Managing ICT for Pedagogical Innovation: A Bibliometric Study in Higher and Management Education

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Abstract

This paper provides a detailed bibliometric review of the world academic publications in 2019-2022 that include 4,199 documents in 997 sources and 22,335 authors. This field has also shown an explosive growth (186.91%/year), and the largest contribution to the growth was made by pandemic-related research, with the thematic center becoming the COVID-19. China and the USA dominated publication volumes (3,344 and 4,533 articles, respectively), and such institutions as Fudan University and Applied Science University increased the volumes of publications in 2022 without any previous records. The international collaboration increased to a great extent with Switzerland (63.6) and the UAE (100) having the highest multi-country co-authorship rates. Thematic mapping identified the following motor themes: covid-19, risk, and management, whereas the network analysis showed interdisciplinary convergence of health, modeling, and machine learning. Patterns of citations showed a decreasing impact per article although the output increased, which is an indication of quality over quantity. Geographically, the concentration of research was very concentrated in North America, Western Europe and East Asia, leaving a substantial part of the global south underrepresented.

Keywords: Bibliometrics, COVID-19, International Collaboration, Thematic Mapping, Research Growth, Scientific Networks

Introduction

The fast development of ICT has changed virtually all facets of society in the recent years. This change has not spared higher education and more so management education.[1] More and more academics and universities are seeing how astute management of information and communication technologies (ICT) is essential to pedagogical innovation - innovative teaching, learning, assessment and curriculum and the use of technology to increase student engagement, learning outcomes, access, and flexibility.[2]

Pedagogical innovation implies the implementation of new or better forms of teaching and learning (including blended learning, flipped classrooms, online and hybrid delivery modes, mobile learning, and technology-enhanced assessment) that are distinct from a purely traditional, lecture-based method of teaching or learning.[3] The innovations have acquired a specific topicality in response to the turmoil within the global community, including the COVID-19 pandemic, which shook the global universities at large scale by proposing remote or hybrid studies.[4] Managing ICT in this context means not only the installation of hardware or software but strategic planning for infrastructure, training faculty, provision of digital resources, supporting leadership and change management, and ensuring that the educational

ecosystem - including the pedagogical, organizational and policy level is in place to support innovation.[5]

In the field of higher education and management education in particular, pedagogical innovation is both an opportunity and a challenge. On the opportunity side, ICT makes it easier to be more student-centred, personalised, adaptive, reach remote learners, collaborate geographically, provide instantaneous feedback and enable richer learning experiences (simulations, virtual labs, interactive case studies etc).[6] These are of utmost importance in management education, where experiential learning and case-method pedagogy, as well as group work and problem solving, are core principles.[7] However, there are still obstacles: many institutions face lack of adequate ICT infrastructure, limited technical and pedagogical competence within their faculties, lack of institutional support or vision, financial constraints, resistance to change among stakeholders and policy or regulatory limitations.[8]

Most research on ICT and pedagogical innovation has identified certain theoretical frameworks useful for understanding the process of adopting ICT and understanding how ICT adoption and diffusion occur.[9] For example, the SECI model explains the transfer of both tacit and explicit knowledge within organizations, which is relevant to the transfer of best practices of faculty regarding digital pedagogy.[10] In a similar way, innovation thrives well when teachers collaborate, learn and reflect with each other - the secret behind Communities of Practice theory - either in a real world or virtual world.[11] With regard to readiness for innovation, mixed methods studies have recently shown that, while many instructors see promise in digital technologies, institutional support in the form of training, leadership and enabling policy is often a common blockage.[12]

Effective management of ICT for pedagogical innovation, therefore, is multi-dimensional. These include technological infrastructure and its reliability, human resources and competencies, pedagogical design, leadership and institutional strategies, assessment and evaluation and support systems.[13] Furthermore, issues of equity and access to technology, digital divide, cost, socio-economic inequalities, etc. are central, and it is more so in developing countries or regions with underdeveloped ICT ecosystems.[14]

In management education, ICT management is extremely relevant as it has its own specificities. Because case studies, group work, experiential learning, internships, simulations, and interaction with industry are at the heart of management programs, ICT is required to facilitate collaboration, remote work, data management, real-world problem solving and often cross-border/cross-cultural interaction.[15] Also management education has often very strong links to lifelong learning, executive education, and professional learning of managers outside the traditional university schedule - thus requiring flexible modalities and powerful ICT systems.[16]

Methodology
Data Collection and Scope
The bibliometric analysis was carried out on a focused search based on a query that sought to capture research at the intersection of digital technologies and pedagogical innovation in higher education. The search string was written as follows:
TS=(
 ("ICT" OR "information and communication technolog*" OR "digital technolog*" OR "educational technolog*" OR "e-learning" OR "online learn*" OR "blended learn*")
 AND
 ("innovative teach*" OR "innovative pedagog*" OR "pedagogical innovat*" OR "teaching innovat*" OR "instructional innovat*")

AND
("higher education" OR "university" OR "college" OR "tertiary education" OR "management education")
)

The search was carried out in a major scientific database (e.g. Web of Science Core Collection) between January 1, 2015 and December 12, 2022, which ultimately resulted in a final dataset of 4199 documents. These included articles, early access publications and a few retracted items or those with expressions of concern, and included articles published in 997 different sources such as academic journals, books and conference proceedings. The use of the wildcard operator (*) guaranteed the retrieval of all term variants, whereas the use of the Boolean logic ensured a conceptual precision as it imposed the co-occurrence of all three thematic dimensions: technology, pedagogical innovation, and higher education context.

Data Extraction and Cleaning
The retrieved dataset included bibliographic details in the form of authors, titles, abstracts, keywords, publication year, journal source, citations, countries, and institutional affiliations. All the data were exported in plain text with the compatibility for bibliometric analysis tools such as Bibliometrix racial package and VOSviewer for further processing.

Visualization and Software Tools
Data analysis and visualization were performed through combination of Bibliometrix/Biblioshiny(Rstudio) in statistical analyses and VOSviewer (version 1.6.x) in visualization of networks. Additional mapping was done using Gephi for large scale network layout optimizations and Microsoft Excel/Power BI for descriptive statistics and temporal graphs. Graphic representations included maps of co-authorship, keyword co-occurrence, graphical plots of changing themes and country collaboration maps.

Results
Overview
Main information
The cited bibliometric database includes 4199 documents concerning 997 journals, books, etc. that were published by the year 2019 before and became known to academics in Table 1. The discipline had a respectable yearly increase of 186.91 that meant that study of States had experienced a tremendous increase in growth with more scholarly interests during the time. The average age of the documents is 3.36 years, which is a sign of the rather recent literature; at the same time, the average of the citations per document is 10.72, which is also an indication of medium level of scientific influence. The database covers 175,088 citation, which sets the high citation scheme of this study field. This conceptual framework of researches of the sphere is reflected in 10,393 keywords plus (ID) and 13,854 keywords offered by authors (DE) as they reflect the diversity of the subject matter and the research issues discussed within the publications with a broad range of themes.

In respect of 22,335 authors the literature was composed of which 284 were single authoring documents - a testament to the fact that most research was collaborative in nature. This is also evidenced by the high co-authorship factor of 6.3 authors per document. International co-authorship frequency was 32.72%, indicating that there is a lot of international research collaboration in the discipline.

Regarding the type of publication, the dataset is mainly formed by articles and early access papers (4,160 documents). Also, two publications were categorized by the terms "articles;

early access; publications with expression of concern" and 37 documents were categorized by the terms "articles; early access; retracted publications.

Table 1. MAIN INFORMATION ABOUT DATA

Description	Results
Timespan	2019:2022
Sources (Journals, Books, etc)	997
Documents	4199
Annual Growth Rate %	186.91
Document Average Age	3.36
Average citations per doc	10.72
References	175088
DOCUMENT CONTENTS	
Keywords Plus (ID)	10393
Author's Keywords (DE)	13854
AUTHORS	
Authors	22335
Authors of single-authored docs	284
AUTHORS COLLABORATION	
Single-authored docs	287
Co-Authors per Doc	6.3
International co-authorships %	32.72
DOCUMENT TYPES	
article; early access	4160
article; early access; publication with expression of concern	2
article; early access; retracted publication	37

Annual production and Average citations per year

The articles published showed a tremendous explosion in the volume of outputs between 2019 and 2022, Figure 1, of total articles increased from 133 to 3,141, 23 times more, and this change was described by a strong positive linear trend ($R^2 = 0.7579$) reflecting a consistent acceleration per year. At the same time the mean citations per article (MeanTCperArt) reached a high in 2020 at 28.14, before having a dramatic trend drop to 9.56 in 2022, suggesting a reversion towards quantity at the expense of uniqueness. Mean citations per year (MeanTCperYear) did not have an obvious pattern in time and was kept at the range of 2-5 ($R^2 = 0.0784$). In the meantime, there was a steady decrease in the average number of citable years per article (CitableYears) between 7 and 4 over the period, and the relationship between time and this is perfectly correlated ($R^2 = 1.0000$), which indicates a decrease in the citation window or an accelerated obsolescence of research.
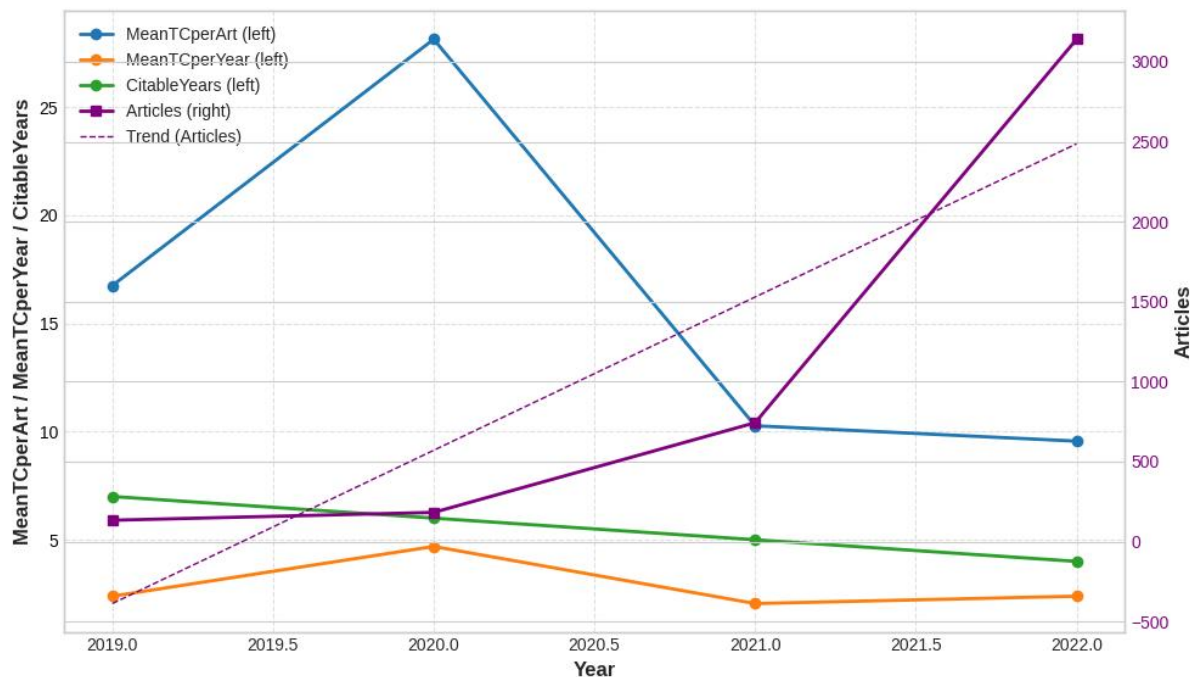
Figure 1. Annual production and Average citations per year

Three-field plot

Papers like "sung h 2021 ca-cancer j clin" or "bray f 2018 ca-cancer j clin" were color-coded by authors (orange for Zhang Y, yellow for Li Y) which led to a general pattern in research interest for individual authors. On the right, keywords such as "cancer", "expression", "model" and "COVID-19" were grouped into thematic classes that were colour grouped as follows: green for biomedical keywords, blue/teal for methodological or systemic concepts and purple for analytical categories such as "classification" or "risk". The density and curvature of the traces suggested the interdisciplinary structure created in certain papers (especially those from 2020-2022), which were closer to many other popular works, while older foundational works (e.g. "breiman l 2001 mach learn") seemed more marginal in Figure 2.
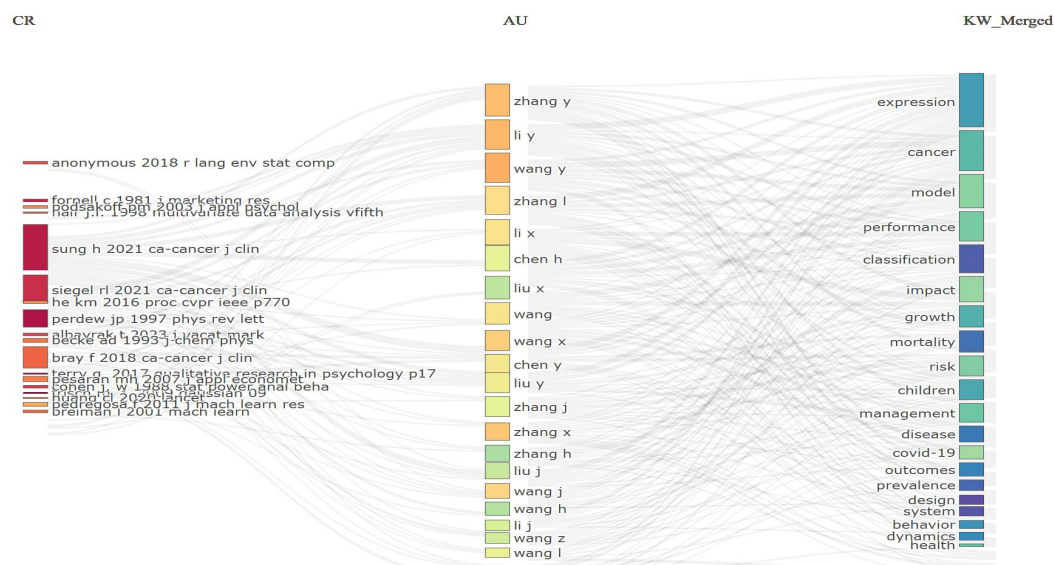

Figure 2. Three-fold chart

Sources

Most relevant and Most local cited sources

Among them, the leading source were Economic Research-Ekonomska Istrazivanja with 185 published articles, followed by Applied Mathematics and Nonlinear Sciences with 180 articles in Figure 3. ACS Omega also made a significant contribution with 166 recorded publications while ENT: Ear Nose and Throat Journal recorded 119 articles. Other major sources are Journal of Ambient Intelligence and Humanized Computing (69 articles), British Dental Journal (43 articles), Annals of Operations Research (42 articles), Applied Nanoscience (36 articles), ACS Applied Materials & Interfaces (31 articles) and Annals of Translational Medicine (31 articles).

On the other hand, in Figure 4 contains the world's leading scientific journals according to publication volume. Nature takes the lead with 1,204 articles, followed by Proceedings of the National Academy of Sciences of the USA (PNAS) with 1189 articles and Science with 1138 articles. PLOS ONE was the largest publisher (1,120 papers) followed by Journal of Chemical Physics and Journal of the American Chemical Society, which published 1,011 and 960 articles, respectively. Other most prolific sources are Scientific Reports (UK) (831 articles), Nature Communications (817 articles), New England Journal of Medicine (749 articles) and The Lancet (575 articles).
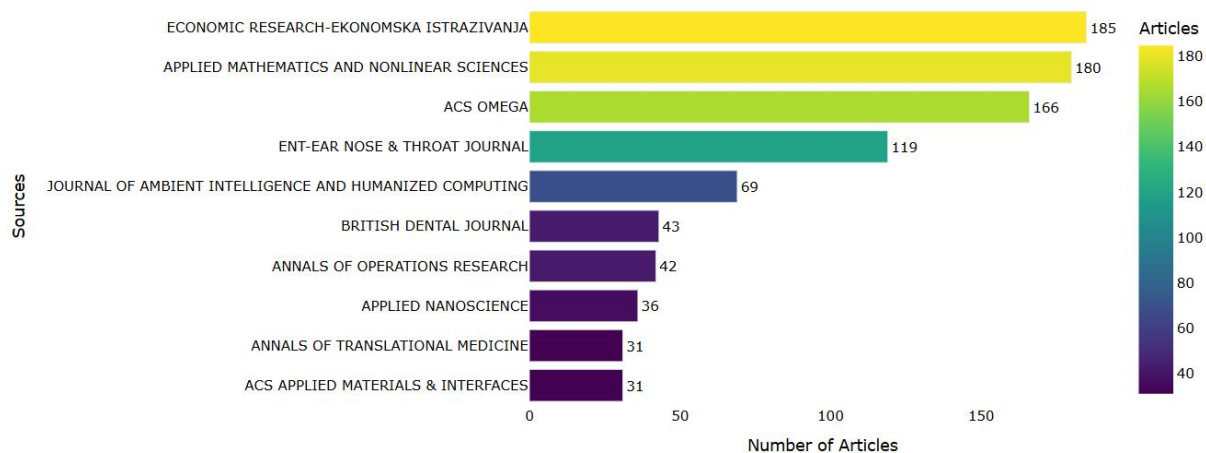

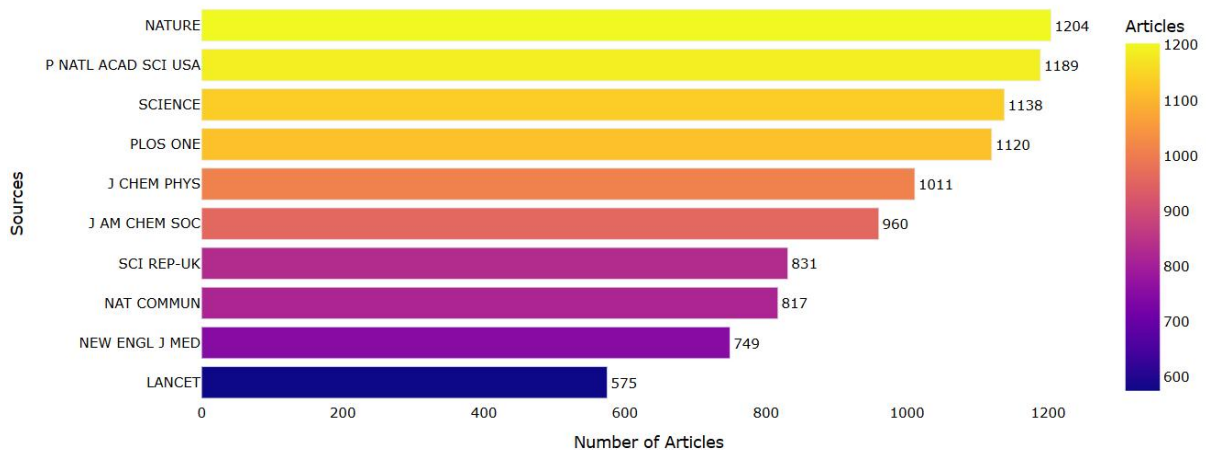Figure 3. Most relevant cited sources

Figure 4. Most local cited sources

Sources of production over time
Averaged across five leading sources, the rate of publication growth between 2019 and 2022 was clearly accelerating, with all journals exhibiting an exponential growth rate after 2020 in Figure 5. The journal ACS OMEGA (pink line) became the most prolific journal source (cumulative curves) in 2022, the cumulative occurrences rising to more than 160 - a sharp increase from close to zero in 2019. Applied Mathematics and Nonlinear Sciences (yellow line) closely followed, showing strong and steady growth in the period. ENT /EAR NOSE and THOAT (light blue line) had recorded a rather slight, yet comparatively steady rise in upswing, although Economic Research - Ekonomska Studija (green line) seemed fairly constant before 2021, but then exploded well over 170 in 2022. By contrast, the Journal of Ambient Intelligence and Humanized Computing which is represented by a purple line, Personality and Social Psychology Bulletin, Monitoring the Future and Special issue on Psychology, Society and Bureau Culture (brown line), was comparatively slower, and by this time has come under heavy criticism, but has experienced relatively moderate growth less than 70 occurrences by 2022.
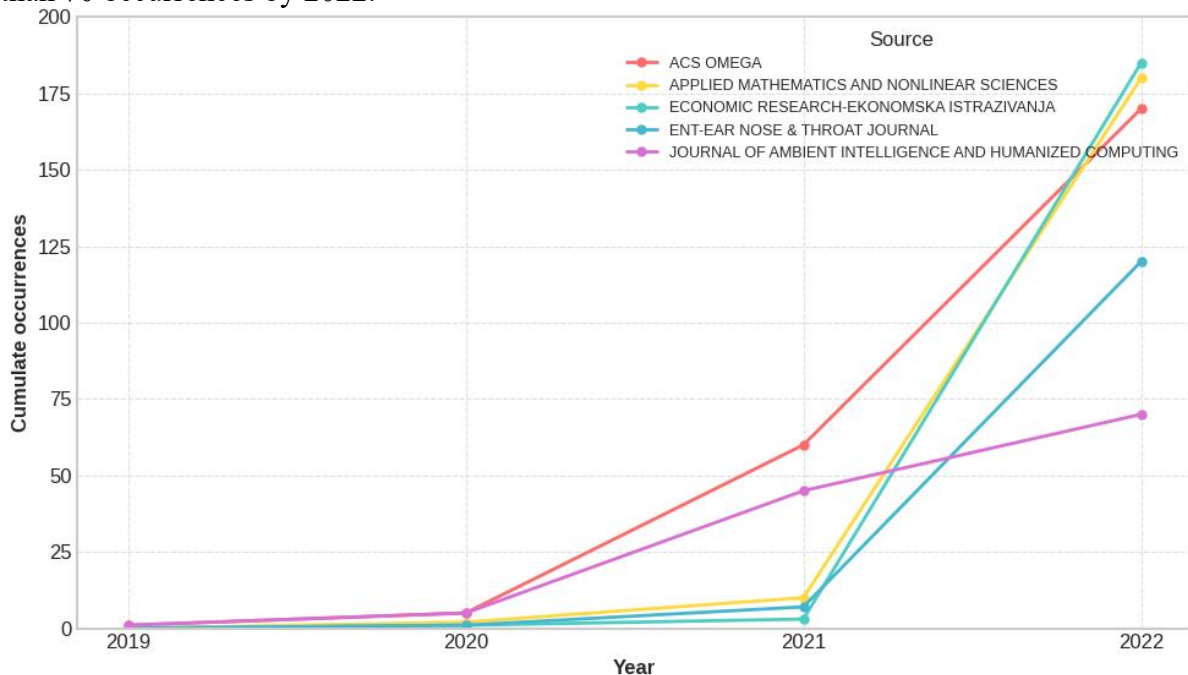

Figure 5. Source's production over time

Authors
Most relevant authors
Based on the dataset analysis of the most productive authors, Wang Y has the highest number of publications with 56 articles, which implies a high contribution to research work in the field in Figure 6. This is closely followed by Li Y with 44 articles and Zhang Y with 42 articles, which indicates their influential position in the academic world. Other notable contributors include the authors Zhang X (41 articles), Wang X (36) and Wang J (35), all of whom have consistently produced research output. Besides Zhang L (33) and Li X (31), Wang (30) and Chen Y (29) have also made significant contributions. Liu Y and Wang L had

a total of 28 publications, and Chen H (27), Zhang J (26) and Li J (23) followed. The other main contributors are Wang Z (23), Liu J (22), Liu X (21), Wang H (21) and Zhang H (21).
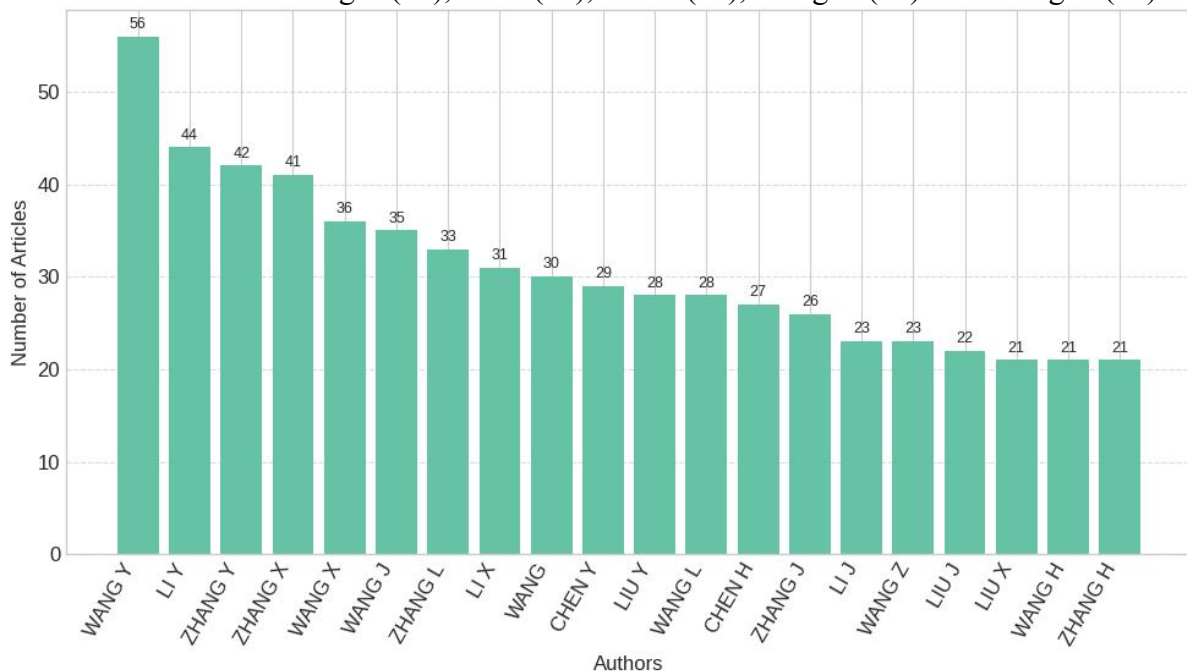

Figure 6. Top authors by number of articles

Affiliations
Most relevant affiliations
Institutional analysis of research output shows that Fudan University has a leading position with 88 publications, highlighting its important role as a research contributor in developing the field of knowledge in Figure 7. It is closely followed by the Applied Science University with 84 publications which reflects high levels of scholarly activity. Renowned international institutes are also well represented on the list, such as the University of Oxford with 81 articles, the University of Washington with 79 and the University of Cambridge with 74, reflecting the leadership in research of high-ranked universities. The University of Toronto (72), Stanford University (71), University of Minnesota (67), University of Pittsburgh (67) and University of Michigan (65) are all well represented in the North American institutions contributing to this literature.

King's College London (69) & Imperial College London (64) are significant extensions from the United Kingdom, and University of North Carolina (62) and the University of Pennsylvania (61) further underline the superior role played by the United States in the global academic scene. The other prominent partners are in response to Duke University (64), Sun Yat-sen University (63) and the University of California, San Diego (60) showing that they have a good culture of research in various geographies. Furthermore, another interesting fact is that Johns Hopkins University (58), Icahn School of medicine at Mount Sinai (57) and the University of California, San Francisco (56) are also characterized by intensive engagement in cross-disciplinary research.
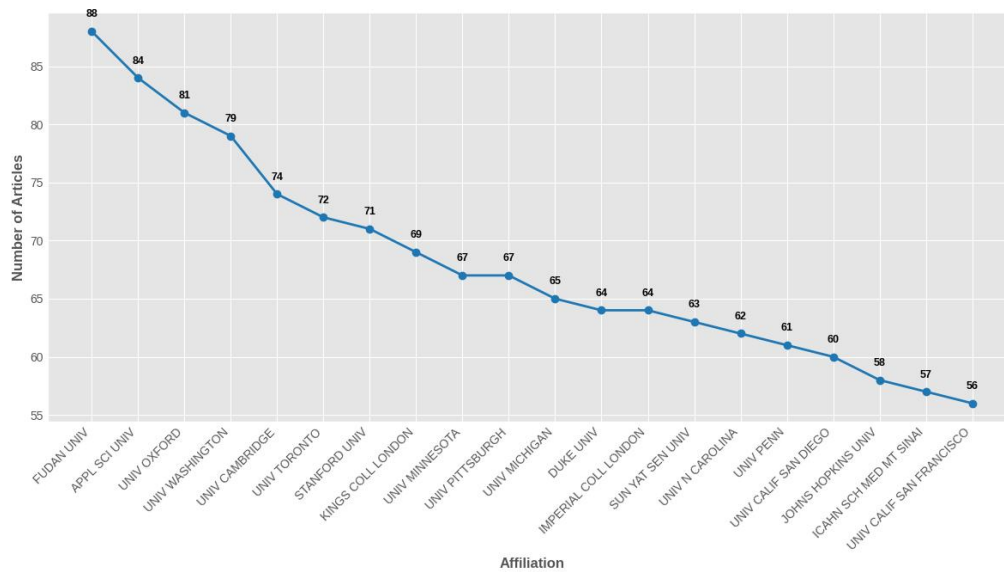
Figure 7. Top affiliations by publication count

Affiliations production over time

The number of the articles in Fudan University stood at 2 articles only in the year 2019 and 2020, and then the number suddenly rose to 14 articles in 2021 and skyrocketed to 88 articles in 2022 in Figure 8. The University of Cambridge, for example, began slightly higher, publishing three articles in 2019, increasing gradually to eight in 2020 and 21 in 2021, ending up with 74 in 2022. The University of Washington had a median of seven articles published in 2019 and 2020, 13 published in 2021, and 79 published in 2022. The University of Oxford, which did not publish any articles in 2019, started publishing in 2020 with four, 14 in 2021, and reached its highest ever number in 2022 of 81. The publication activity was inert until 2021, when the Applied Science University published three articles, and then it boomed with 84 papers in 2022 (the highest that institution had among all institutions in that year).
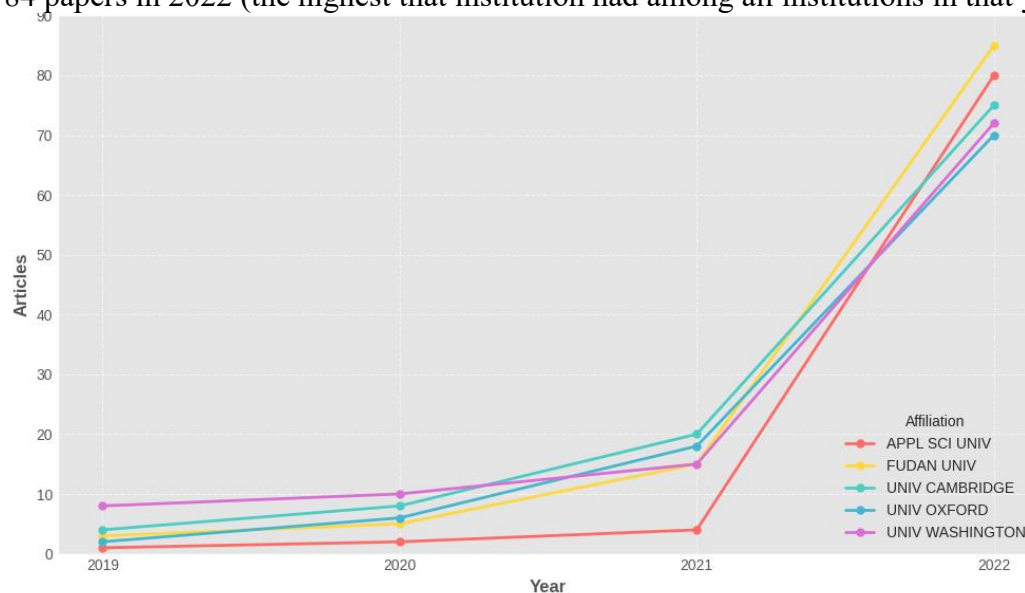

Figure 8. Affiliations over production of time

Countries

Corresponding authors countries

China was the top in the list with 836 total articles, including 625 in SCP and 211 in MCP - 25.2% of its output being cross-border collaboration. The USA ranked second with 733 articles, 565 of them were SCP and 168 MCP (22.9% international collaboration). The United Kingdom generated 367 articles, out of which a significantly larger share, 39.8% was a result of multi-country collaboration, amounting to 146 MCPs. Germany got 231 articles of which 158 were SCP and 73 MCP (31.6% collaboration). Italy reported 145 articles and 40.7% of the product was MCP, whereas, the Netherlands, Canada, and France reported about 39-41 percent international collaboration. Australia had the highest proportion of articles with multi-country co-authorship (52.4%) out of 84 articles. The highest international collaboration rate was found in Switzerland (63.6%) and 28 out of 44 articles from Switzerland were MCP. Notably, the United Arab Emirates had 100% of its 14 articles assigned as MCP, meaning every piece of the research it had done was in collaboration with other countries. At the lower end of the spectrum, countries such as Poland, Romania and Bulgaria reported low or no international collaboration in Figure 9.
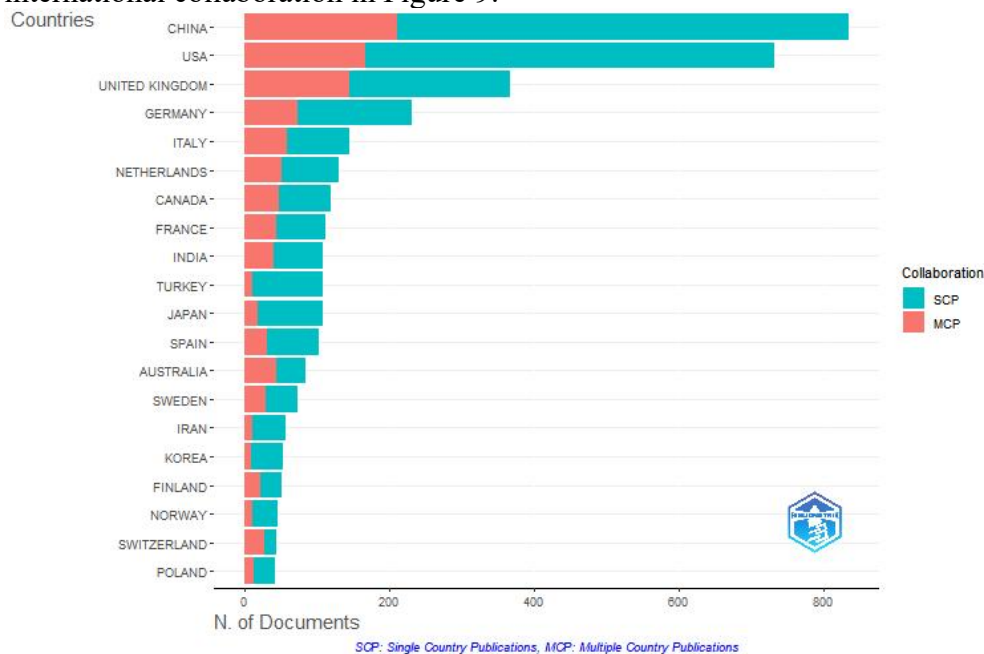

Figure 9. Corresponding author's countries

Countries scientific production

The United States was the most active region with a frequency of 4,533 and is rendered in vivid yellow and dominates the North American region. China came close behind with 3,344, in orange-yellow, reflecting its heavy contribution to the world's research. The United Kingdom, Germany, Italy, Canada, France, Spain, and Japan were all in shades of orange to red indicating high but lesser levels of activity than the top two. Countries such as Australia, Turkey, Sweden, Switzerland, South Korea, Finland, Iran, Norway, Belgium, Brazil and Saudi Arabia were colored mid-to-dark purple, indicating moderate levels of output. Many countries in Africa, Central Asia and parts of Latin America were rendered in very dark blue, indicating very limited activity - for example, countries such as Algeria, Ethiopia, Nigeria, Morocco and Uganda had frequencies of less than 30. On the other hand, a number of small or less-research-intensive countries - such as Tonga, Zambia and Bhutan - saw frequencies of 1 or 2, only just above the scale in Figure 10.
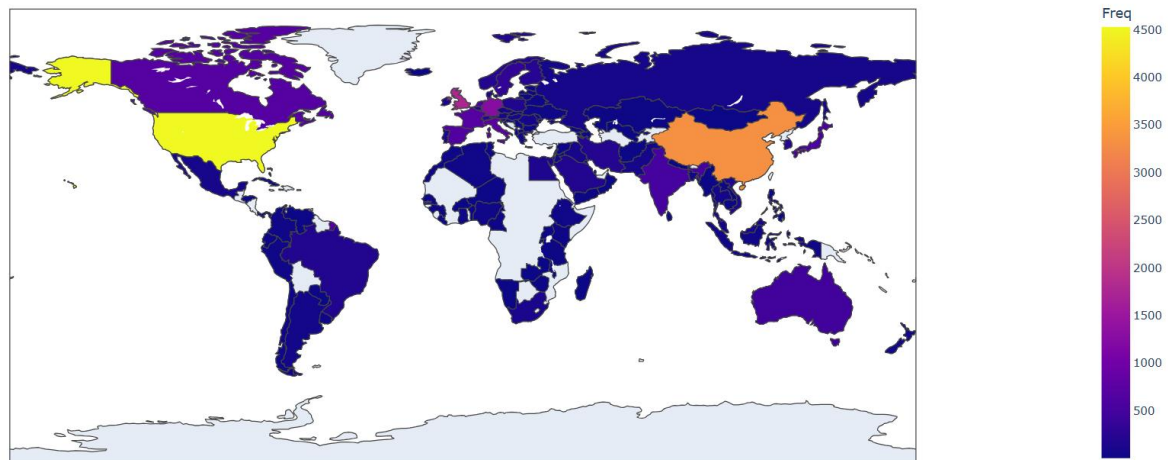
Figure 10. Countries scientific production

Countries production over time

The United States topped the list with 237 articles in 2019, rising to 504 in 2020, soaring to 1,114 in 2021 and reaching its high point of 4,533 in 2022 -- the most of all the countries depicted. China started with 106 articles in 2019, jumped to 174 in 2020, then to 562 in 2021, and had an explosive rise to 3344 in 2022. The United Kingdom started from 53 articles in 2019, gradually increased to 175 articles in 2020 and 545 articles in 2021, and further broke out to 1,760 articles in 2022. Germany, which had published 31 articles in 2019, went up to 134 in 2020, 437 in 2021 and reached 1,275 in 2022. IThough the publication record of the journal was low in 2019, with only 11 articles, it grew a little in 2020 with 42 articles, then became substantial with 208 articles in 2021, and came to a resolution to 756 articles in 2022. The growth of all five countries has accelerated from 2021 to 2022 with the USA and China once again being the countries displaying the most dramatic growth relative to each other, reflecting their leading positions in terms of global research output over this time frame in Figure 11.
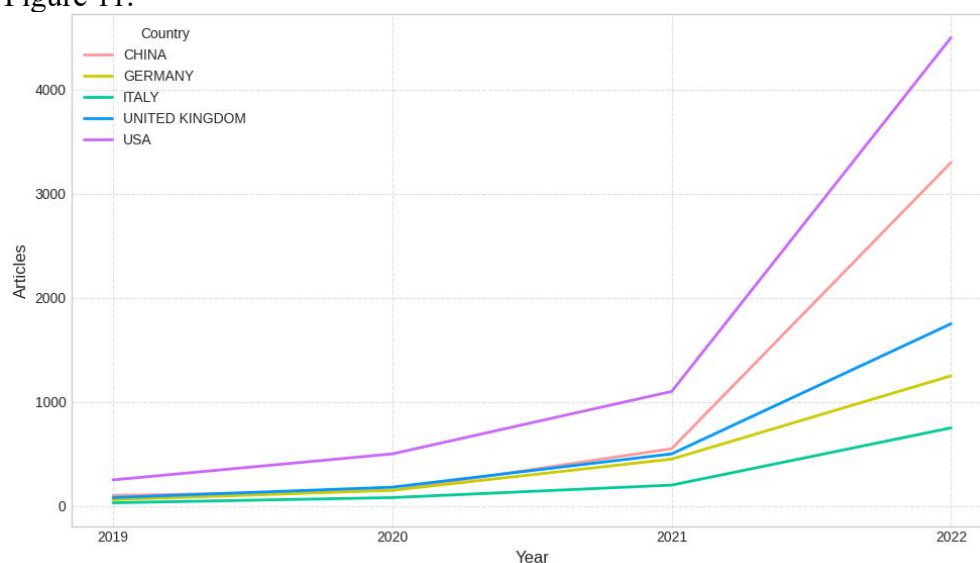

Figure 11. Countries production over time

Documents
Documents
Most global cited documents
The publication by Soliman SA, 2022 (Nature Medicine) was the most cited publication, having 10,727 citations, several times more than the others. Following it was the publication, Chen et al., HU (2021, Nature), which had 827 citations. Hernandez A (2020, Nature Biotechnology) received 412 citations, and at the same time Huang Y (2020, Nature Communications) received 298. Others like Economou E (2022, eLife) with 245 citations, Jamie WA (2021, Nature Medicine) with 207 and Lee YH (2020, Nature Computational Science) with 184 citations are high-ranking publications. Lang S (2019 Physiology) reached 180 and Stevenson MD (2022 Blood) and Kim HJ (2021 Nature Immunology) had 162 and 162 respectively, being at the bottom of the scale in Figure 12.
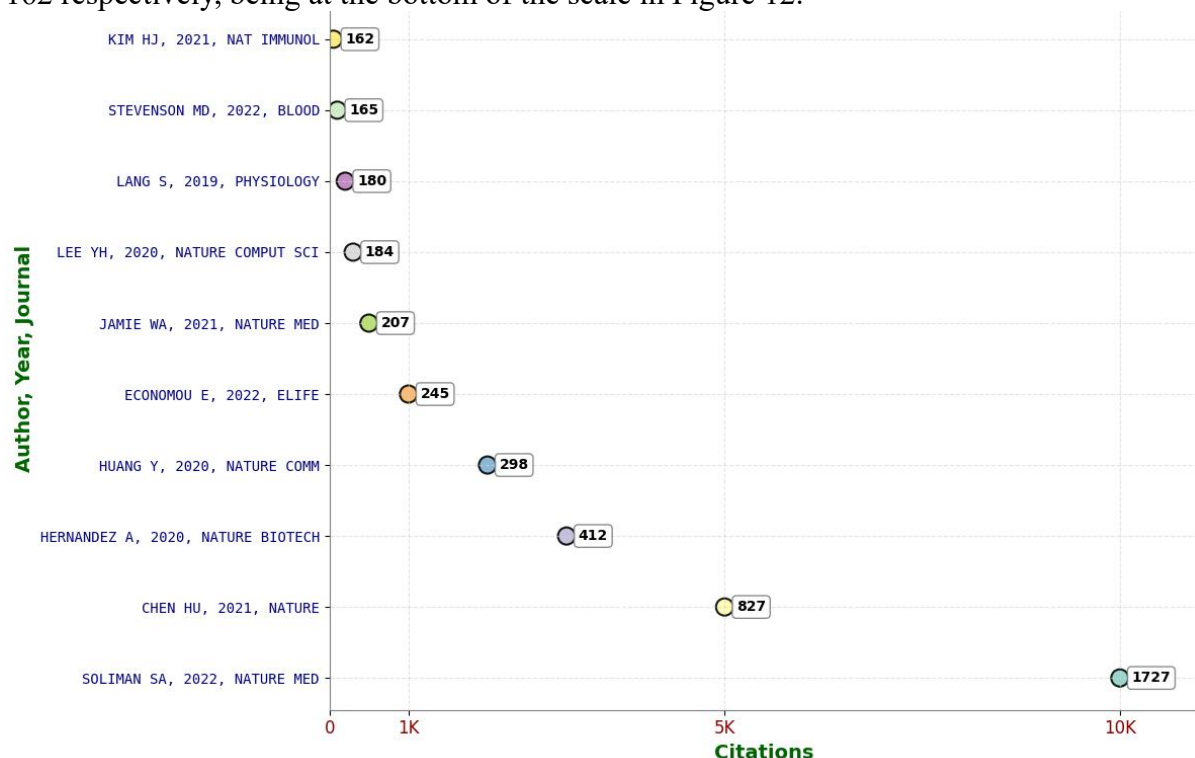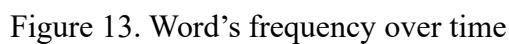

Figure 12. Most global cited documents

Words
Word frequency over time
The name Covid-19 was the most explosively growing one - starting at zero in 2019, then skyrocketing to 6 in 2020 and a massive 189 in 2021, representing the fact that it dominated the research discussion about the world. Impact also increased steadily, going up to 166 in 2022 since it was 7 in 2019, and same case applied to Model, which was 2 in 2019 and 152 in 2022. The risk changed to 140 (as compared with 9), and Performance changed to 139 (as compared with 4), which indicates more evaluation and outcomes. The trends were strong in both "Management" and Health as they both ended at 132 and 93 respectively. there was an upswing of 2 to 90 in Cancer and upswing of 0 to 61 in Growth, and this is a pointer towards the increasing interest in the areas of development and oncology. "Children" went from 5 in 2019 to 70 in 2022, a sign that an understanding of the need for paediatric or youth-related research is emerging in Figure 13.

Figure 13. Word's frequency over time

Clustering

Clustering by coupling

Figure 14 revealed the clusters of closely correlated papers, in particular, in cancer research (e.g. Chen D, 2022; Huang B, 2022), artificial intelligence in healthcare (Hafeez U, 2022; Gianchandani N, 2020), and renewable energy systems (Nagahama A, 2019; Candelaria-Morales NP, 2022). Other hub documents, like Zhang Q, 2023 were also hub documents, connecting several clusters to show that they were the most important and therefore connected several groups of research. Other nodes were more peripheral since they represented the contribution of niche (less cited). The shape of the network presupposed the manner in which the knowledge transformed over time - earlier pieces of work (2019-2020) were more likely to build the base relations in the later and narrower study (2021-2022).
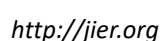
Figure 14. Coupling network of documents using CR

Conceptual structure
Network approach
The word "covid-19" was the centre to be woven with a loose web of similar health- and social terms. Other significant themes, such as management, impact, model and performance organizational themes were clustered around this center, forming loosely connected subnetworks, suggesting that they were also frequently discussed in association with pandemic-related works. Terms like "prediction", "machine learning" and "expression" appeared in one separate cluster, which represented interdisciplinary interactions by computational and biological fields.Other clusters centred around terms such as "nanoparticles", "energy" and "design", indicating unexploded but still active areas of research. Each of the nodes was sized according to how often it was used, with the bigger nodes ('risk', 'impact' and 'management') being more prominent in Figure 15.
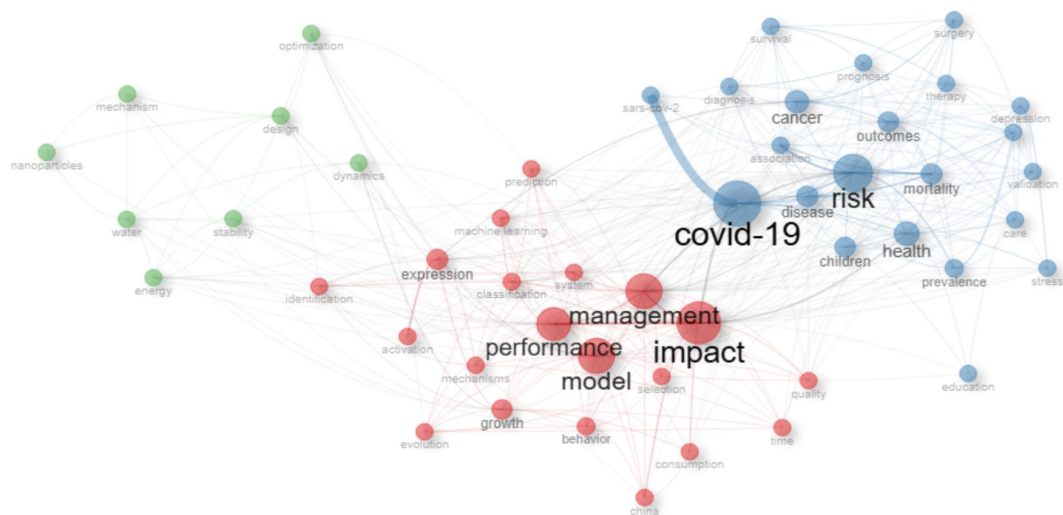

Figure 15. Network representation of the words

Thematic map
In the top right quadrant labeled "Motor Themes" -- terms that seem to reflect more specific aspects of the current pandemic like "covid-19," "risk" and "management" were moved to the central position as items of high impact that revealed both high growth and high centrality areas in the scholarly landscape. The quadrant at the top-left corner, "Niche Themes," included such terms as "expression," "classification," and "mechanisms" that exhibited moderate to low centrality but were nevertheless being actively developed. The group around "model", "performance", "growth" in the lower left "Emerging or Declining Themes" showed the least development, and were not considered as relevant, as they were still on the decline or had yet to become prominent in Figure 16.
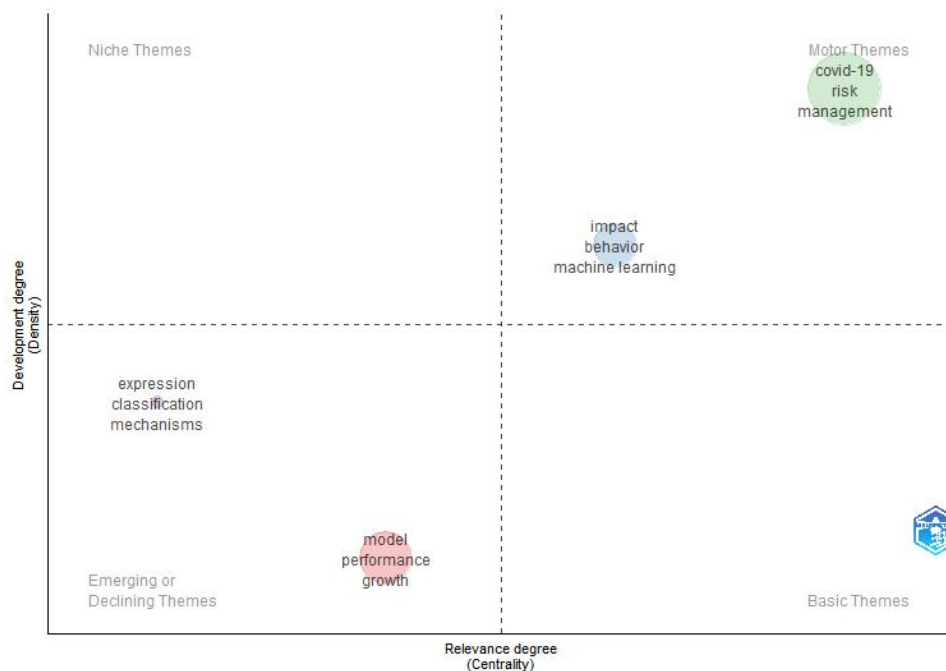
Figure 16. Thematic approach representation of the words

Factorial approach

Factorial analysis

At the bottom level, terms that are closely associated (e.g. expression, classification, mechanisms, institutions) formed tight subgroups indicating that they were often discussed in the same contexts. Moving up the tree, the groups became more general: Here you have the health-related terms such as disease, mortality and risk clustered on one branch; on the other, you have computational and behavioral concepts such as machine learning, prediction and behavior. Words such as cancer, therapy and survival are grouped together, which suggest a strong thematic connection in the field of oncology or clinical research. Other clusters had terms such as "nanoparticles," "energy" and "design," which capture interdisciplinary areas in materials science or engineering. The vertical axis was the distance at which clusters merged with values indicating greater dissimilarity between clusters in Figure 17.
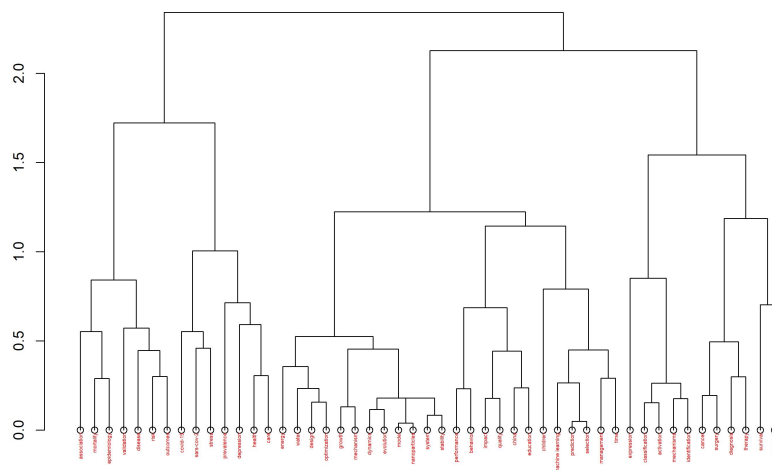
Figure 17. Dendrogram representation of the factorial approach analysis

Social structure
Countries' collaborations world map
Countries were colored in different shades of blue (lighter shades being lower, or negative, frequencies and darker shades representing higher positive frequencies). For example, Australia had high positive frequencies with countries like New Zealand (171.48), Singapore (103.82) and Malaysia (109.70), indicating positive levels of connection or exchange in the past in Figure 18. Conversely, large negative frequencies prevailed in South America countries such as Argentina, Brazil, Chile, Colombia and Peru - mainly with each other - suggesting low contact and/or inverse relationships in the period under study. Europe exhibited moderate to high frequencies amongst its members. For instance, Germany, France and the UK had significant positive relationships with each other and with distantly related partners like Japan and Australia. Meanwhile, Middle Eastern countries like Saudi Arabia and UAE were relatively high with Asian countries and European countries, however negative or low for African and South American countries.
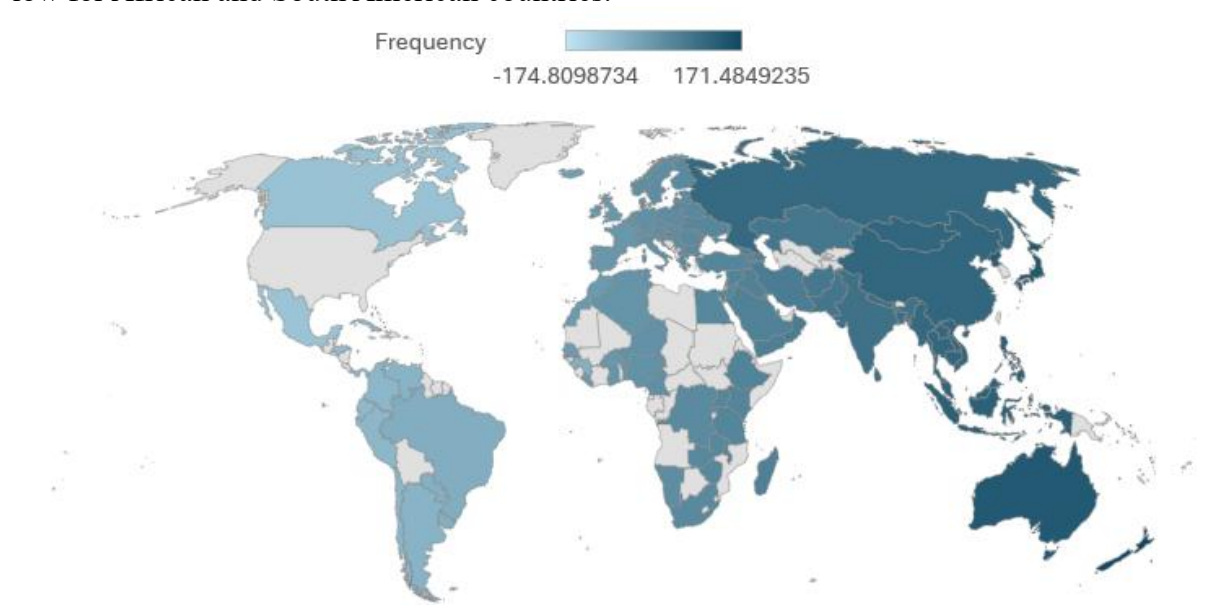

Figure 18. Countries collaborations

Discussion
This research sought to understand the intellectual, geographical, and collaborative dynamics of an emerging growth area of research work between 2019 and 2022. The analysis showed explosive growth (with a 23-fold increase in the number of annual publications and an annual growth rate of 186.91%) led by the overwhelming global research response to the pandemic response for Covid-19. Despite the increase in output, the citation impact per article has been dramatically reduced after 2020, and the distribution of citation window shrinks from 7 to 4 years, which indicates the change in the style of publishing from building long-term scholarly impacts to high-volume publishing with quick payoffs. Thematic mapping proved that motor themes "COVID-19," "risk," and "management" were predominant, and institutional and authorship analyses demonstrated that Chinese and U.S.-based researchers played a significant role in this field, and Fudan University and Wang Y, were the most prolific affiliation and authors in this field respectively. International collaboration was high (32.72%

of documents), especially with smaller scientific nations such as the UAE (100% MCP) and Switzerland (63.6%) compared to the Northern American, Western European, and East Asian regions where research output was still highly concentrated.

The drastic development of "COVID-19" as the focal point of both keyword co-occurrence and bibliographic coupling networks can be explained with national trends based on the tendencies of the global scientific literature in the previous bibliometric studies,[17] which identified the redistribution of scientific research interest around the pandemic-related issues across research fields. The concentration of terms around COVID-19 such as risk, mortality, health and children shows the emerging multi-dimensional public health emergency which is not just clinical, but also social and policy related.[18] Just as the simultaneous increases in "model," "machine learning," and "prediction" indicate the convergence of computational methods into epidemiological and healthcare research, work showing how AI can be used for pandemic response has also been reflected in other recent empirical work.[19] The categorisation of these themes in the thematic map under the name of Motor ThemesSiehe narrates is not just a central theme, but also an interdisciplinary integration theme in a continuous process of development, which proves the hypothesis of crisis mobilising interdisciplinary integration.[20]

The dominance of China and the USA in publication volume (836 and 733 articles, respectively) is in line with broader context in scientific output across the world.[21] The high productivity of institutions such as Fudan University and the University of Oxford together with steep growth trajectories post-2020 implies strategic investment in pandemic-related research or a good access to data and infrastructure. It is also interesting to mention that the systematic overrepresentation of the Chinese family names among the most popular authors (e.g. Wang, Li, Zhang) validates the results of Cao et al. (2023) about the growing power of China in the global science.[22] However, the mid-level research nations (e.g. UAE, Switzerland) show a high rate of international collaboration as indicative of their strategic use of international research networks in order to increase their scientific visibility, a pattern similarly seen in research economies in emerging economies.[23]

The opposite relationship between publication and citation performance (i.e. the decrease of MeanTCperArt from 28.14 (2020) to 9.56 (2022)) is representative of fears about pressures to 'publish or perish' during the COVID-19 pandemic.[24] The reduction in citable years (R^2 = 1.0000; see below) may represent accelerating obsolescence caused by rapid development or expansion of early access/intermediated forms and preprint forms as observed in other pandemic-era bibliometric studies.[25] For all these high rates of co-authorship (6.3 authors per document), and despite the high rate of collaboration across national borders (32.72%) suggested that much research was still under national silos, despite the increase in connections between thematic networks observed in global health research over time.[26]

This analysis is limited by using only one bibliographic database (a likely web of science or Scopus article) which is likely to underrepresent non-English, regional, or grey literature - especially from low-income countries which feature minimally on the world map. Inclusion of early access materials and even retracted publications could overestimate output metrics while underestimating quality metrics. Furthermore, the choice of "Frequency" as a proxy for strength of collaboration in the map of the world is not accompanied by Methodological Transparency, as negative values (eg between South American countries) mean very difficult to interpret, without clear definition. Finally, the short timeframe (2019-2022) records a highly anomalous period characterized by the predominance of a global health emergency

and reduces the possibility of generalizing the trends when more stable scientific contexts are considered.

Conclusion

The period between 2019 and 2022 has seen an extraordinary growth in scholarly production, generated mainly by the worldwide response to the pandemic related to the disease Coronavirus 2019. The impact was a paradoxical increase of total publications - the quantity of publications increased substantially, especially from China and the USA - and a decrease of the effect of publications in terms of citations: they became less influential, on average, per unit of time, but more rapidly disseminated. Institutions such as Fudan University and Applied Science University turned out to be extremely scalable and became important contributors within two years. From the public health domain to the AI domain, covid-19 was like a gravitational center around which all domains had to orbit and change research directions across the world. The international collaboration increased (especially among medium-sized countries), an indication of developing a culture of international scientific collaboration. But geographical imbalances still existed whereby many African, Latin American and Central Asian countries remained marginal in output. In terms of methodology network and factorial analyses were employed to identify coherent thematic clusters in an effort to indicate the progression of knowledge within the domain knowledge that was linked.

Conflict Of Interest

The authors declare that there is no conflict of interest.

References

1. Kumar, K. (2025). From Blackboard to Bytes Transformation of Commerce and Management Education in Digital Era. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5130205
2. *Shaping Digital Education*. (2023). https://doi.org/10.1787/bac4dc9f-en
3. Betancur, R. R., Pardo-del-Val, M., & Pérez, M. (2022). Strategic orientation to educational innovation: A systematic review and conceptual model. *Intangible Capital*, *18*(3), 442. OmniaScience. https://doi.org/10.3926/ic.1686
4. Guzzo, T., Ferri, F., & Grifoni, P. (2023). Lessons Learned during COVID-19 and Future Perspectives for Emerging Technology. *Sustainability*, *15*(14), 10747. https://doi.org/10.3390/su151410747
5. Cuong, D. H., Son, P. N., Thương, Đ. T. K., Linh, N. T. T., & Hien, N. V. B. (2024). Building an Innovative Learning Ecosystem: A Model for Secondary Schools in Hanoi, Vietnam. *TEM Journal*, 2115. https://doi.org/10.18421/tem133-39
6. Schleicher, A. (2024). Toward the Digital Transformation in Education. *Frontiers of Digital Education.*, *1*(1), 4. https://doi.org/10.1007/s44366-024-0018-7
7. Chandna, V., & Newaz, T. (2023). We can all be winners: The influence of team composition and a delivery modality on business students' satisfaction and simulation performance. *Ekonomski Horizonti*, *25*(3), 279. https://doi.org/10.5937/ekonhor2303279c
8. Dondi, C., Palumbo, J., Zygouritsas, N., Fasoulis, V., Borotis, S., & Kastis, N. (2013). Future Challenges Report Editors. *HAL (Le Centre Pour La Communication Scientifique Directe)*. https://telearn.hal.science/hal-01202007
9. Kreijns, K., Vermeulen, M., Kirschner, P. A., Buuren, H. van, & Acker, F. V. (2013). Adopting the Integrative Model of Behaviour Prediction to explain teachers' willingness

to use ICT: a perspective for research on teachers' ICT usage in pedagogical practices. *Technology Pedagogy and Education, 22*(1), 55. https://doi.org/10.1080/1475939x.2012.754371

10. Toro, Prof. Ms. U., & Joshi, Milind. J. (2015). Tacit to Tacit Knowledge Sharing using ICT In Higher Education. *INTERNATIONAL JOURNAL OF MANAGEMENT & INFORMATION TECHNOLOGY, 10*(7), 2318. https://doi.org/10.24297/ijmit.v10i7.596

11. Trevisan, O., Christensen, R., Drossel, K., Friesen, S., Forkosh-Baruch, A., & Phillips, M. (2024). Drivers of Digital Realities for Ongoing Teacher Professional Learning. *Technology Knowledge and Learning, 29*(4), 1851. https://doi.org/10.1007/s10758-024-09771-0

12. Yulin, N., & Danso, S. D. (2025). *Assessing Pedagogical Readiness for Digital Innovation: A Mixed-Methods Study.* https://doi.org/10.48550/ARXIV.2502.15781

13. Morgado, E., & Henriques, S. (2014). Support indicators for educational leadership in ICT management: The role of information system. *2022 17th Iberian Conference on Information Systems and Technologies (CISTI),* 1. https://doi.org/10.1109/cisti.2014.6876983

14. Owen, S., White, G. T., Palekahelu, D. T., Sumakul, D. T. Y. G., & Sediyono, E. (2020). Integrating Online Learning in Schools: Issues and Ways Forward for Developing Countries. *Journal of Information Technology Education Research, 19,* 571. https://doi.org/10.28945/4625

15. Shen, B. (2024). The Practice of Project-Based Learning in a Management Information Systems Course for Graduate Students. *Higher Education Research, 9*(6), 148. https://doi.org/10.11648/j.her.20240906.11

16. Schrey-Niemenmaa, K., & Nørgaard, B. (2018). PART-TIME ENGINEERING MASTER PROGRAMS UTILIZE JOB ASSIGNMENTS OR PROFESSIONAL CHALLENGES AS MEANS OF LEARNING. *Research Portal Denmark.* https://local.forskningsportal.dk/local/dki-cgi/ws/cris-link?src=aau&id=aau-c283bcbc-4486-4d19-948f-5628708cab26&ti=PART-TIME%20ENGINEERING%20MASTER%20PROGRAMS%20UTILIZE%20JOB%20ASSIGNMENTS%20OR%20PROFESSIONAL%20CHALLENGES%20AS%20MEANS%20OF%20LEARNING

17. Neto, A. R. de S., Carvalho, A. R. B. de, Silva, M. D. F. da, Neta, M. M. R., Sena, I. V. de O., Almeida, R. N., Filha, F. S. S. C., Silva, L. L. L. e, Costa, G. R. da, Lira, I. M. da S., Portela, D. M. M. C., Silva, A. T. O. e, Rabêlo, C. B. de M., Valle, A. R. M. da C., Moura, M. E. B., & Freitas, D. R. J. de. (2023). Bibliometric Analysis of Global Scientific Production on COVID-19 and Vaccines. *International Journal of Environmental Research and Public Health, 20*(6), 4796. https://doi.org/10.3390/ijerph20064796

18. Redhead, C., Silverio, S. A., Payne, E., Greenfield, M., Barnett, S., Chiumento, A., Holder, B., Skirrow, H., Torres, O., Power, C., Weiss, S. M., Magee, L. A., Downe, S., Frith, L., & Cameron, C. (2025). A consensus statement on child and family health during the COVID-19 pandemic and recommendations for post-pandemic recovery and re-build. *Frontiers in Child and Adolescent Psychiatry, 4.* https://doi.org/10.3389/frcha.2025.1520291

19. Gawande, M. S., Zade, N. N., Kumar, P., Gundewar, S., Weerarathna, I. N., & Verma, P. (2025). The role of artificial intelligence in pandemic responses: from epidemiological modeling to vaccine development [Review of *The role of artificial intelligence in pandemic responses: from epidemiological modeling to vaccine development*].

Molecular Biomedicine, *6*(1). Springer Nature. https://doi.org/10.1186/s43556-024-00238-3

20. Goyal, A., Singh, A., Raghuraman, M., Ghosh, P., & JADHAV, A. A. (2024). Unveiling Trends in Forecasting Models for Crop Pest and Disease Outbreaks: A Systematic and Scientometric Analysis. *Research Square (Research Square)*. https://doi.org/10.21203/rs.3.rs-5304041/v1

21. Rong, G., Chen, Y., Ma, F., & Koch, T. (2025). *40 Years of Interdisciplinary Research: Phases, Origins, and Key Turning Points (1981–2020)*. https://doi.org/10.2139/ssrn.5085453

22. Cao, K., Xia, Y., Yao, J., Han, X., Lambert, L., Zhang, T., Tang, W., Jin, G., Jiang, H., Fang, X., Nogues, I., Li, X., Guo, W., Wang, Y., Fang, W., Qiu, M., Hou, Y., Kovarnik, T., Vocka, M., Lu, Y., … Lu, J. (2023). Large-scale pancreatic cancer detection via non-contrast CT and deep learning. *Nature medicine*, *29*(12), 3033–3043. https://doi.org/10.1038/s41591-023-02640-w

23. Wagner, C. S., Park, H. W., & Leydesdorff, L. (2015). The Continuing Growth of Global Cooperation Networks in Research: A Conundrum for National Governments. *PLoS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0131816

24. Vásconez-González, J., Izquierdo-Condoy, J. S., Naranjo-Lara, P., García-Bereguiain, M. Á., & Ortiz-Prado, E. (2024). Integrity at stake: confronting "publish or perish" in the developing world and emerging economies. *Frontiers in Medicine*, *11*. https://doi.org/10.3389/fmed.2024.1405424

25. Jamali, H. R., Nicholas, D., Sims, D., Watkinson, A., Herman, E., Boukacem-Zeghmouri, C., Bravo, B. R., Świgoń, M., Abrizah, A., Xu, J., Tenopir, C., & Allard, S. (2023). The pandemic and changes in early career researchers' career prospects, research and publishing practices. *PLoS ONE*, *18*(2). https://doi.org/10.1371/journal.pone.0281058

26. English, K., & Pourbohloul, B. (2017). Health policy and systems research collaboration pathways: lessons from a network science analysis. *Health Research Policy and Systems*, *15*(1). https://doi.org/10.1186/s12961-017-0241-5