles, as evidenced by the focus on automation in Industry 4.0 and the global growth of this industry (Sahin & Celikkan, 2020). Through literature reviews, the authors observed that due to the heightened reliance on IT across multiple industries, most organizations have a separate IT strategic plan that aligns with their business and organizational goals. Thus, to achieve corporate goals, it is essential to have a competent workforce that can meet evolving IT requirements (Muraski et al., 2021). With growing interest in this field, several existing researchers have examined the discipline of IT and its role in interdisciplinary spaces. Said et al. (2021) found that the widespread adoption of computing across various sectors of society, diverse computing technologies, and the depth and interconnectedness of information processed have had a significant impact on people of all categories. Their work expands the computing domain and introduces a new academic disciplinary field called Information Technology (IT) to serve the increasing demand for IT talent needs of applied computing professionals. Said et al. (2021) broadly defined IT as having four independent components: technology, information, people, and solutions or needs. This covers leveraging the technology of the time to proffer solutions that address the needs of people. It is evident that IT is a practical computing field with rising demand, and it has seen significant advancements in technologies and frameworks. One proposed by Said et al. (2021) caters to the open opportunities in IT research to meet the requirements of people, existing technologies, and information. Similarly, a study conducted by Riep et al. (2023) described the growing talent shortage for IT professionals, mentioning solutions to fill the needs of the people and citing the importance of filling this gap. Further, Bastý et al. (2023) mentioned that IT is fast evolving, with four phases observed under this evolution, while the current phase is “Information Technology Research & Education.”

In a further literature review, studies explored how the field of IT can address the shortage of skilled workers in the rapidly changing IT industry, especially exploring mechanisms that incentivize transitions at each level to motivate future IT talent to enhance their training, capabilities, and skills (Parra-

Valencia et al., 2023). However, there has been a lack of research on how IT has impacted other industries, particularly in today's world, where IT is cross-cutting and essential (Sahin & Celikkan, 2020). Understanding how technological advancements are transforming the job market and the necessary skills for the future is crucial, especially considering how IT evolution affects the abilities of different groups of workers. With IT rapidly changing the skills landscape, it is critical to grasp the impact of technological advancements on the job market and identify the essential skills for different worker groups in the future.

While research on talent shortages centers on IT, the focus is shifting to attracting and retaining talent across industries, and this aligns with our interests (Muraski et al., 2021). There is an observed gap in the research of IT workers, not just in the field of IT but in industries in general. There is also the evident impact of workforce skilling due to the evolution of IT. This gap is what our work seeks to spotlight and address.

Though some studies discuss the automation of workplace processes by using IT strategies (Gavin Lai et al., 2020), there are, nonetheless, few works that exist around the impact of these processes on skills over the years relating to the evolution of IT. Most research focuses on how IT can be used for streamlining work and other ways IT can be leveraged for work improvements (Mehmood, 2021).

The purpose of this study is to fill the research gap by investigating how the development of IT has affected the abilities and expertise of workers in various industry groups. As information technology races forward, the skills workers' needs are rapidly changing. Understanding this dynamic is crucial to ensure the workforce has the tools to excel. Given this, the research question for this study is:

*What is the impact of the evolution of Information Technology on the skills of the workforce in diverse industries?*

## METHODOLOGY

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This study follows the systematic literature review (SLR) methodology mentioned by Kitchenham and Charters (2007). This approach integrates a mixed methods approach, combining quantitative and qualitative methods, which offers a comprehensive understanding of the literature (Akbarighatar et al., 2023). This approach (see Figure 1) was inspired by the methodology used in Akbarighatar et al. (2023) and added some novel steps to that methodology for getting more accurate topic clusters to conduct precise thematic analysis. It involves three primary phases: (i) systematically collecting relevant papers from different digital libraries based on search criteria, (ii) conducting topic modeling using BERTopic on the collected papers, and (iii) performing a manual thematic analysis on selected papers for the primary study within the relevant themes identified through topic modeling. This approach proved to be highly beneficial for our study as we had to sift through a substantial number of academic articles. Given the constraints of time and resources, this method was particularly advantageous for the systematic literature review process, expediting the analysis, especially when conducting thematic analysis on a large volume of text data. Furthermore, the capability to generate graphs and visualizations through this computational method compared to other traditional methods has proven to be invaluable for our analysis.

In the first phase, a corpus of papers was collected by using the search queries (see Table 2) and utilizing the inclusion and exclusion criteria mentioned in Table 1. In the second phase, a topic modeling technique in natural language processing (NLP) on text data was utilized to identify the preliminary topics. This was conducted using an iterative approach, where the topics generated by a clustering model developed by the BERTopic Python library were checked for outliers. Where outliers existed, the topics were screened again for the assessment to be in line with the research question at each iteration until no outliers were detected. The BERTopic model was identified and screened for relevance to the research question. The generated topics were screened independently by the first two authors manually in each iteration. They revalidated their selections with each other in each iteration and selected a set of topics for further analysis by checking for potential new topic clusters. In

the third phase, the findings from the second phase were utilized to create a list of papers for further analysis. This approach provides an efficient solution for analyzing large volumes of data (Akbarighatar et al., 2023). In the BERTopic model, a cluster that is classified as an outlier can potentially contain a topic that comprises common words that are unrelated and cannot be interpreted in a meaningful way. Considering this and the accuracy of human intuition, the manual content analysis was conducted on selected topic clusters and checked for the non-existence of outlier clusters in each iteration.

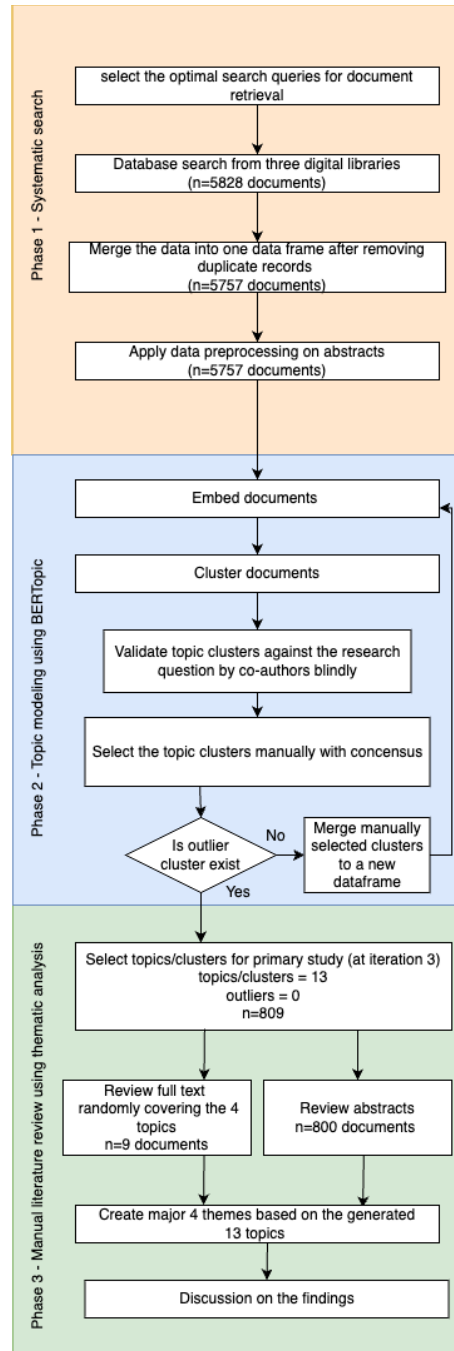


Figure 1. Flowchart of methodology

## ***INCLUSION AND EXCLUSION CRITERIA***

To explore the evolution of information technology, this study utilized the ACM, IEEE, and Scopus digital libraries. These renowned databases for computing professionals encompass various publications across various fields. We employed specific inclusion and exclusion criteria (detailed in Table 1) to extract relevant data aligned with our research question. The timeline of the articles was not a factor, as our focus was on the broader trends in IT development.

**Table 1. Inclusion and exclusion criteria**

<b>Inclusion criteria</b>	<b>Exclusion criteria</b>
Articles relevant to information technology, its history and evolution	Articles written in non-English languages
Articles that focus on the industry	Articles that describe academic programs
Articles that focus on the industry workforce and their skills	Books
Articles that are peer-reviewed journal articles	Encyclopedias
Conference proceedings and book chapters	Videos
Magazines	

## ***SEARCH PROCESS***

The first and second authors independently accessed the university’s digital libraries on Monday, November 20, 2023, to screen articles based on titles for selection. After several iterations, the optimized final search queries were developed for different databases, as shown in Table 2.

**Table 2. Search queries**

<b>Database</b>	<b>Final optimized search query</b>	<b>Search results</b>
ACM	[All: information technology and] AND [All: workforce and] AND [All: transformation and] AND [All: it skill gap and] AND [All: evolution]	1063 documents
IEEE	(“All Metadata”:information technology) AND (“All Metadata”:workforce) AND (“All Metadata”:evolution) OR (“All Metadata”:IT talent gap) OR (“All Metadata”:skills) AND (“All Metadata”:transformation)	300 documents
Scopus	(“information technology” AND workforce AND evolution AND ( industry OR transformation OR “industry skill gap” ) )	4465 documents

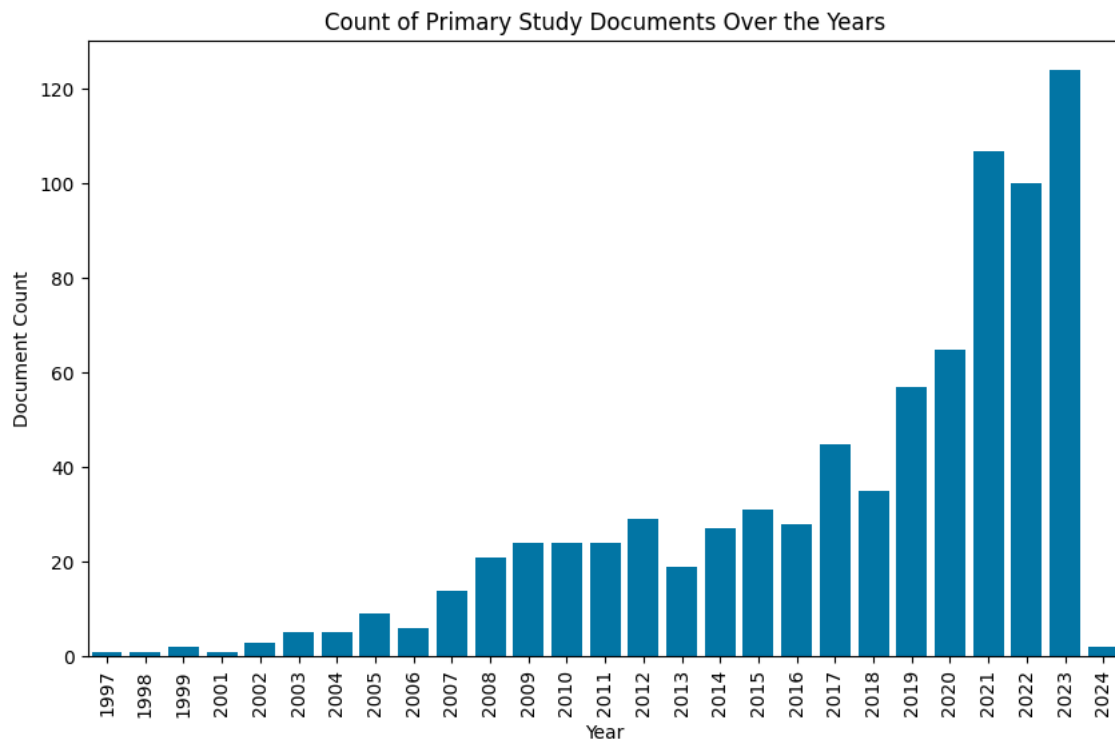
The articles were downloaded as separate CSV files from three digital libraries with bibliographic data, including abstracts of relevant papers. The articles were merged into one data frame with 5,828 documents using the Python programming language to perform text preprocessing. After removing duplicate records and data preprocessing, 5757 documents were qualified for applying topic modeling in Phase 2.

Topic modeling techniques use statistical modeling, machine learning, and natural language processing to extract topical patterns from a collection of unlabeled texts (Kotsialos & Vassilakopoulou, 2023). Automated topic modeling can reduce analysis costs but has lower accuracy than manual practices (Akbarighatar et al., 2023). One of the advantages of using BERTopic, a Python library, is that it can detect outliers automatically by eliminating unrelated articles, and it uses the Transformers for efficient topic selection (Akbarighatar et al., 2023). The study utilized a mixed-method approach that combined BERTopic for topic modeling with manual content analysis by the authors until optimal

topics were generated. The manual content analysis was conducted by the first two authors and was based on the research question that had been formed. Here the topics generated by the model were screened manually for selecting the proper set of documents suitable for further analysis. This was conducted independently by the two authors. They reached a consensus on topics suitable for the research question by looking at the common words generated by the model and removing words that were deemed not related to the research question. Thus, at each iteration, a certain number of topics were removed. Three iterations were conducted based on this approach, and the results obtained at the third iteration are presented in the results section.

## RESULTS

There are 809 documents in the primary study corpus, published between 1997 and 2024. Figure 2 indicates the distribution of these articles according to the year of publication. It shows that more than 60 documents relating to IT evolution in the workplace have been published annually since 2020, implying that the COVID-19 pandemic has led to a significant shift towards digital transformation across industries. This shift resulted in most industries going virtual in 2021.

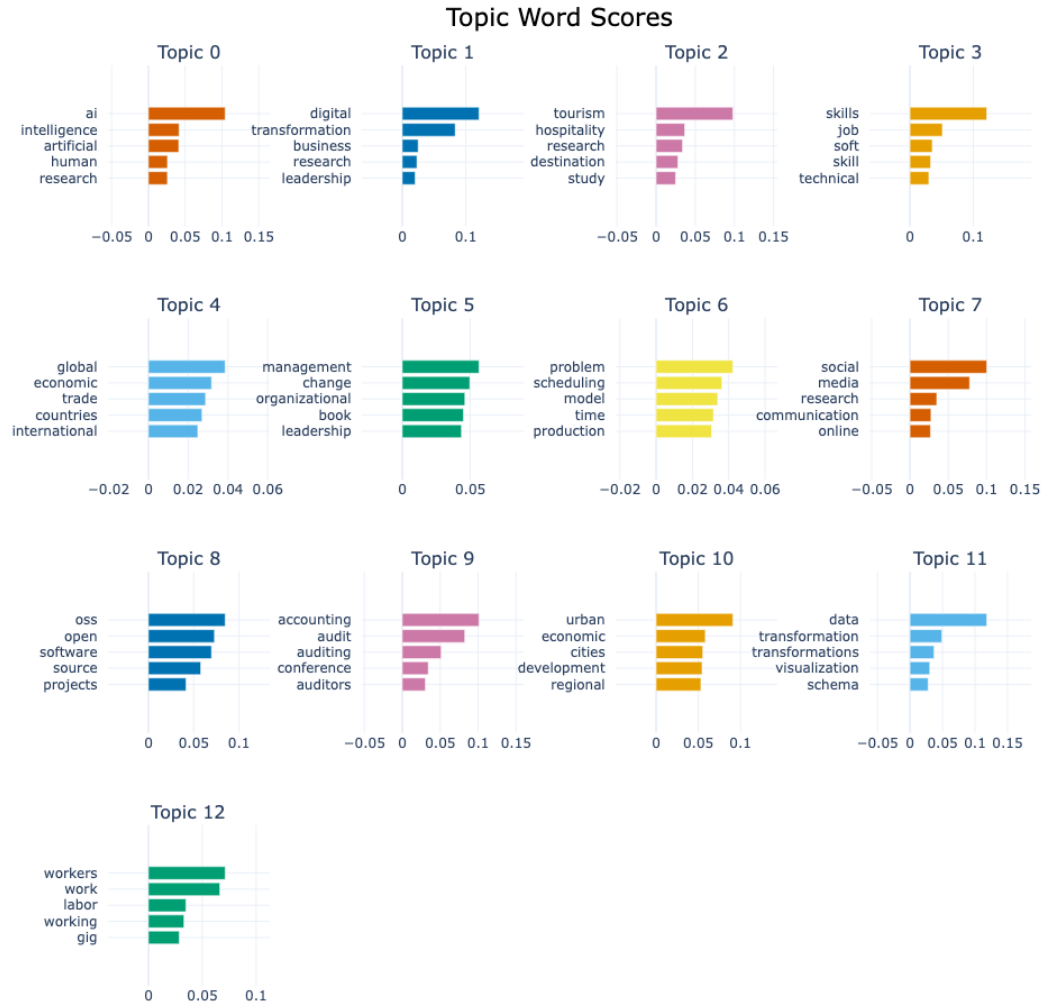


**Figure 2. Distribution of documents over the years**

In Phase 1, a total number of 5,757 articles were selected as input to Phase 2. Phase 2 was repeated for three iterations until the model generated topic clusters with no outlier clusters. In the first iteration, the BERTopic model generated 83 topic clusters, out of which one cluster contained 1,404 documents that were considered outliers. The two authors manually analyzed these topics based on the research question and selected 40 topics for further clustering, with 1,567 articles selected as input for the second iteration. In the second iteration, the model produced 35 topic clusters, and one cluster with 47 documents was considered an outlier (the model represents outliers as a -1 cluster where irrelevance words are detected). Again, based on the research question, the authors manually analyzed these topics and selected 26 topics for the next iteration, which consisted of 809 articles. In the third iteration, 13 topic clusters were created by the model (Figure 3), which were screened to ensure their

compatibility with the research question, and found that no outlier cluster was generated. Hence, Phase 2 generated 809 articles as input to Phase 3, where manual content analysis was conducted.

Figure 3 visualizes the selected terms for a few topics by creating bar charts from the c-TF-IDF scores for each topic representation. Insights can be gained from the relative c-TF-IDF scores between and within topics. Using c-TF-IDF scores, it is easy to compare topic representations to each other.



**Figure 3. Topic words visualization from 3rd iteration**

The main themes for the thematic analysis were identified by analyzing the top word frequencies for each topic presented in Figure 3. A similarity matrix was then created (Appendix A) to confirm the relationships between each topic. The topics were renamed based on their similarity, and an inter-tropical distance map was used (Appendix B) to measure the vector distance between topic clusters. The main distinct themes were identified by generating a hierarchical clustering dendrogram (Appendix C), which helped to understand the relationship among the clusters.

Table 3 represents the distribution of primary study articles over the years in relation to the 13 topic clusters. It is evident that the Artificial Intelligence sector has been continuously developing since 2015. The Tourism and Hospitality industry has undergone rigorous, fast development since 2005. From 2000 to 2015, there is little evidence of IT advancements in the governance or leadership sector. Of the 13 topic clusters, the authors identified four major themes, as shown in Table 4.

**Table 3. Primary study articles distribution over the years for different topics**

Topics	Years	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025
ai_artificial_intelligence_human		0	0	0	1	19	84
digital_transformation_leadership_business		0	0	1	0	34	58
tourism_hospitality_destination		0	0	6	5	26	43
skill_job_soft_skill_technical		1	3	18	16	23	14
gobal_economic_trade_countries_international		0	5	16	30	14	9
management_change_organizational_book_leadership		0	7	16	17	16	16
poblem_scheduling_model_time_production		0	1	5	9	22	28
social_media_research_communication_online		0	0	5	13	14	16
oss_open_software_source_projects		0	1	6	12	20	7
acounting_audit_auditing_conference_auditors		0	0	2	2	7	27
urban_economic_cities_development_regional		1	5	4	11	10	9
data_transformation_transformations_visualization_schema		0	0	8	9	12	8
workers_work_labor_working_gig		2	1	2	5	13	14

**Table 4. Major themes identified**

Major theme	Topic no.	Descriptive themes from the frequent words
Shift in required skills and knowledge	Topic 0 Topic 1 Topic 6	AI, Digital transformation, Research, Problem-solving
Need for adaptability and lifelong learning	Topic 3 Topic 7	Change, Skills, Learning, Online platforms, Remote work
New opportunities for workers	Topic 4 Topic 12	Gig economy, Online platforms, Remote work, Global trade, Countries
More globalized and interconnected workforce	Topic 4 Topic 7	International, Communication, Global trade, Countries

## DISCUSSION

To bridge this growing gap between worker skills and industry demands, this research delves deeper into the specific skill shortages emerging across various sectors. The results show that the fast-paced IT evolution, particularly post-2020, is reshaping the worker landscape. The demand for skills, adaptability, and lifelong learning has increased, indicating a dynamic shift in industry-based skill needs. This shift resulted in most industries going virtual in 2021.

Furthermore, to uncover the impact of the evolution of Information Technology on the skills of the workforce in industries, Figure 2 illustrates an increase in IT domain publications since 2020, attributed to the COVID-19 pandemic catalyzing widespread digital transformation and virtualization across sectors. Given the absence of location data in the primary study, it limits a country-specific analysis.



The first major theme underscores a paradigm shift in required professional skills and knowledge, embracing AI, digital transformation, research, problem-solving, and technical skills. As these areas emerge, the second major theme emphasizes the need for adaptability and lifelong learning, which catalyze change. It also touches on upskilling or reskilling to allow for the ease of pivoting with the emergence of new technologies for the workforce. A consequence of this is the prevalence of online tools, which has caused growth in the areas of remote work and online schools. The third major theme further highlights new opportunities for workers in the gig economy through the existence of online platforms that have been modeled beyond just remote work but are essential for fostering seamless global trade and cross-border collaborations. Lastly, the fourth major theme further presents a more globalized and interconnected workforce, riding on international communication to strengthen global trade. The impact of the results is true even for present settings by stimulating consideration of the importance of focused skill development and strategic adaptation to meet the changing demands of modern industries.

It is observed that the constant evolution of Information Technology (IT) has significantly impacted the skills required by the modern workforce across industries. This study identified four key themes with corresponding topics that capture the multifaceted effects of IT on workforce skills.

Existing research shows widespread changes in the working environment in diverse industries, with an example focused on interpreters whose field has new and higher demands on their capabilities and qualities, requiring them to learn and master advanced translation technologies (Xiao, 2022). This is evident in our first major theme, skill transformation. Topics such as AI, digital transformation, and big data highlight the growing demand for specialized skills and knowledge. Automation of tasks previously performed by humans further drives the need for high-level expertise. Industries reliant on IT, like technology, finance, and healthcare, are at the forefront of this skills transformation.

Similarly, regarding the growth as IT evolves in the workforce and talent hiring, existing work proposes an AI capability framework for Human Resource Management applications, which includes identifying the resources required to successfully adopt AI within organizations to ensure these complement human skills. This framework facilitates the development of workforce knowledge and collaborative intelligence capability (Chowdhury et al., 2022).

Another key finding from our work is adaptability and lifelong learning. Workers must remain agile and readily acquire new skills to stay relevant in the digital age. Research, change management, and skills development initiatives are crucial to equip individuals with the necessary tools and knowledge. In addition, online platforms and remote work opportunities further facilitate learning and adaptation for a flexible and adaptable workforce. In their paper, Song et al. (2022) reveal that integrating AI agents into human teams improves coordination, communication, and performance, enabling teams to adapt to disruptions more effectively. From our findings, AI-assisted human teams devote more effort to information handling and exploring the solution space more broadly, hence empowering humans to focus on creative problem-solving. New Frontiers for Workforce Development have erupted with the wave of evolution described as catalyzed by digitalization. This was evident from our study as the evolution of IT opens doors for innovative approaches to workforce development. The gig economy, fueled by online platforms connecting skilled workers with global opportunities, empowers individuals with career control. This fosters a dynamic and accessible environment for talent development and utilization, acting as a bridge between digital business strategies and their execution through well-defined digital transformation roadmaps (Brown & Brown, 2019).

A growing, interconnected, and globalized workforce fueled by IT advancements necessitates seamless integration across borders and cultures. Effective communication, cultural awareness, and strong leadership are now crucial for individuals and organizations to thrive in this digital landscape. Research highlights the importance of leadership in digital transformation to bridge cultural gaps and facilitate smooth collaboration (Urs et al., 2023).

Our findings resonate with existing research highlighting the transformative impact of IT on workforce skills. Studies by Huang and Wang (2022) and Garrido et al. (2010) emphasize the increasing demand for high-skilled workers and the need for continuous upskilling and reskilling, especially following the pandemic when industries have been transformed. Additionally, research by Pomfret (2014) highlights the importance of collaboration between educational institutions, governments, and businesses to address the evolving skill gaps. The work analyzes the relationship between Industry 4.0 and international business, identifies research gaps, and proposes future research agenda domains in international competitiveness and organization. From the above, it is evident that these skill gaps require solutions beyond just general adaptability and lifelong learning.

## CONCLUSION

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Rapid IT innovation is causing substantial talent gaps across businesses. Expertise in AI, big data analysis, and machine learning is becoming increasingly important in industries such as technology, finance, and healthcare to fully maximize the use of these powerful technologies. Similarly, digital transformation skills such as cloud computing, cybersecurity, and digital marketing are in great demand across many industries. As evidenced by the requirement for interpreters to grasp sophisticated translation technology, these skill shortages necessitate targeted solutions. While lifelong learning and adaptation are crucial, establishing industry-specific training programs focusing on AI, big data, and digital transformation can help to close the skills gap and ensure a workforce prepared for tomorrow.

Based on these findings, we recommend prioritizing lifelong learning, developing technology-specific skills, embracing flexible work models, nurturing soft skills, and forming global collaboration for workforce development. Industry experts have emphasized the importance of educational institutions updating their curricula to align with industry demands as well. In conclusion, given the rapidly changing job market and the increasing use of technology in the workplace, educational institutions must update their curricula to align with industry demands and provide students with the necessary skills to succeed in the workforce.

## *LIMITATIONS*

There are limitations to the study. Although knowing the relevance of literature is a critical step in any research endeavor, it is worth noting that the keywords used for this purpose may not be consistent across different subject areas and languages. There may have been some bias in the article selection identified in the review due to the search terms used. Consequently, there is a risk of overlooking some valuable studies based on the selected keywords and search terms. However, due to the lack of country labels in the compiled dataset, this analysis was not possible. As technology applications and depth vary across different countries, a comprehensive study should consider the technological situation in major countries. Furthermore, this study was limited to articles from a specific number of years, which restricts the analysis of the real evolution of IT. Moreover, another limitation is that it is difficult to know whether the required information is present in the title and/or abstract when screening since this study majorly considered the abstracts but not the entire paper except for nine papers that were selected randomly from the primary studies. This study encountered several articles that were insufficiently informative to document satisfactorily in the extraction form. Specifically, it was observed that the methods were not adequately described, issues of bias and validity were not addressed, and methods of data collection and analysis were not well-explained in many instances.

## *FURTHER WORK*

For the furtherance of this work, it would be beneficial to include more articles from additional data sources such as Google Scholar, Web of Science, and other relevant sources. The articles analyzed in the primary study, spanning more years, did not have location data to help us capture a country-by-country snapshot of the research question.

This study was conducted using a qualitative method that involved a systematic literature review. As a future work, we aim to extend this study by incorporating dependent and independent variables to find causal relationships related to the workforce levels and the stages of the evolution of information technology. This quantitative research will help us better understand the relationship between workforce levels and information technology evolution.

To gain a broader understanding of the skills required for the post-pandemic era workforce and the digital transformation efforts of major corporations, it would be beneficial to consider not only academic literature but also contemporary works and emerging themes that directly examine these topics.

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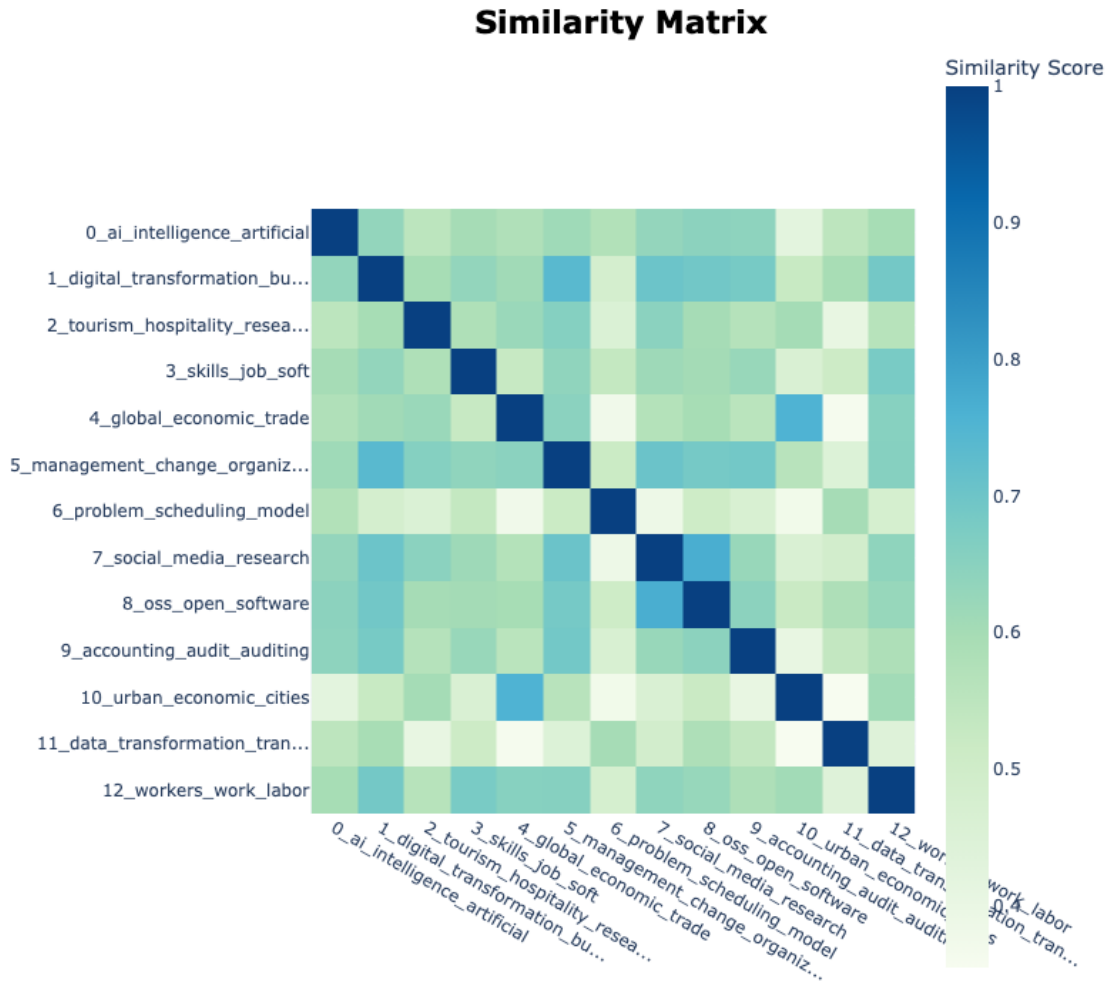
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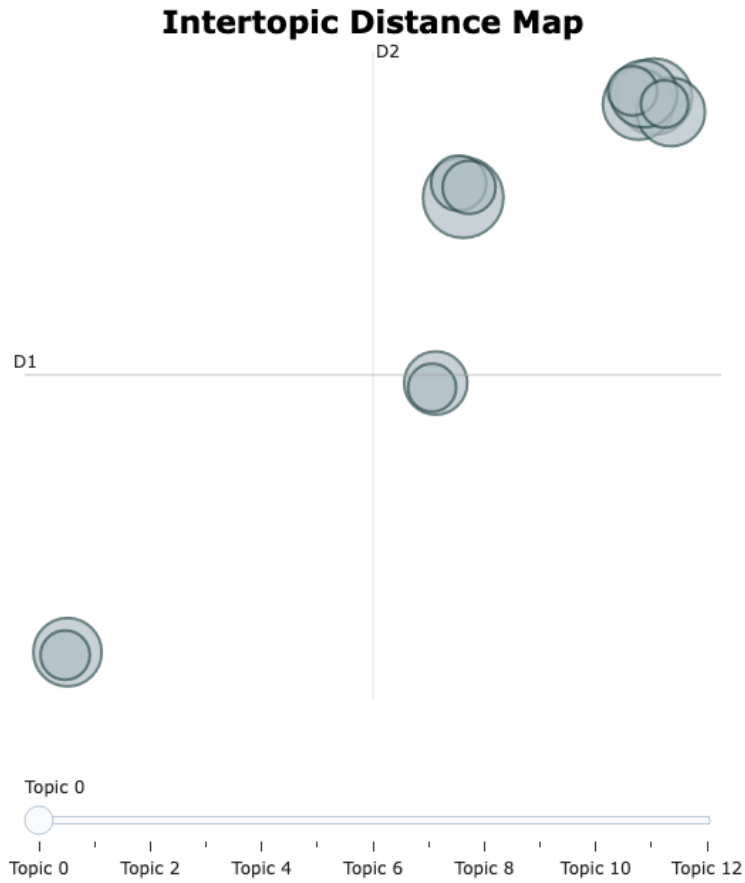
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# APPENDICES

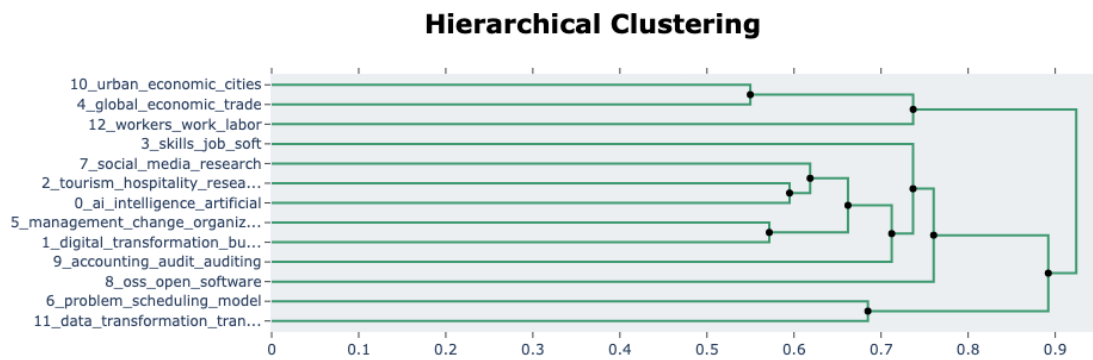
## APPENDIX A



*APPENDIX B*



*APPENDIX C*



## AUTHORS

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**Hansinie Madushika Jayathilake** is a Graduate Research Assistant at the University of Cincinnati (UC) and is currently working as a full-time doctoral student in UC's Ph.D. in Information Technology program. She has a master's degree in Big Data Analytics and has experience in data analysis and leveraging natural language processing and machine learning in research endeavors. She has experience working as an educator for undergraduate students in the field of computing. Her research interests focus on applying information technology to address socio-economic issues.



**Lily Edinam Botsyoe** is a PhD student in Information Technology, part of UC's inaugural Presidential Fellowship Program, and a former adjunct instructor. She is an ardent contributor to technology communities and speaks widely on issues relating to the internet, with a particular interest in women's and youth inclusion, accessibility, cybersecurity, privacy, and digital sustainability. She has experience working with security frameworks and regulations such as GDPR, ISO27001, and NIST 800. As a believer in the power of technology to accelerate development, her work focuses on human-centered approaches to building technology that ignites real impact for users.



**Dr. Hazem Said** is a Professor of Information Technology and the Director of the School of Information Technology (SoIT) at the University of Cincinnati (UC). He is a certified Project Management Professional (PMP). Dr. Said founded the UC Information Technology Solutions Center (ITSC) in 2012, where he consults with government, public, and private organizations and leads teams of professionals, as well as graduate, undergraduate, and high school students, to investigate, develop, and support a variety of information technology solutions. In addition, Dr. Said is a co-founder and co-director of the Ohio Cyber Range Institute and the Justice, Law, and Information Technology Institute. Dr. Said is the recipient of over 200 grants and contracts totaling over \$30 million and has authored over 27 articles on topics related to information technology education.