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Applied Training in Conducting Scientometric Professional Studies and Mapping and Analyzing Medical Scientific Networks.

Mohammad Bagher Negahban

Associate Professor of Information Science & Knowledge, Dep. Information Science & knowledge, Persian Gulf University, Bushehr, Iran. mbnegahban@pgu.ac.ir, bm.negahban@gmail.com, https://orcid.org/0000-0001-6849-9555

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Resumen

The document is a structured, applied training guide designed to bridge the educational gap in conducting professional scientometric studies, with a specific focus on the mapping and analysis of medical scientific networks. Scientometrics is presented as a key approach for systematically assessing knowledge structure, trends, and collaboration, which is indispensable in the rapidly evolving fields of medicine. The guide proposes a practical eight-step framework for the researcher, beginning with a clear definition of a research objective and thematic scope. Crucial steps include selecting authoritative data sources such as Web of Science or Scopus and formulating a precise search strategy using Boolean operators. Following data collection and refinement, the process focuses on network visualization and analysis. For analysis, it is recommended to export complete records to specialized tools such as VOSviewer, CiteSpace, and Gephi. These software programs are used to generate maps of co-authorship, co-citation, and co-word networks, which reveal the social, intellectual, and conceptual structure of a field. The document emphasizes that the interpretation is vital. This phase transforms visualizations and metrics into meaningful insights, which connect with research objectives and allow for the detection of emerging trends or knowledge gaps. Furthermore, the guide introduces advanced bias and integrity detection, using AI to identify anomalies such as citation circles or redundant patterns. Finally, the author underscores the need for clear, transparent, and reproducible reporting, ensuring that the findings serve as a strategic and reliable tool for decision-making and scientific policy. **Conclusion:** This paper offers a practical eight-step guide that integrates visualization tools and AI techniques to not only map medical scientific networks but also detect bias and integrity, thus providing a comprehensive and reproducible approach to bibliometric research in the health sciences.

Keywords: Scientometrics; Bibliometrics; Scientific Network Analysis; Knowledge Mapping; Medical Research; VOSviewer; Web of Science (WoS); Research Integrity.

Introduction

In recent decades, scientometrics has emerged as a key approach for systematically assessing, analyzing, and mapping the structure of knowledge across various scientific domains. The rapid growth of scientific output, the expansion of bibliographic databases, and the advancement of analytical tools have provided researchers with the means to investigate scientific structures, trends, and interactions in greater depth. Among the most powerful tools in this field are the mapping and analysis of scientific networks such as co-authorship, co-citation, keyword co-occurrence, and citation networks which reveal the internal architecture and dynamic evolution of scientific disciplines.

Despite the increasing accessibility of scientometric tools and resources, many researchers particularly medical early career scholars face conceptual and technical challenges when designing, implementing, and interpreting such studies. From selecting appropriate data sources to network analysis and the interpretation of knowledge maps, there is a pressing need for practical, step by step guidance. This paper seeks to fill that educational gap by providing an applied and structured training for conducting professional scientometric studies in medical. With a specific focus on scientific network mapping and analysis in medical education, the article integrates theoretical concepts with practical tools and workflows to enable readers to independently and professionally design and execute their own scientometric research.

In the diverse and rapidly evolving fields of medicine, scientometric analysis has become indispensable for understanding the complex semantic and thematic networks that underlie research activities. By systematically mapping the interconnections among medical disciplines, specialties, and emerging subfields, scientometrics enables the identification of both convergent and divergent thematic patterns. This approach not only reveals how topics interact and evolve over time but also provides valuable insights into interdisciplinary collaboration, research priorities, author and journal biases, plagiarism and knowledge gaps. Furthermore, applying scientometric methods across various branches of medical science supports evidence-based policy making, strategic planning, and the rational allocation of research resources. Consequently, scientometrics serves as a critical analytical framework for advancing a deeper, data-driven understanding of the intellectual and structural landscape of modern medical research. The guide not only introduces commonly used tools and methods but also emphasizes how to effectively apply them in analyzing the structure of science. Scientometrics, as a specialized branch of bibliometrics, evolved to systematically study the dynamics of scientific production, communication, and structure using empirical data. It applies a set of standardized indicators and principles to evaluate scientific performance, researcher impact, and knowledge structures. Key scientometric indicators include: Publication Count, Citation Count, H-index, G-index, Relative Citation Impact, Collaboration Index, Scientific Growth Rate, Cited Half Life.

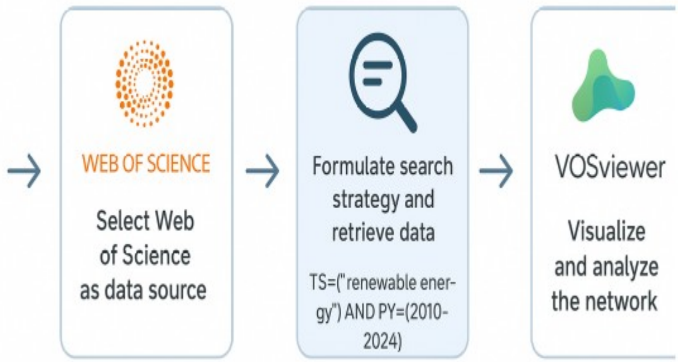

Figure 1. Data extraction database, search formula, and analysis software.

To construct effective scientific maps (figure 1) whether they are co-authorship, co-word, co-citation, or citation networks, it is essential to define the analytical framework based on these indicators. The next step involves selecting reputable data sources for extracting scientific publication data, such as: Web of Science, Scopus, PubMed, Dimensions, Cross Ref, Lens.org, Google Scholar (with caution and appropriate tools). After data collection, various software tools can be used for scientometric mapping and network analysis, including: VOSviewer (for co-authorship, co-word, and clustering analysis), Pajek (for large scale network analysis), Gephi (an open-source tool for complex network visualization), CiteSpace (for trend analysis and concept clustering), BibExcel (for data preprocessing in scientometrics), UCINET (for advanced social network analysis), HistCite (for citation history analysis).

This article will elaborate on each of these stages and provide practical examples to guide readers in applying them in real world scientometric research medical. Of course, after bibliometrics and scientometrics, two other metric based approaches have emerged: webometrics and altmetrics. Similar to scientometrics, these methods utilize their own sets of rule, indicators, tools, and software for data extraction and analysis. However, these alternative approaches fall outside the scope of the current study and will be addressed in a separate applied training guide. In what follows, we present a structured and hands-on roadmap for conducting a professional scientometric study medical. This step by step guide is designed to support researchers in navigating each critical phase from data collection and indicator selection to network mapping and interpretation using real world tools and workflows grounded in scientometric principles.

Key Steps in Conducting a Scientometric Study: A Step by Step Practical Framework

To conduct a professional scientometric study, one must follow a structured and standardized process based on internationally recognized methodologies. This process typically includes a series of essential steps that begin with defining the research question and selecting the thematic domain, and culminate in the mapping and interpretation of scientific knowledge networks. The following section outlines each phase in a clear and actionable way, providing researchers with the practical tools and conceptual understanding needed to carry out a comprehensive scientometric analysis. By following this framework, researchers can not only grasp the theoretical foundations of scientometric indicators but also gain the applied skills necessary to work with scientific data and specialized software effectively.

1. Define the Research Objective and Thematic Scope

Every scientometric study begins with a clear and focused research objective. This could range from analyzing the growth of a specific scientific field, identifying influential authors or institutions, to mapping the structure of a research domain. The key actions are:

- Formulate a specific and researchable question.
- Define the scope (e.g., time period, disciplines, geographic region).
- Decide on the type of network to be analyzed (e.g., co-authorship, co-citation, co-word).
- Select the Appropriate Data Source.

The quality and relevance of your data directly affect the reliability of your analysis. Choose one or more comprehensive bibliographic databases based on your field and access. These are some of the more common data sources:

- Web of Science (WOS) – trusted for high-quality citation data.
- copus – broad coverage, good for interdisciplinary research.
- PubMed – ideal for life sciences and medical research.
- Google Scholar – use cautiously with supporting tools (e.g., Publish or Perish).

2. Formulate Search Strategy and Retrieve Data

Develop a comprehensive search query using Boolean operators, subject keywords, filters (e.g., by year, document type, language), and export the results in a format compatible with analysis tools. Important points to remember are:

- Document your search query and filters for reproducibility.
- Export full records, including titles, abstracts, author names, source titles, keywords, and cited references.
- Preferred formats: CSV, BibTeX, RIS, or plain text (depending on the software).

3. Building a search formula in Web of Science

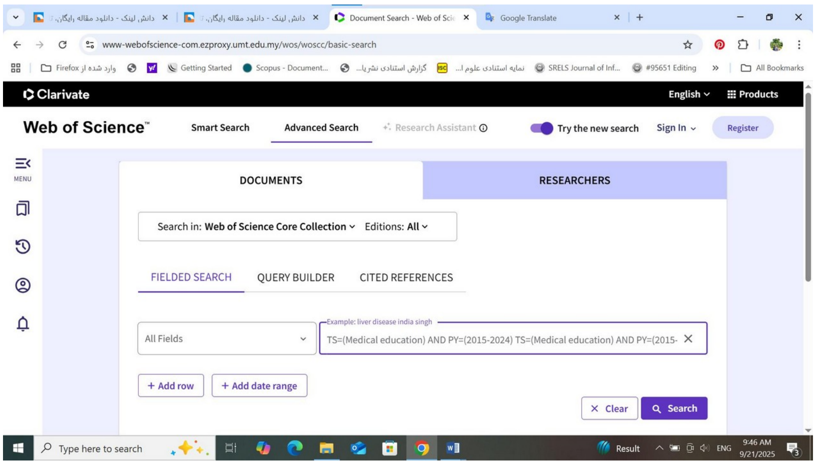

Figure 2. Search formula in Web of Science.

1. Open your browser and go to Web of Science. Log in to your academic or personal account.
2. Select the search box. On the WoS home page, the search box appears (figure 2). You can select one or more search fields (Topic, Title, Author, Journal…).
3. Use Field Tags WOS. These are some of the most commonly used Field Tags:
   - TS= Topic → includes title, abstract, keywords TS=("climate change")
   - TI= Title TI=("medical education")
   - AU= Author AU=("Smith J")
   - SO= Journal (Source) SO=("Nature")
   - OG= Organization/University OG=("Harvard University")
   - PY= Publication Year PY=(2015-2024)
4. Use Boolean Operators to combine conditions:
   - AND → both conditions must be met
   - OR → one of the conditions must be met
   - NOT → the second condition must be omitted
5. To search for an exact phrase, we use " ". Example:

   TS=(Medical Education) AND PY=(2015-2024)

   This formula finds articles with the topic " Medical education ", published between 2015 and 2024, and published in the journals web of science.
6. Enter the formula in the search box for running the search.
7. Click Search. The results will be displayed at the bottom of the page (figure 3).
8. By selecting Citation Report, you can view citation-based indicators:
   - Number of citations per 100,652 Documents. You may also like…
   - Analyze Results
   - Citation Report
   - Create Alert

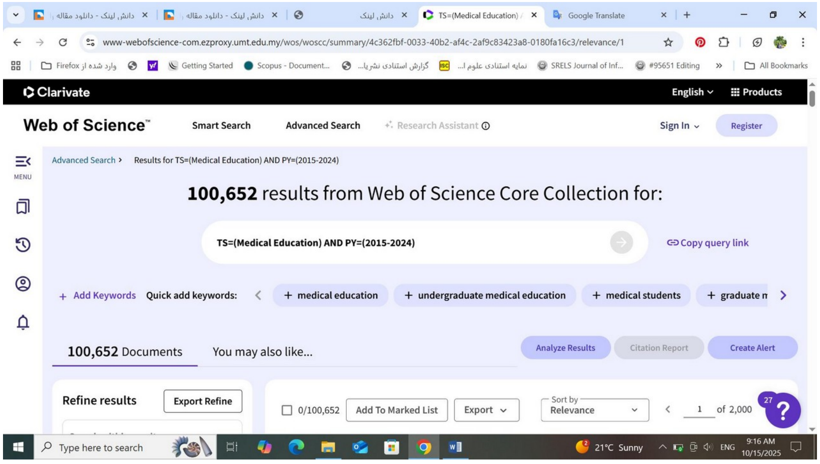

Figure 3. Web of Science search results.

4. Advanced Search in Web of Science

After accessing Advanced Search, we will execute the search and view the results. The query should be a clear and efficient way to extract bibliographic data for scientometric studies. By focusing on the topic (Medical Education) and restricting the publication years (2015–2024), you can generate a dataset that can later be exported and analyzed in scientometric tools such as VOSviewer, CiteSpace, or Gephi. Here's a step-by-step explanation for what happens after running a search in Web of Science. (e.g., TS=(Medical education) AND PY=(2015-2024) → ~100,652 documents retrieved).

5. Step-by-step after running a search in Web of Science.

1. *Step 1: Refine Results.* On the left-hand side (or top) of the results page, you will find the **Refine Results** option. This allows you to filter and narrow down your dataset. Common refinements include:
    1. Publication Years → Focus on specific years (e.g., only 2020 or 2019–2021).
    2. Document Types → Select only articles, reviews, proceedings papers, editorials, or books.
    3. Open Access → Restrict to freely accessible publications.
    4. Highly Cited Papers / Hot Papers → Focus on high-impact or emerging studies.
    5. Organizations / Authors / Countries → Limit results by institution, researcher, or region. This step ensures you create a clean, targeted dataset for analysis.

2. *Step 2: Analyze Results* (Built-in Analysis). Click Analyze Results to quickly generate Web of Science charts and tables (figure 4). This provides an overview of your dataset, such as:
    - Publication distribution by year.
    - Top contributing countries or institutions.
    - Most productive journals.
    - Subject categories most relevant to your topic. These are quick insights but limited compared to external tools.

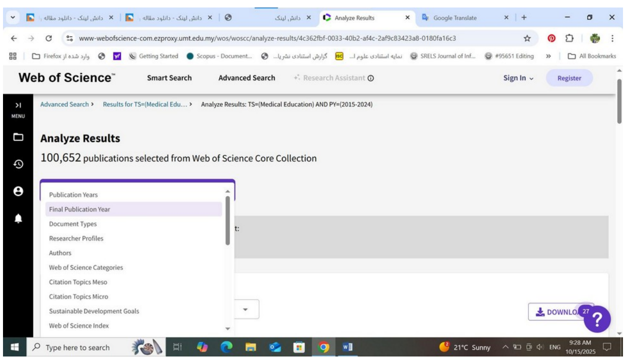

Figure 4. Web of Science Basic Data Analysis Window.

3. *Step 3: Citation Report.* You obtain a report useful for assessing the impact of the retrieved literature, that includes:
    - year.
    - h-index for your result set.
    - Trends showing citation growth or decline.

4. *Step 4: Export Results.* To move to advanced scientometric tools, you need to export the dataset. Web of Science allows export in batches (up to 1,000 records at a time). Most common formats are Plain Text, BibTeX, CSV. Always choose Full Record and Cited References so you capture metadata and citations. Once exported, you merge the files into one dataset and import them into analysis software.

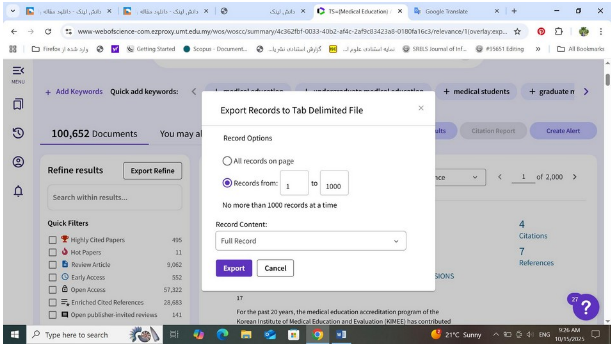

Figure 5. Web of Science data storage window for analysis in the software.

5. *Step 5: WOS analysis.* At this stage, you can perform Internal Web of Science Analysis. Quick and easy. Limited to pre-built charts (e.g., year, countries, journals). Good for overview and descriptive stats.

6. *Step 6: Visualize and Analyze the Network.* Use specialized software to map and analyze the network structures. These tools generate graphs, clusters, and visual indicators of relationships. Some of the most used software are:
    1. VOSviewer: for creating co-authorship, co-word, and citation maps with clustering.
    2. Gephi: for advanced network visualization and layout manipulation.
    3. CiteSpace: for detecting research fronts and emerging trends.
    4. Pajek: for handling large and complex networks.
    5. UCINET: for social network metrics and in-depth analysis.
    6. HistCite: for chronological mapping of citation networks.

    - <u>Step 6A. Workflow:</u>
        1. Data input → CSV or BibTeX files are loaded from the database.
        2. Select the type of analysis → Co-authorship, synonymy, co-citation or citation network.
        3. Map drawing → The software displays the network graph (nodes = authors/keywords/articles and edges = their connections).
        4. Cluster analysis → Colors and groupings indicate scientific topics or communities.
        5. Interpretation of indicators → The network is examined with indicators such as Centrality, Modularity, Citation Counts.

    - <u>Step 6B. Expected output:</u>
        1. Scientific collaboration map → Identify key authors or institutions.
        2. Thematic map (Co-word map) → Reveal conceptual clusters.
        3. Citation map → Show the flow of knowledge and the impact of important articles.
        4. Trend analysis → Discover new areas and emerging trends.

- <u>Practical example:</u>

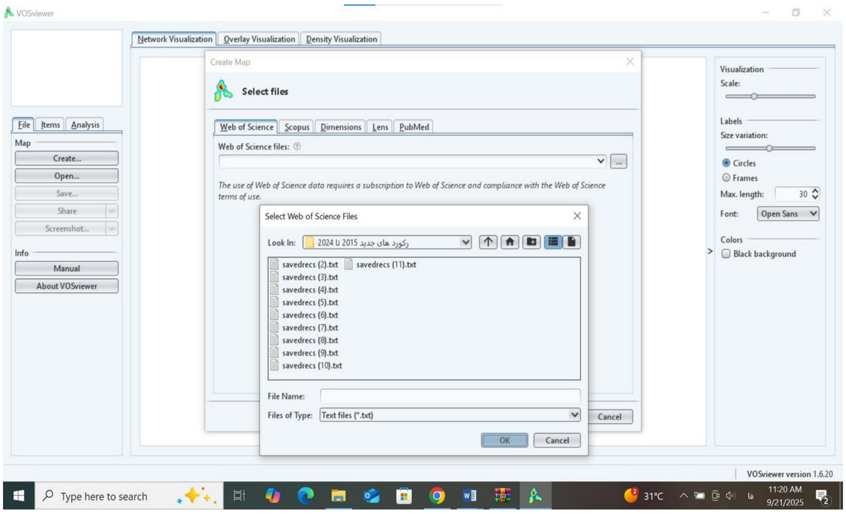

Figure 6. Submitting Web of Science data in the software VOS.

1. Import the Files into VOSviewer.
2. Open VOSviewer.
3. From the left menu, select: Create Map → Create → Create a map based on bibliographic data.
4. In the dialog window (like in your screenshot), choose Web of Science as your data source.
5. Click the ... button and select all the exported savedrecs files (from 2015–2024 in your case).
6. After downloading your Web of Science data → you import the savedrecs files into VOSviewer → choose the appropriate network type (Co-authorship, Co-citation, Co-word, etc.) → apply thresholds → generate and interpret the network map to understand the intellectual, social, or conceptual structure of your research field.

    1. Choosing the Network Type. VOSviewer lets you choose the type of network you want to build:
        1. Co-authorship → Collaboration patterns among authors, organizations, or countries.
        2. Co-citation → Intellectual structure of the field (papers cited together).
        3. Bibliographic coupling → Links between documents citing the same references.
        4. Co-word analysis → Thematic and conceptual structure through keyword co-occurrence.
        5. Citation network → Knowledge flow and influence between articles.

    2. Setting Thresholds and Filters. Define minimum thresholds for inclusion, they will reduce noise and help highlight the most significant elements, e.g.:
        1. Only authors with at least 5 publications.
        2. Only keywords that occur at least 50 times.

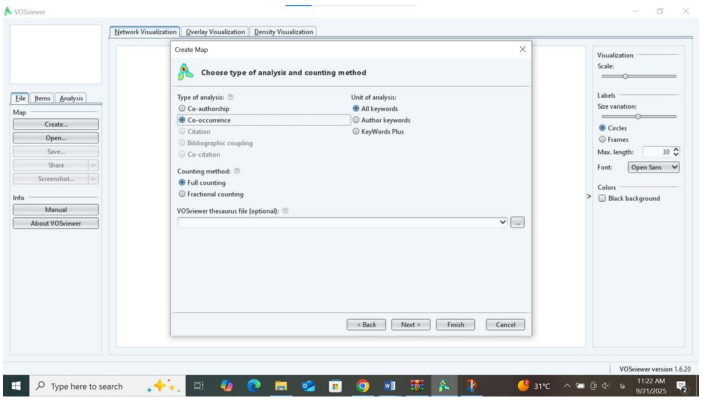

Figure 7. Selecting the network type for drawing a map in VOS software.

3. Visualizing the Map. Once processed, VOSviewer generates a network map:
    1. Nodes = items (authors, keywords, or documents).
    2. Size of nodes = importance (e.g., number of publications, citation count).
    3. Colors = clusters or thematic groups.
    4. Links = relationships (collaboration, co-citation, co-occurrence).

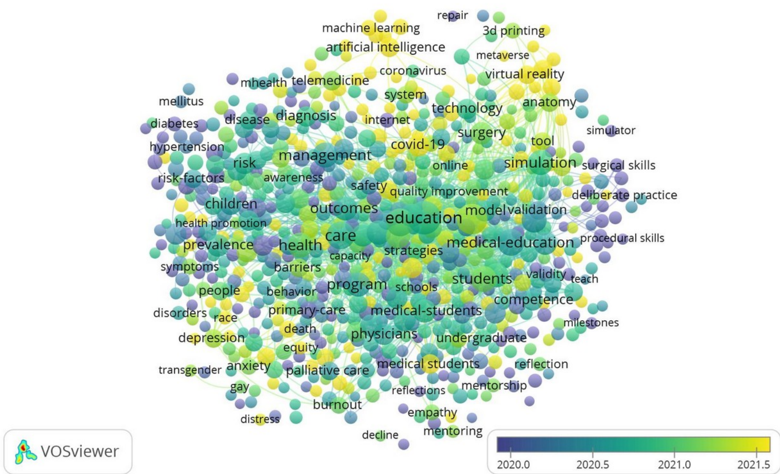

Figure 8. Example of drawing a co-occurrence map in VOS software

7. *Step 7: Interpret Results & Draw conclusions.* The map can reveal:
    - How research topics cluster into thematic communities.
    - Emerging research fronts and gaps in the literature.
    - Rather than stopping at descriptive statistics or graphs, this phase connects the findings back to the original research objectives and provides evidence-based conclusions. These are the key considerations (figure 11):

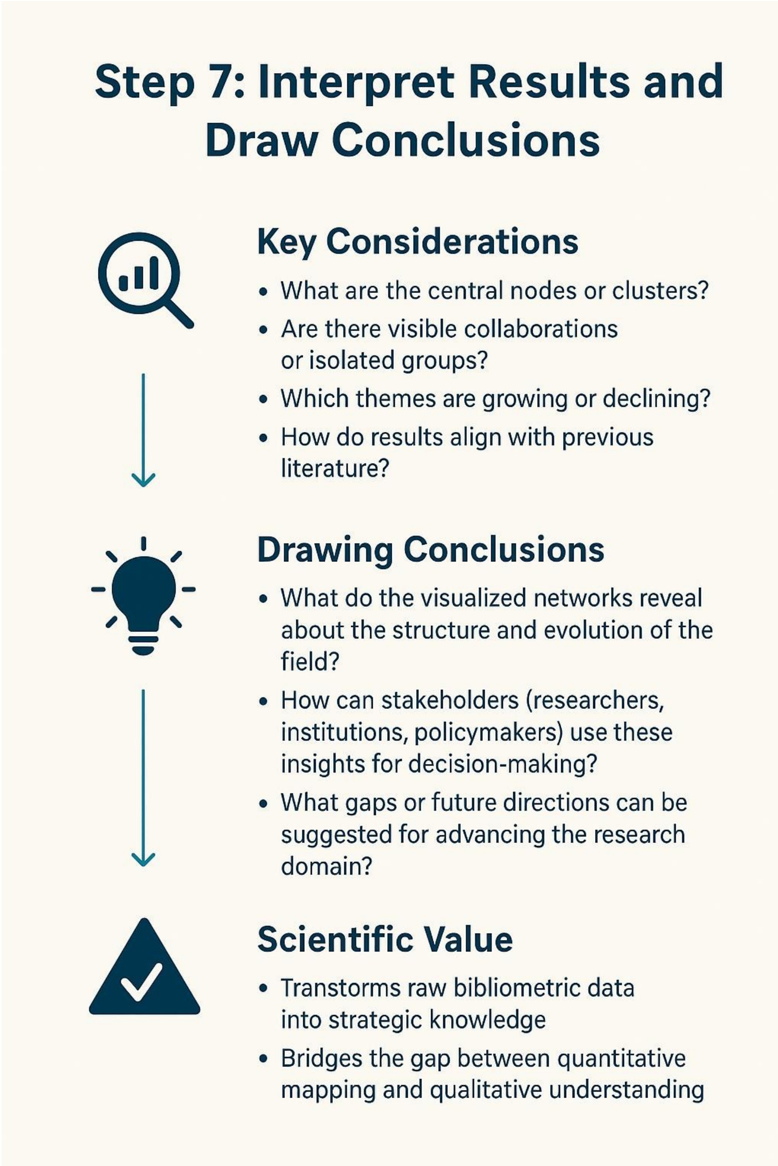

Figure 9. The interpretation of results and drawing of conclusions in scientometric studies.

1. Key Considerations. This part emphasizes on identifying network patterns and comparing them with the existing literature:
    1. Which nodes or clusters in the network are most important? (authors or central topics)
    2. Are there clear patterns of collaboration or isolated groups?
    3. Which thematic trends are growing or declining?
    4. How do the results fit with previous studies or scientific literature?

2. Drawing Conclusions. After identifying the structures, the analysis should analyze:
    1. What do the networks reveal about the structure and evolution of the scientific field?
    2. How can stakeholders (researchers, institutions, policymakers) use these results to make decisions?
    3. What gaps or future directions for research are identified?

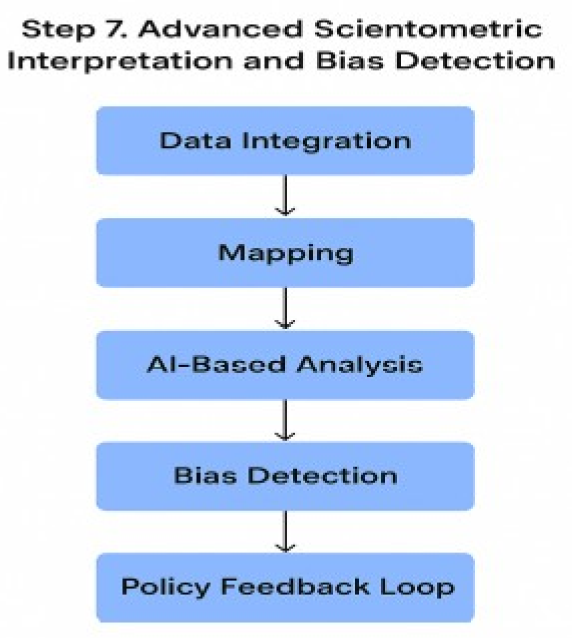

Figure 10. Advanced Scientometric Interpretation and Bias Detection.

4. Advanced Scientometric Interpretation and Bias Detection. After completing data integration and scientometric mapping, this stage focuses on advanced interpretation and diagnostic analysis. Scientometrics, at this level, extends beyond descriptive visualization it becomes a strategic and analytical framework for assessing both the intellectual structure and ethical integrity of scientific production. In this step, the mapped data are subjected to multi-layer analytical validation using text mining, data mining, and semantic network analysis supported by artificial intelligence algorithms. These techniques enable the identification of non organic citation clusters, redundant publication patterns, and unusual co-authorship or keyword linkages that may indicate systematic publication bias or artificial research inflation. Through semantic mapping of topic convergence and divergence, researchers can detect thematic inconsistencies between local or national publication trends and global scientific evolution, revealing cases where certain medical subfields produce repetitive, low impact, or commissioned articles. Moreover, AI assisted clustering and anomaly detection highlight potential "paper mills," citation manipulations, and institutional or editorial lobbies influencing the literature. By integrating these diagnostic techniques into the scientometric workflow, researchers move from merely visualizing scientific structures to evaluating the ethical and epistemic quality of knowledge production. Thus, scientometrics not only serves as a foundation for science mapping and policy planning but also as a precision instrument for safeguarding research transparency, detecting bias, and reinforcing scientific integrity across medical and interdisciplinary domains.

- *Contextualizing Scientometric Outputs.* The interpreted maps, clusters, and citation networks should be aligned with the broader scientific, social, and policy environment. Researchers analyze how thematic clusters correspond to real-world medical priorities, funding trends, or institutional collaborations. This alignment enables evidence-based foresight: identifying emerging topics, revealing underexplored intersections, and supporting data-driven scientific policymaking.

- *Transition from Mapping to Diagnostic Analysis.* Once the visual and statistical structure of the research field is defined, the same network data can be repurposed diagnostically. Scientometric outputs especially citation and co-authorship matrices can reveal patterns inconsistent with natural scientific evolution. Abnormally dense clusters, limited cross linking with global topics, or excessive self-citation loops may indicate closed publication ecosystems that operate under non-academic motives.

- *Integrating AI and Data Mining Techniques.*
  1. Through the integration of text mining, data mining, and semantic network analysis supported by artificial intelligence, these anomalies can be systematically evaluated.
  2. Text mining enables the extraction of linguistic patterns suggesting rhetorical bias or ideological framing.
  3. Data mining detects publication surges from specific institutions or journals with repetitive thematic orientation.
  4. Semantic network analysis compares local topic structures with global convergence trends, identifying divergence zones that may represent biased or commissioned literature.

- *Identifying Bias and Integrity Risks.* Using these methods, the scientometric framework can identify several red flags:
  1. Citation circles or reciprocal citation among limited author groups.
  2. Clusters of articles disconnected from the global thematic network.
  3. Sudden bursts of publications in narrow, commercially or politically sensitive domains.
  4. High overlap in author affiliations suggesting coordinated publication behavior.
  5. These features, when visualized through VOSviewer or similar tools, appear as isolated or over connected subnetworks, distinguishable from organically developed research communities.

- *Extending Scientometrics Toward Integrity Assessment*. By applying AI-assisted diagnostic models to scientometric data, researchers can move from descriptive evaluation to integrity-oriented analysis. This enables the detection of unethical publication behavior, ghost authorship, and systemic bias within medical and interdisciplinary domains. Scientometrics thus serves a dual role:
  1. Mapping and interpreting the intellectual landscape of medicine.
  2. Safeguarding scientific authenticity through quantitative identification of structural bias.

8. *Step 8: Report the Study and Ensure Transparency.* The final step of a scientometric study is, as illustrated in figure 11, clear reporting and ensuring reproducibility. This step is the connecting link between the research conducted and its value to the scientific community. Here are some key points to summarize:
   - Clear Reporting: Results should be accompanied by clear graphs, maps, and tables so that the reader can easily follow the patterns discovered. At the same time, methodological limitations (such as database bias or differences in indicators) should also be stated so that a realistic assessment of the findings can be made.

   - Transparency & Reproducibility: Providing data, code, or software settings (to the extent legally and ethically possible) allows other researchers to reproduce or improve on your results. This greatly improves the quality and credibility of scientometrics.

   - Future Directions: Scientometrics results should not be seen as an end point, but rather as a research roadmap. Conducting longitudinal studies to monitor long-term trends, combining quantitative measures with qualitative analysis, and finally paying attention to newer areas such as Webometrics and Altmetrics can open new horizons in science analysis. In conclusion, a professional scientometrics study is only complete when not only the data collection and analysis steps are carried out correctly, but also the final report is transparent, accurate, and reproducible. This will allow your research to be used as a reliable source for scientific decision-making, research policy-making, and even inspiration for future research.

6. Conclusions.

This document has presented a comprehensive, step by step framework for conducting professional scientometric studies, from the initial definition of research objectives to the visualization and interpretation of scientific knowledge networks. By integrating methodological rigor with practical tools such as Web of Science, Scopus, and visualization software like VOSviewer, CiteSpace, Gephi, and Pajek, the guide has shown how scientometric research can be systematically designed and implemented.

Figure 11. Report the Study and Ensure Transparency.

The key contribution of this framework lies in bridging the gap between conceptual understanding and practical application. It not only clarifies how to collect, refine, and analyze bibliographic data but also demonstrates how to translate these quantitative findings into meaningful insights that reflect the intellectual, social, and thematic dynamics of a scientific field. Importantly, the emphasis on interpretation ensures that scientometric studies go beyond descriptive statistics and visualizations, producing evidence based conclusions that can inform strategic decision making.

The structured approach outlined here highlights several critical outcomes:

- Mapping Scientific Structure Knowledge maps generated through co-authorship, co-citation, and co-word analyses provide clear insights into the organization of research domains and the interaction between scientific actors.
- Identifying Emerging Trends Longitudinal analysis of keywords, citations, and clusters allows researchers to detect new and growing themes, offering valuable guidance for future investigations.
- Evaluating Collaboration Networks By examining institutional and international co-authorship patterns, the framework sheds light on the strength and gaps in scientific collaboration, which can guide policymakers and institutions in fostering stronger partnerships.
- Strategic Application of Indicators Scientometric indicators such as h-index, citation counts, and collaboration indices, when combined with network maps, provide a robust evidence base for evaluating research performance.

- Ensuring Transparency and Reproducibility The importance of clear reporting, data sharing (when permissible), and acknowledgment of methodological limitations was emphasized as essential to building credibility and advancing cumulative scientific knowledge.

Ultimately, this training underscores that scientometrics is not merely a technical exercise but a strategic tool for understanding and shaping the development of science. Well designed scientometric studies can inform researchers, institutions, funding bodies, and policymakers by identifying influential actors, detecting emerging areas of inquiry, and revealing collaboration dynamics. In conclusion, the applied roadmap provided here equips researchers with both the conceptual and technical skills to independently design, execute, and interpret scientometric analyses. By adhering to methodological rigor, transparency, and thoughtful interpretation, scientometric studies can serve as powerful instruments for advancing scientific knowledge, Scientific biases, supporting evidence based policy, and shaping the future directions of research. Finally, the table 1 shows a glossary of common terms in scientometrics.

Table 1. Glossary of key terms in scientometric analysis.

Término	Definición breve
Scientometrics	Science that measures scientific production, dissemination, and impact through the analysis of quantitative data.
Bibliometrics	A subfield of scientometrics focused on bibliographic metrics, such as publications and citations.
VOSviewer	Software for creating and visualizing network maps based on co-citation, co-wording, or other bibliometric relationships.
CiteSpace	A tool that allows the detection of emerging trends and conceptual clusters from bibliographic data.
Gephi	A graph visualization and analysis platform that incorporates layout algorithms and network metrics.
WoS (Web of Science)	A multidisciplinary scholarly citation database widely used for scientific impact analysis.
Scopus	A scholarly citation and abstract database managed by Elsevier, with broad subject and time coverage.
PubMed	A biomedical literature repository maintained by the United States National Library of Medicine.
Co-authorship network	A network that represents collaborations between authors through links indicating shared publications.
Co-citation network	A network in which nodes represent articles and edges indicate simultaneous citations by other works.
Co-word (co-occurrence) network	Network based on the combined frequency of keywords within the analyzed texts.
Citation circle	Circular citation patterns that may reflect bias or potential collusion between authors or journals.
AI-assisted diagnostic model	Artificial intelligence algorithm applied to scientometric data to detect integrity anomalies (e.g., ghost authorship or plagiarism).
Open Access	Publications available without paywalls; in databases such as WoS, this attribute can be filtered.
Highly cited papers	Articles with a higher-than-average number of citations or identified as "hot" according to database criteria.
Transparency & Reproducibility	Practices that ensure the availability of data, code, and configurations to enable replication of studies.

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