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Research Article

Exploring AI Applications in Occupational Safety: A Bibliometric Perspective on Accident Prevention

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Abstract

Occupational accidents that happen in the world of work have attracted, over time, the concern of how to implement preventive measures to avoid them. The International Labour Organization (ILO) estimates that 2 million people die worldwide each year from work-related causes. In Brazil, in the year 2022, there were 1,828 accidents involving electricity resulting in 592 deaths. A solution to improve this process is the use of available technology, especially with the modernization brought about by the so-called 4th Industrial Revolution, or Industry 4.0, This article aims to present a bibliometric research, identifying the main publications, authors, universities, countries and keywords that address the applications of artificial intelligence in work safety, with a focus on accident prevention. Data were collected from the Web of Science database, using the keywords ("artificial intelligence") AND (workplace OR "occupation health and safety" OR "accident prevention"). Data interpretation was carried out through performance analysis, based on WoS reports; and scientific mapping, using the VOSviewer software. 272 articles were found that were analyzed and composed the research. It was evident that the subject of artificial intelligence applied to work safety is still little explored, however, from 2020 onwards, there was a significant increase in scientific publications. As proposal for future studies, suggests conducting research using alternative keywords, as well as searching various databases to try to find new articles that address the topic.

Keywords

Artificial Intelligence, Work Safety, Prevention

1. Introduction

Workplace accidents have been reported since ancient times as a problem that requires preventive measures to avoid them. The New Testament of Luke mentions the collapse of the Tower of Siloam, which killed 18 probable workers. About two thousand years before Christ, Hippocrates, known as the Father of Medicine, described lead poisoning, which affected a mine worker [1].

According to the International Labour Organization (ILO), nearly 2 million people worldwide die each year from causes related to work [2], In Brazil, according to the Statistical Yearbook of Social Security (AEPS), in 2019 there were 582, 507 reported workplace accidents, of which 2, 540 resulted in deaths and 15, 923 in permanent disability [3]. Although there are regulations to ensure safety at work, paradoxically, the national prevention system is still flawed and does not contribute satisfactorily due primarily to the dominance of behavioral safety approaches, which are heavily dependent on humans, the ones who drive professional practice and safety

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programs in companies [4].

Understanding the great challenge that accident prevention poses for organizations in terms of productivity, economy, and quality, there are approaches using Industry 4.0 technologies for workplace accident prevention [5]. In this context, the use of Artificial Intelligence (AI) currently proves to be a technology capable of elevating companies to a new level, making them more competitive in the market and enabling value creation, either through its ability to assist workers, allowing productivity increases, improving consumer experience, or even predicting and solving problems [6]. The introduction of these new technologies allows for innovative approaches, contributing to improved workplace safety [7].

Given the above, this article aims to present a bibliometric research study identifying the main publications, authors, universities, countries, and keywords on AI applications in occupational safety. Thus, the guiding question to be answered in this article is: What are the main studies that address the application of AI in occupational safety, focusing on accident prevention, and where in the world are they concentrated? The contribution of this research lies in deepening the understanding of AI applications in occupational safety.

The article is divided into six sections. In this Section 1, the topic is presented, along with a brief theoretical framework addressing artificial intelligence and occupational safety, as well as the research problem and proposed objective. In Section 2, methodological aspects are presented. Continuing, in Section 3, data analyses are conducted to compose the article. The work concludes with Section 4, presenting the main findings and contributions on the topic, followed by Section 5, which offers recommendations for future research, and ends with the references used in the research in the final section.

2. Methodology

This research is classified as quantitative, which, according to Gil (2008), considers everything quantifiable, meaning translating opinions and numbers into information that will be classified and analyzed [8].

As a research method, bibliometrics was used through a systematic search in databases, followed by the analysis of results. According to Donthu (2021), bibliometric analysis is a popular and rigorous method for exploring and analyzing large volumes of scientific data [9]. This method allows us to uncover the evolutionary nuances of a specific field while shedding light on emerging areas in that field.

The maps generated by the bibliometric study allow for the analysis of main citations, co-citations, bibliographic coupling, co-authorship, among others [10].

To conduct the bibliometric analysis, this research was divided into three stages, as shown in Figure 1, with the purpose of answering the proposed research question: What are the main studies that address the application of artificial intelligence in occupational safety, aiming at accident prevention, and where in the world are they concentrated?

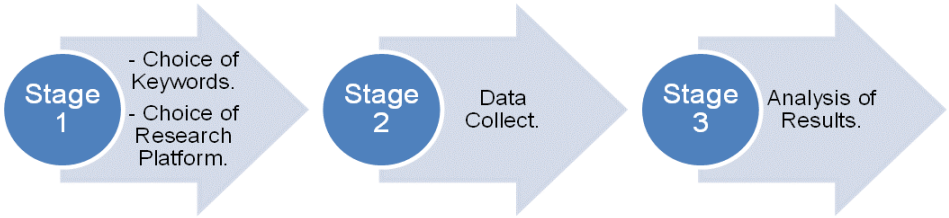

Figure 1. *Phases from the search bibliometric.*

In Stage 1, the keywords and research platform were selected. The keywords used in this article were ("artificial intelligence") AND (workplace OR "occupational health and safety" OR "accident prevention"), as these are terms aligned with the research topic of applying artificial intelligence in the workplace for accident prevention. The research platform chosen was Web of Science (WoS) from the Institute for Scientific Information (ISI), due to its multidisciplinary nature, global recognition in clustering scientific publications, and large number of relevant citations, making it widely used in bibliometric studies [11-13].

In Stage 2, data were collected based on the defined keywords, with the search conducted on February 13, 2023. Only articles were selected, and after applying the exclusion criteria, the number of articles returned was 272.

Stage 3 involved analyzing the results found. To interpret these results, an analysis of the performance reports from WoS was conducted, including the most cited publications and authors, universities, countries, as well as the most frequently used keywords. For the scientific mapping, the VOSviewer software was used. This tool enables the visualization and construction of bibliometric maps created from data viewed from different perspectives such as authors, keywords, citations, and more [14].

In this stage, a performance analysis was conducted to examine the contributions of the research constituents to a specific field. This type of analysis can be found in most reviews, even those not involving scientific mapping. This mapping is also presented in the research and concerns the intellectual interactions and structural connections between the research components [9].

3. Results It Is Discussion

As a first result, it is important to discuss the contribution of academia regarding the scientific production on the theme of Artificial Intelligence. Following the protocol presented in Figure 1, it was possible to extract some research data from the Web of Science database, as shown in Table 1.

Table 1. *Data from the search Wos.*

Publications	272
Articles what made the citations	2, 952
Number in citations	3, 210
Average per item	11.8
H- index	26

The data extracted show a good number of citations (3, 210), which is the total number of times all articles were cited. This also indicates that these citations were made by 2, 952 articles, despite the relatively low number of articles retrieved (272). Regarding the average citations per item, which is the ratio between the number of citations (3, 210) and the number of articles returned in the search (272), it was 11.8, indicating that, on average, there were approximately 12 citations per article.

Regarding the H-index, the result was 26, meaning 26 articles have 26 citations or more. This index is of great importance for evaluating highly cited articles, as it discounts the disproportionate weight of some articles that may be highly cited or those that have not yet been cited. In this case, it can be inferred that at least 26 articles have a good number of citations compared to others.

Figure 2 shows the evolution of publications, indicating the number of citations and publications over time.

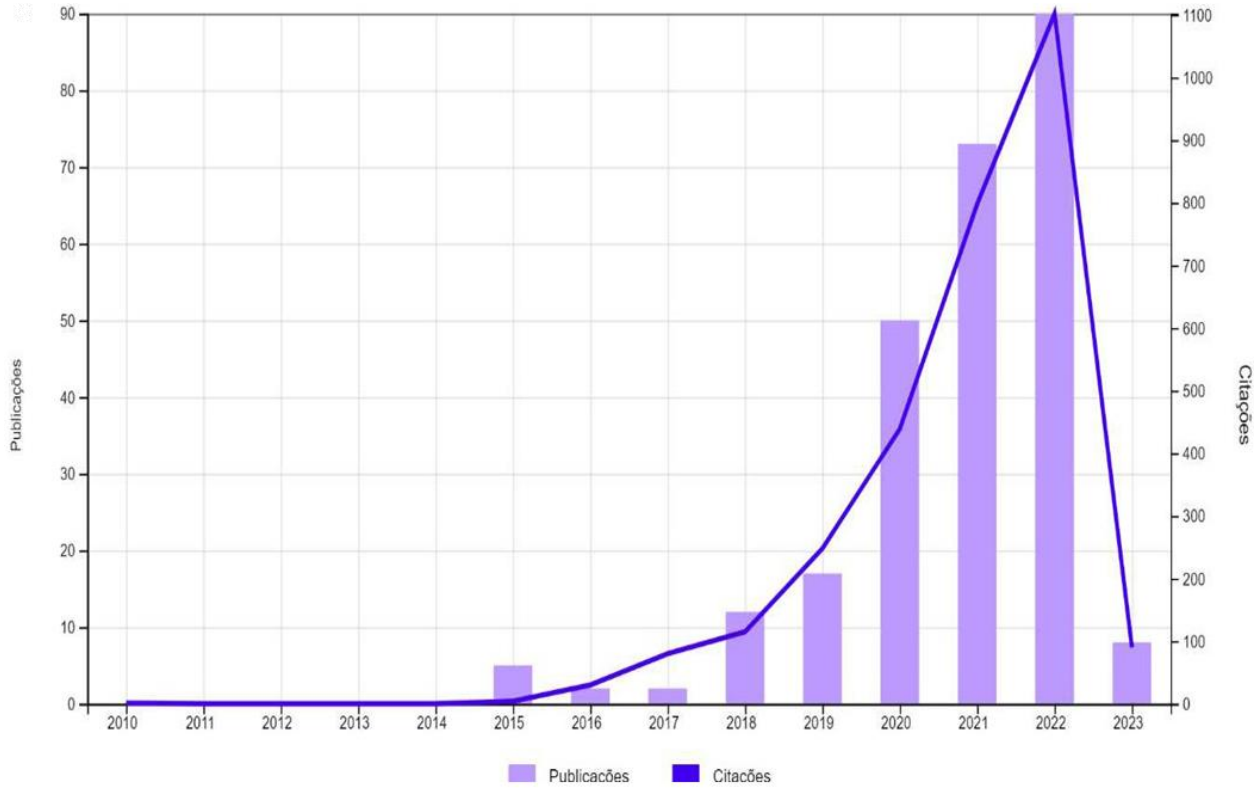

Figure 2. *Number of citations and publications over time.*

Before 2018, the number of publications was negligible. Figure 2 shows an increase in publications starting in 2018, with a significant rise in publications from 2019 to 2020 (17 in 2019 and 50 in 2020), maintaining the trend from 2020 to 2022 (50 publications in 2020, 73 in 2021, and 90 in 2022). Analyzing the citations, the year 2022 also stands out with 1, 102 citations, a substantial increase compared to 2021, which had 798 citations, maintaining the growth trend. As the year 2023 is still ongoing, a careful analysis was not conducted, despite the topic being very prominent, with a sample of eight publications and 90 citations. The number of publications from 2020 onwards indicates that the topic is gaining importance in the academic world, and the trend is expected to continue to grow in the coming years, with AI also being applied to worker safety.

Continuing the research, the data extracted from the WoS were exported, selecting the 10 most cited articles, as well as the title and author (s), as shown in Table 2.

Table 2. *Most cited articles.*

Title	Author	Quotes
Why are there still only many jobs? the history and future of workplace automation	(Author, 2015) [15]	870
Smart Technology, Artificial Intelligence, Robotics, and Algorithms (STARA): Employees' perceptions of our future workplace	(Brougham and Haar, 2018) [16]	137
Towards understanding the impact of artificial intelligence on labor	(Frank et al., 2019) [17]	120
Radar-based fall detection based on Doppler time-frequency signatures for assisted living	(Wu et al., 2015) [18]	110
"You're Fired," Says the Robot: The Rise of Automation in the Workplace, Technophobes, and Fears of Unemployment	(McClure, 2018) [19]	97
Real-Time Detection System of Driver Distraction Using Machine Learning	(Tango It is Botta, 2013) [20]	97
A great place I'm work!? Understanding crowdsourced employer branding	(Dabirian, Kietzmann and Diba, 2017) [21]	71
Risk prediction and factors risk analysis based on IFOA-GRNN and a priori algorithms: Application of artificial intelligence in accident prevention	(Xie et al., 2019) [22]	61
How will service robots resets leadership in hotel management? The Delphi approach	(Xu; Stienmetz; Ashton, 2020) [23]	47
Impacts of digitization on auditing: A Delphi study for Germany	(Tiberius and Hirth, 2019) [24]	47

The most cited articles were published starting from 2013, once again demonstrating the timeliness of the topic.

It is worth noting the article "Why are there still so many jobs? the history and future of workplace automation" with 870 citations, 6.35 times the number of citations of the second most cited article, which obtained 137 citations. In the most cited research, Autor [15] explores the question that even after some decades of the introduction of automation in workplaces, a large portion of jobs have not been eliminated, establishing a relationship between automation and work, resulting in increased productivity.

The other articles follow an almost linear trend in the decrease of the number of citations. The articles by Brougham and Haar [16], Frank et al. [17], McClure [19], Tiberius and Hirth [24], and Xu, Stienmetz, and Ashton [23] also address the impact of automation in workplaces, involving or not the use of Artificial Intelligence, which also highlights the interest in the topic, as in the article "You're Fired, Says the Robot: The Rise of Automation in the Workplace, Technophobes, and Fears of Unemployment" [19]. The author highlights the little concern of scholars regarding the increasing apprehension of a large portion of the population about the rapid changes brought about by the implementation of technology. The term "technophobes" is used in the article to describe those who fear robots, artificial intelligence, or any other technology they cannot understand.

The articles by Wu et al. [18], Tango and Botta [20], and Xie et al. [22] directly address workplace safety issues. For example, in the article titled "Risk prediction and factors risk analysis based on IFOA-GRNN and apriori algorithms: Application of artificial intelligence in accident prevention," Xie et al. [22] draw attention to disaster risk prediction as one of the most efficient ways to prevent accidents, proposing a new method of risk prediction and factorial risk analysis.

The article "A great place to work!? Understanding crowdsourced employer branding" by Dabirian, Kietzmann, and Diba [21] shows how companies can use crowdsourced employer branding intelligence to become great places to work, attracting highly qualified employees.

All the most cited research deals, directly or indirectly, with the human versus technology relationship in workplaces. This shows the concern of technological advancement in the occupational world, but the greatest concern highlighted is more focused on job loss than worker safety in work environments.

Continuing the research, the data from the 272 articles in the WoS database were exported, and the VOSviewer software was used to analyze the relationship of the most cited articles, forming clusters as shown in Figure 3.

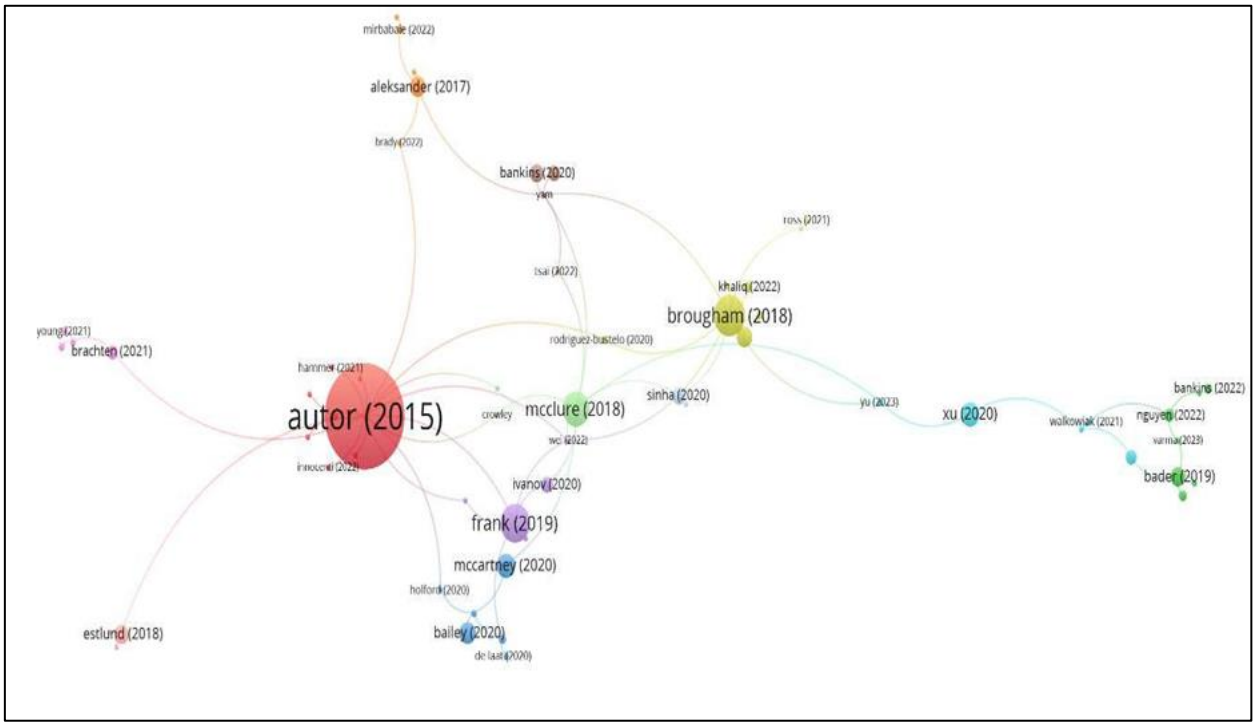

Figure 3. *Clusters of articles more cited.*

Figure 3 shows the relationship between citations and documents. Thirteen clusters and 73 links were formed, with a significant dominance of Autor [15] in the red cluster, who has the highest number of citations in his articles. This cluster formed 17 links, nearly double the number of links of the cluster with the second highest number of links, the light green cluster of Brougham and Haar [16], which has 10 links. It is evident that the interaction between author citations is still weak, being highly concentrated in just two authors, Autor [15] and Brougham and Haar [16].

Regarding the most cited authors, Table 3 provides their information.

Table 3. *List of most cited authors.*

Author	Citations
author, david H.	845
brougham, david	135
haar, jarrod	135
author, david	119
kiss, James It is.	119
brynjolfsson, Erik	119
cebrian, manuel	119
deming, david j.	119
feldman, maryann	119
frank, morgan r.	119
groh, Matthew	119
Wolf, Joseph	119
I live, Esteban	119
rahwan, iyad	119
wang, dashun	119
you, hyejin	119

Sixteen of the most cited authors were selected because from author four onwards, all had the same number of citations (119). David H. appears as the most cited (845), consistent with what was shown in Table 1, with the most cited article. The difference between the most cited article and the others is substantial, possibly because the article "Why Are There Still So Many Jobs? The History and Future of Workplace Automation" brings a discussion on job loss in the face of technological advancements, which aligns with the topic proposed in this research, applying AI in the labor world.

Figure 4 was designed to highlight the formation of clusters among the authors.

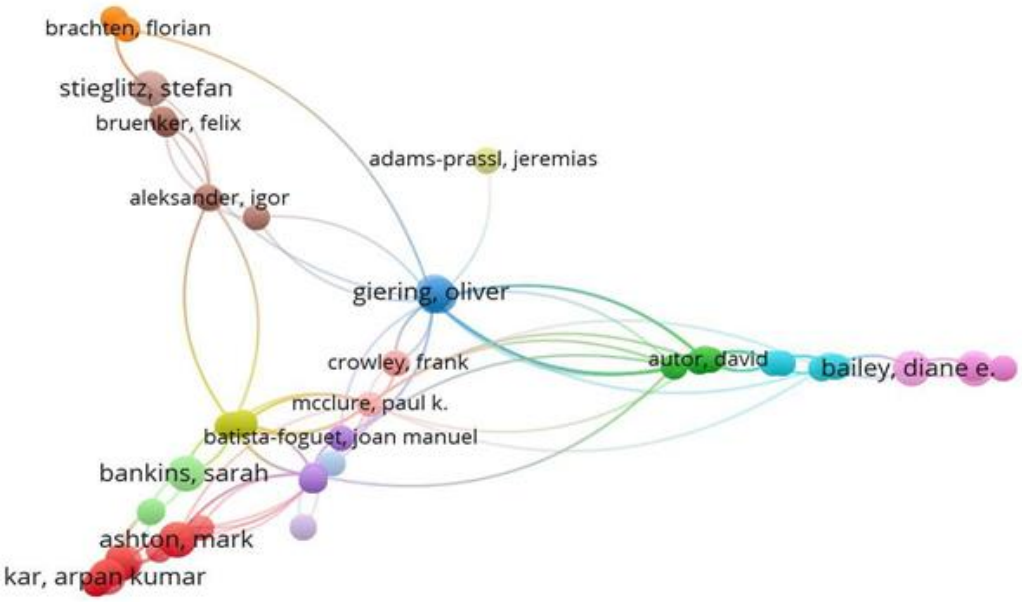

Figure 4. *Clusters of articles more cited.*

Autor stands out with great relevance and numerous interactions. Oliver also stands out, as well as Giereing and Bailey. There is the formation of several clusters, with the creation of strong relationships between the green and blue clusters. The various relationships presented show that among these authors, there were several interactions, with a few notable exceptions as mentioned.

Regarding the countries that stand out the most in the research, Table 4 presents the ranking of the top 10 countries.

Table 4. *Number in articles per countries.*

Country	Publications
USA	65
England	29
China	29
Germany	28
Australia	21
India	21
Canada	18
Spain	15
Italy	8
Netherlands	8

It is evident that the United States stands out in terms of the number of publications, with more than double the publications of England and China, which each have 29 publications. While Western countries dominate the topic, China and India are beginning to emerge in terms of the number of publications. European countries also appear to be strong contributors to technology research, and if we consider Europe as one entity, it would account for 40% (88) of published articles (including England, Germany, Spain, Italy, and the Netherlands). Even though some countries are beginning to stand out in this scenario, there is still a substantial gap compared to the United States, which alone has 29% (65) of published articles among the ten countries with publications, demonstrating its supremacy over the others. Brazil is still far from appearing in this ranking, as the research conducted returned only one article, highlighting the need for more investment in AI research in the country.

Regarding the relationship between countries and their publications, Figure 5 was created to analyze these connections.

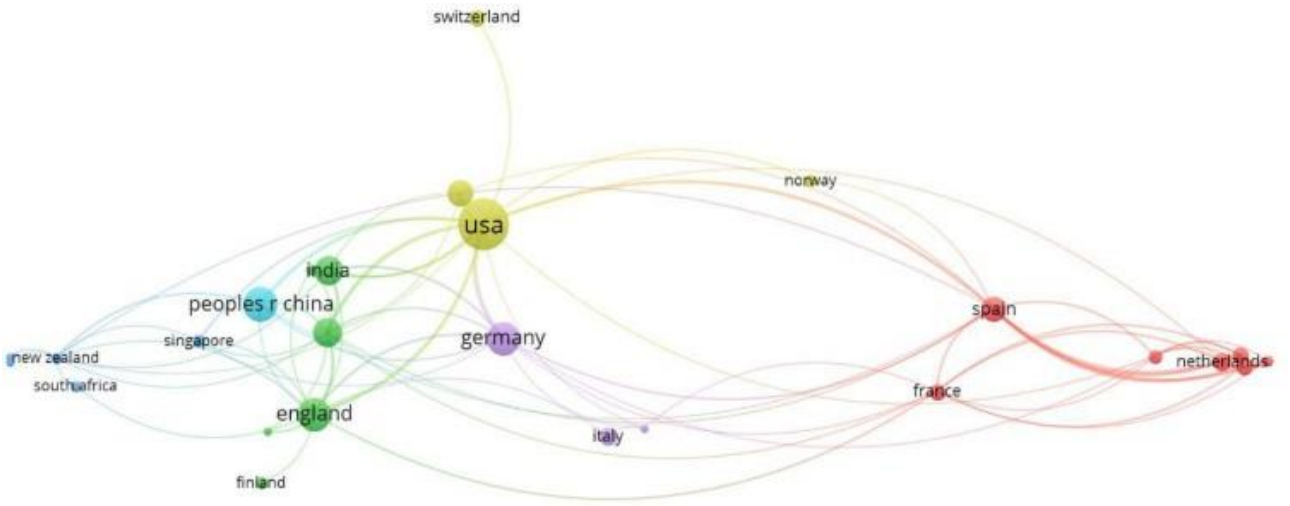

Figure 5. Relationship in countries It is your publications.

The map generated shows that publications from the United States have strong relationships with other countries such as India, Australia, and England, which form the Green Cluster. This cluster also has links with Spain, Germany, and China. Spain has strong relationships with the Netherlands and France, perhaps because they are European countries and are geographically close. New Zealand, South Africa, Singapore, and Finland also appear on the map, but with weaker connections. A notable negative aspect is that Switzerland only has a relationship with the United States, according to the figure.

Focusing on the institutions involved in the process of producing the articles, Table 5 presents the 10 universities that stand out in relation to the topic.

Table 5. Institutions more cited.

University	Citations	Country
Massachusetts Institute of technology	1047	USA
Harvard university	124	USA
Arizona State University	121	USA
University of North Carolina at Chapel Hill	121	USA
Northwestern University	119	USA
University Surrey	72	UK
Simon Fraser University	69	CAN
University of British columbia	51	UK
Cornell University New York University	45	USA
National Institutes of technology	42	IND

Following up on the countries with the most publications, as shown in Table 3, there is also a notable emphasis on the United States, with six universities among the top 10 most cited regarding publications. The top five most cited universities are also located in the U.S., highlighting the Massachusetts Institute of Technology (MIT), which is a highly respected institution in science and technology. Once again, the concentration of AI research in the U.S. becomes evident. If only considering MIT, it accounts for 58% (1, 047) of the most cited institutions among the top 10, as shown in Table 5.

Figure 6 illustrates the map of clusters formed by these institutions.

Figure 6. Universities more cited.

In this cluster formation, the Massachusetts Institute of Technology (MIT) forms the Red Cluster, with other institutions such as the University of Wisconsin and the Berlin Institute of Technology, among others. There is also the formation of links with other clusters, such as the Purple Cluster, with the most prominent being the University of

Oxford. MIT again demonstrates strong relationships with other institutions. However, it is worth noting the weaker relationships involving the University of Surrey.

In an attempt to identify the most commonly used keywords in research discussing the application of artificial intelligence in workplaces with a focus on accident prevention, a map was generated in VOSviewer, mapping the co-occurrence of keywords used, based on data extracted from the WOS database, as shown in Figure 7.

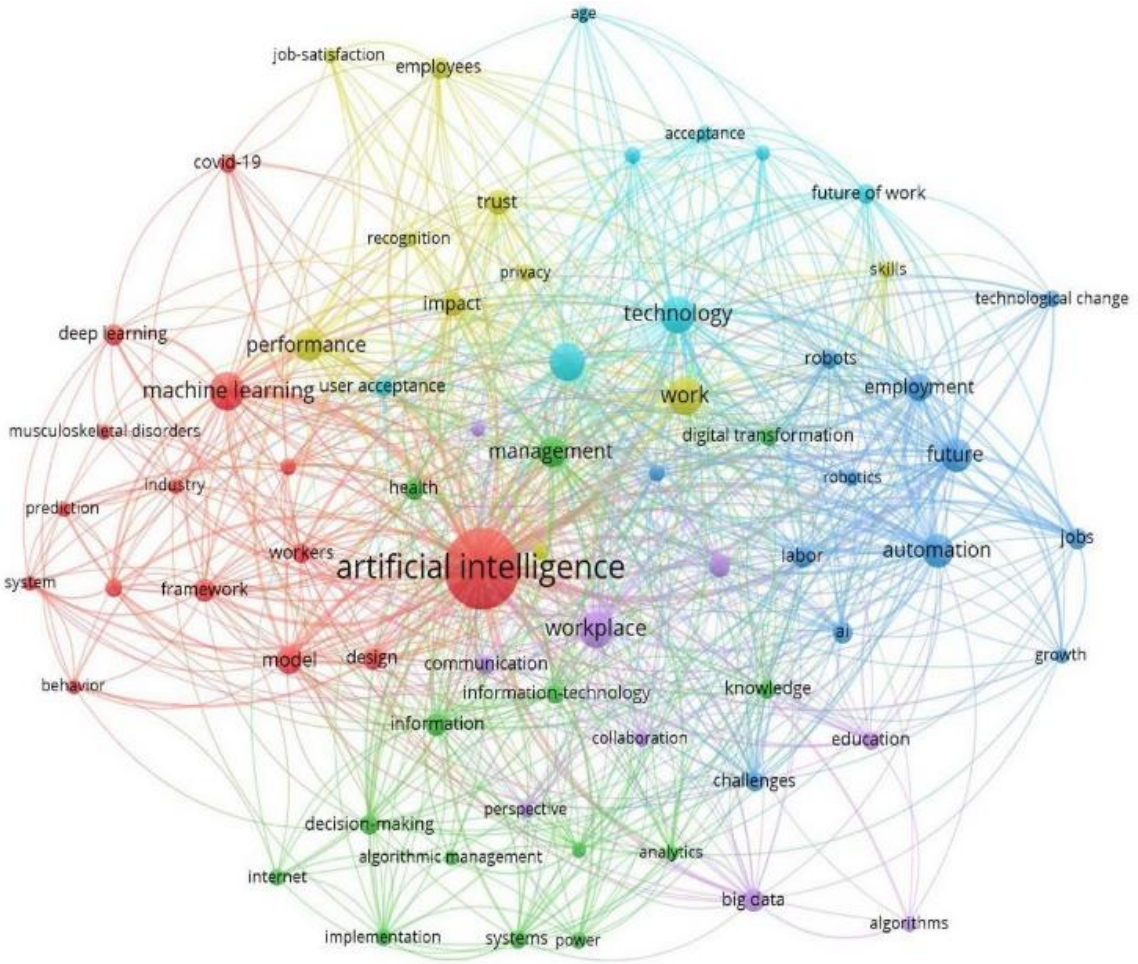

Figure 7. *Occurrence in key words.*

It is worth noting that the generated map did not use only keywords directly related to AI, but all keywords found in the articles researched. This suggests that the topic is quite broad, with various techniques available, demonstrating a good diversity of tools in relation to AI. The map shows that the term "artificial intelligence" is the most common in this type of research. Other prominent terms include "machine learning" and "deep learning," which are subdivisions or techniques of artificial intelligence.

Some other terms "shaded" the AI theme, such as "algorithms," "big data," "automation," "robotics," "technology," among others. The other group of terms is more related to the workplace, such as "workplace," "work," and "workers," among others. Since the research focuses on artificial intelligence and workplace safety, it was expected that words related to these topics would stand out.

The interaction between artificial intelligence, workplace environments, and technology is illustrated in the figure with the interactions presented between the Red, Purple, Green, and Blue Clusters. Other terms that emerged from the map show some concern for quality of life at work, such as "job satisfaction," "future of work," "privacy," "behavior," among others. This demonstrates another significant concern in the occupational world, which is the balance that must be maintained between health and safety and work.

4. Final Considerations

This study presents a bibliometric analysis of the application of artificial intelligence in workplace environments, focusing on accident prevention. A search expression that encompasses the entire proposed theme was used, employing the Web of Science (WoS) database, which returned 272

articles related to the topic. These articles were analyzed and used to generate bibliometric maps in VosViewer.

The goal of this research was to identify which and where the main research areas are related to the application of artificial intelligence in workplace environments, with a focus on accident prevention. This objective was achieved. However, the number of returned articles is very small given the importance of the topic. Additionally, many articles did not focus specifically on the application of AI in workplace environments, tending instead to discuss the future of work in the face of new technologies and whether this could impact workers' jobs. An initial analysis suggests that the topic of artificial intelligence applied to workplace safety is still underexplored globally.

It is worth mentioning the significant increase in the number of articles returned from 2020 onward, with the number of publications almost tripling compared to 2019 (17 in 2019 and 50 in 2020). There was also notable growth in 2022, with 90 publications, indicating increased interest in the topic in recent years. Although China and India have begun to stand out in this field, as well as some European countries, most research is conducted in the United States (27% of research among the 10 countries with the most publications), demonstrating the country's significant lead in comparison to others. On a negative note, Brazil was not featured in any of the topics researched in this study. Only one article was returned, placing it on par with countries such as Zimbabwe, Colombia, Bulgaria, the Philippines, and others. This highlights the need for investment in technology research in these countries, including AI.

As contributions of this work, the study highlighted the main institutions, authors, and countries in the field of AI and workplace safety. It also analyzed some interactions through collaboration networks and mapped key authors, countries, and educational institutions. Additionally, the study emphasized the most commonly used keywords in the research.

5. Future Perspectives

Due to the low number of articles returned, a proposal for future studies suggests conducting research using alternative keywords, as well as searching various databases to try to find new articles that address the topic.

Abbreviations

AI	Artificial Intelligence
ILO	International Labour Organization
AEPS	Statistical Yearbook of Social Security
WoS	Web of Science
ISI	Institute for Scientific Information

Author Contributions

Alexandre Silva: Conceptualization, Resources, Formal Analysis

Frederico Dutra: Data curation, Methodology

Fábio Corrêa: Formal Analysis, Validation

Vinícius Faria: Investigation, Review

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Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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