An Approach to the Methodology of Social Network Analysis and Information Metrics Studies

Aproximación a la metodología del Análisis de Redes Sociales y los Estudios Métricos de la Información

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Abstract

This essay presents a theoretical approach to Social Network Analysis (SNA) and Information Metrics Studies (IMS), particularly bibliometrics, as complementary methodologies for analyzing scientific collaboration. The main objective is to argue for the relevance of integrating both approaches to enrich the understanding of knowledge production and dissemination processes, especially within the field of library and information science. The methodology is based on a documentary and conceptual review of specialized academic literature, which enabled the identification of theoretical foundations, commonly used indicators, and technological tools associated with each approach. The essay discusses key bibliometric indicators such as the co-authorship and collaboration indexes, as well as structural metrics from SNA, including degree, centrality, and betweenness. As a result, the combined use of both methodologies is shown to allow not only the measurement of scientific productivity but also the visualization of relationships among actors, the detection of collaboration patterns, the identification of strategic nodes, and the development of informed recommendations to enhance editorial processes and research management. The essay concludes with a proposal to strengthen the teaching and practical application of these methodologies in academic and scientific settings, positioning them as powerful tools for more comprehensive, evidence-based, and context-sensitive decision-making.

Keywords: social network analysis, bibliometrics, scientific collaboration, academic research.

Resumen

Este ensayo expone una aproximación teórica al Análisis de Redes Sociales (ARS) y a los Estudios Métricos de la Información (EMI), en particular a la bibliometría, como metodologías que pueden aplicarse de forma complementaria en el análisis de la colaboración científica. El objetivo principal es argumentar la pertinencia de integrar ambos enfoques para enriquecer la comprensión de los procesos de producción y circulación del conocimiento, especialmente en el ámbito de la bibliotecología. La metodología se basó en una revisión documental y conceptual de literatura académica especializada, que permitió identificar los fundamentos teóricos, indicadores más utilizados y herramientas tecnológicas vinculadas a cada enfoque. Se analizan los principales indicadores bibliométricos, como el índice de coautoría y de colaboración, así como las métricas del ARS, tales como grado, centralidad e intermediación. Como resultado, se evidencia que la articulación entre ambas metodologías permite no solo medir la productividad científica, sino también visualizar las relaciones entre los actores, detectar patrones de conexión, identificar nodos estratégicos y formular recomendaciones informadas para mejorar los procesos editoriales y la gestión de la investigación. Se concluye con una propuesta para fortalecer su enseñanza y aplicación práctica en entornos académicos y científicos, como herramienta para una toma de decisiones más integral, empírica y contextualizada.

Palabras clave: análisis de redes sociales, bibliometría, colaboración científica, investigación académica.

INTRODUCTION

Scientific collaboration has become an essential practice in the generation of knowledge, driven by the need to share resources, technical capabilities, and expertise among researchers, institutions, and countries. This cooperation has intensified in recent decades, not only due to the advancement of information technologies but also because of the growing complexity of scientific problems, which require interdisciplinary approaches and broader working networks (González *et al.*, 1997; Mora Valverde, 2019).

In the field of academic publications, analyzing co-authorship relationships allows for an understanding of how scientific production is structured, how knowledge communities are formed, and how widespread collaboration is among researchers. To this end, various methodologies have been developed, notably bibliometrics and Social Network Analysis (SNA). These two distinct approaches, when combined, allow for the study of both the volume of production and the relationships among the involved actors (Mora Valverde, 2019; Sebastián, 2000; Spinak, 1996).

As a subfield of information metric studies, bibliometrics enables the quantitative analysis of scientific production behavior, providing indicators such as the collaboration and co-authorship index (Rubio Liniers, 1999). Meanwhile, SNA allows for the visual representation and analysis of the structure of these relationships through nodes and links, applying metrics that reveal connection patterns, key actors, and communities within a network (Molina *et al.*, 2008).

This essay is part of a broader investigation and aims to present a theoretical approach to the combined use of both methodologies. Based on a documentary review, the conceptual foundations of bibliometrics and SNA are described, along with their evolution, main indicators, and associated technological tools. The focus is specifically on the field of librarianship, with the goal of promoting its use as a methodological resource in scientific research, evaluation processes, and institutional decision-making (Acevedo *et al.*, 2020).

To construct this essay, a literature review was conducted, focusing on academic texts related to Social Network Analysis (SNA) and Information Metric Studies, particularly bibliometrics. The methodological process involved searching for and selecting theoretical and empirical texts published between 2005 and 2024, available in scientific databases such as Scopus, Redalyc, SciELO, and Google Scholar. Priority was given to documents that addressed key concepts, methodological applications, and case studies in scientific collaboration, with an emphasis on the fields of librarianship and information science. Inclusion criteria considered thematic relevance, the editorial reputation of the sources, and the timeliness of the approaches, while duplicated texts, those without full access, or those of low academic rigor were excluded.

This approach is relevant because it allows us to understand how the complementary use of SNA and bibliometrics can expand our capacity to analyze academic collaboration processes. It does so by integrating both the structural component of relationships and the quantitative measurement of scientific production. Furthermore, it provides a useful conceptual foundation for strengthening decision-making in editorial, institutional, and scientific contexts, promoting research that is more contextualized, strategic, and open to new forms of academic collaboration.

Development

Information Metric Studies and Scientific Collaboration

Information Metric Studies are a well-established field within library and information science, focusing on the quantitative evaluation of scientific production and its dissemination patterns. A key subfield is bibliometrics, which applies statistical and mathematical methods to the study of academic literature to describe and understand how knowledge is generated, disseminated, and used (Rubio Liniers, 1999; Spinak, 1996).

Bibliometrics has become a crucial tool for analyzing the behavior of authors, journals, institutions, and countries. It allows for the evaluation of not only the quantity of publications but also their impact, visibility, and influence in various fields of knowledge. One of the most prominent phenomena in these analyses is scientific collaboration, defined as the joint work among researchers who contribute simultaneously to the creation of new knowledge (González Alcaide & Gómez Ferri, 2014; Mora Valverde, 2019).

To measure this collaboration, bibliometrics offers a series of indicators, such as the co-authorship index and the collaboration index. These indicators enable the analysis of the evolution of collaborative work, the formation of research teams, and the degree of internationalization of scientific publications (González de Dios *et al.*, 1997; Rodríguez-Faneca *et al.*, 2021).

Moreover, bibliometric studies make it possible to detect areas of knowledge concentration, dominant publishing networks, and emerging themes. This type of information is highly useful for editorial management, institutional evaluation, public policy development, and strategic research planning (Acevedo *et al.*, 2020; Rodríguez Treviño, 2013).

From my perspective as a researcher in librarianship, I believe that while bibliometrics is a powerful tool for measuring scientific activity, it can be limited if analyzed in isolation. Integrating it with relational approaches like Social Network Analysis allows for a broader interpretation of the data and provides a richer understanding of collaborative processes. This combination not only quantifies production but also helps identify opportunities for improvement, strategic alliances, or gaps in the scientific participation of certain actors or regions.

Social Network Analysis as a Complementary Methodological Approach

Social Network Analysis (SNA) is a methodology used to study the relationships between actors within a system. It employs graphical representations to show the links between individuals, groups, institutions, or countries (Wasserman and Faust, 1994; Molina *et al.*, 2008).

In the scientific domain, SNA allows for mapping co-authorship networks, citation networks, and institutional ties. It is important to clarify that SNA is an independent methodology with its own theoretical and procedural foundations, not merely a technique derived from bibliometrics. However, it can be applied as a complementary approach within Information Metric Studies, particularly in research that analyzes scientific collaboration (Brand and Gómez, 2009; Ibáñez-Cubillas, 2016).

Through representations called graphs, it's possible to observe how relationships are structured, which actors hold central positions, who acts as a bridge between communities, and how cohesive or dispersed a network is.

One of SNA's most significant contributions is its ability to visualize and quantify the structure of interactions. Analysis metrics—such as degree, centrality, closeness, betweenness, or density—provide key information for identifying relevant nodes and understanding the network's overall behavior (Pérez Beltrán *et al.*, 2015).

In my opinion, SNA provides a structural and visual dimension that bibliometrics alone cannot achieve. In practice, by representing co-authorship or citation networks, patterns often overlooked in traditional analyses are revealed. I believe that, especially in fields like librarianship, where collaboration between institutions and academic communities is key, this structural perspective is essential for making relationships visible, strengthening ties, and recommending actions aimed at more equitable and cohesive scientific production.

Key Concepts of Social Network Analysis

According to Polanco (2006, p. 11), all the concepts mentioned below are useful when analyzing any network. Some of these concepts are illustrated with examples from Matemáticas IES (2021) and Torres Valencia (n.d.):

- A "graph" is a set of objects called nodes or vertices, which can be joined (connected) by lines called edges. In simple graphs, there can be no more than one edge connecting any two vertices (see Figure 1).

- A "Mode 1 adjacency matrix" is a square matrix that has the same number of rows as columns (see Figure 2). In this adjacency matrix, each element is equal to 1 when there is an edge connecting the vertices; otherwise, the element is 0. Therefore, this matrix is composed of zeros and ones.

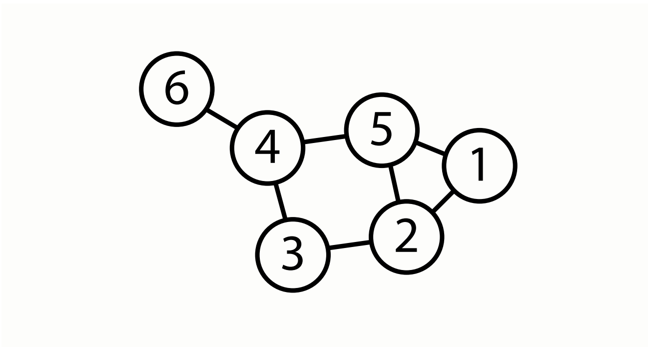

Figure 1
Example of a graph

Note: Matemáticas IES (2021, párr. 1)

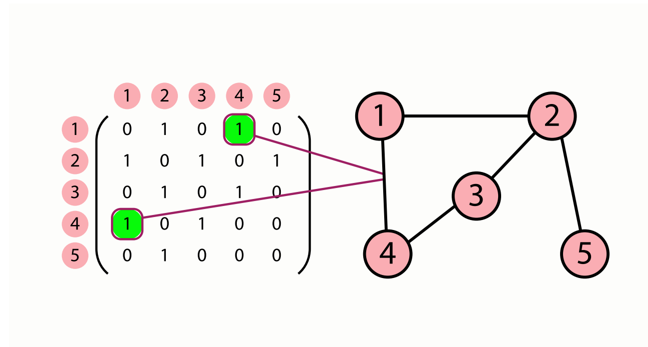

Figure 2
Example of adjacency matrix

Note: Matemáticas IES (2021, párr. 9)

- The **"Mode 2 adjacency matrix"** is not a square matrix; it is created based on the number of events. Unlike a Mode 1 matrix, the diagonal does not apply. Events have a temporal aspect, and actors are related to these events. A Mode 2 analysis can be used to observe affiliation networks, which consist of sets of relationships between individuals and events. It also offers the possibility of observing the network of relationships between different groups based on people's membership in two or more groups (Mote, 2005, pp. 94-95).

- The **"degree"** of a node is the number of nodes adjacent to it—the number of relationships incident to it. In a directed graph, a node can be "adjacent to" or "adjacent from" another node, depending on the direction of the arc (see Figure 3).

- **Out-degree** is the number of arcs originating from ni, while in-degree is the number of arcs terminating at ni,. The out-degree of a node, dout(ni), is the number of nodes adjacent from ni. It is equal to the number of arcs of the form rk=<ni,nj>, for all rk∈R and for all nj∈N.

- **The in-degree** of a node din(ni) is the number of nodes that are adjacent to ni. It is equal to the number of arcs of the form rk=<nj,ni>, for all rk∈R and for all nj∈N (see Figure 4).

- A **"path"** is a sequence of nodes such that each node has an edge (or relationship or connection) to the successor node. A path is said to be simple if none of its nodes are repeated.

- The **"length of a path"** is the number of edges used by that path (see Figure 5).

- **Geodesic distance** between two nodes is the shortest number of edges in a path between them. It's the shortest path between one node and another. For example, in Figure 5, the geodesic distance would be the one shown in Figure (b).

- The **diameter** of a graph is the greatest distance between any two nodes in the same network. Following the example in Figure 5, the diameter would be the longest distance among all pairs of nodes in the network, as shown in Figure (a).

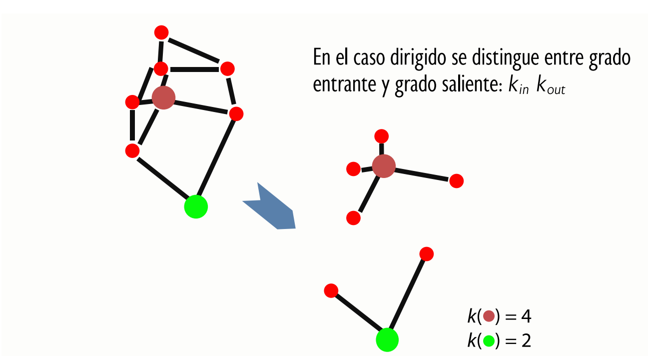

Figure 3
Example of a degree in a network

Note: Torres Valencia (s.f., p.16)

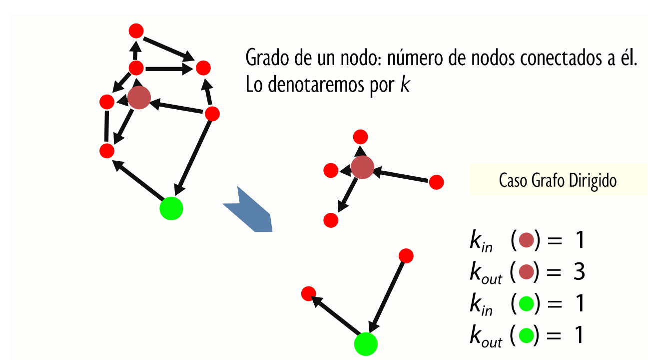

Figure 4
Example of incoming and outgoing degree in a network

Note: Torres Valencia (s.f., p.17)

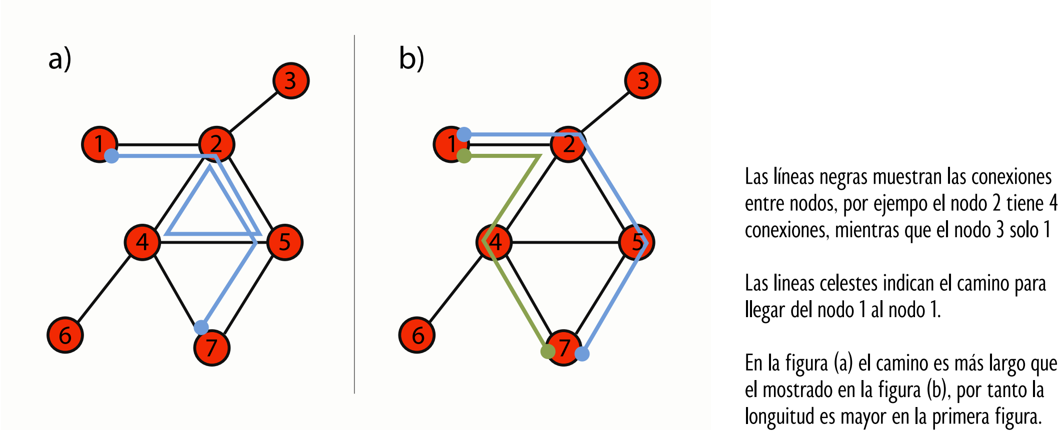

Figure 4
Example of path and length in a network

Note: Jaimes (2015, walks and distances, par. 1)

Based on the concepts from Borgatti *et al.* (2002, as cited by Pérez Beltrán *et al.*, 2015, pp. 130-131), the following metrics are used to conduct studies within the framework of network analysis theory:

- **Degree** is defined as the number of other actors to which an actor is directly connected or adjacent. It organizes actors by the effective number of their direct relationships within the entire network. This indicator provides information on the local centrality of an actor with respect to nearby actors.

- **Eigenvector centrality**[1] assumes that links to more central actors are more important than links to peripheral actors. Therefore, this index measures the centrality and power of each actor based on their own degree and the degree of the nodes to which they are connected. The most central nodes, in this sense, correspond to the centers of dense regions in which all actors are connected to each other.

- **Closeness:** is the property by which an actor can form relationships with other actors through a small number of steps in a network. Closeness is based on the measure of proximity and its opposite, farness. It provides a better description of overall centrality because actors are valued by their distance, measured in steps, from all other actors in the network. An actor has a high closeness centrality value when the number of steps they must take through the network to connect with everyone else is low. Closeness also indicates an actor's autonomy from others and can be used, along with betweenness, to specify or qualify the relevance of the degree value, as it refers to the point at which the actor is closest to all others.

- **Betweenness:** This is the extent to which a focal actor lies on the shortest path between other actors. It gives an idea of the control an actor has over the flow of information in the network. Actors with high betweenness often serve as bridges, connecting different subgroups or blocks.

- **Density:** This metric represents the number of existing links between nodes compared to the maximum possible number of links (i.e., if every node were connected to every other node). Density can also be measured in weighted networks, where relationships have different values. This is called weighted density, which is calculated by dividing the total value of all relationships by the total number of possible relationships.

- **Modularity:** This describes how the network is organized into sub-networks or communities. A value greater than 0.4 is generally considered significant for this metric.

- **Diameter:** This is the longest shortest path between any two nodes in the network. An infinite diameter can indicate that the graph has an infinite number of vertices or is simply not connected. The average diameter is the average of the distances between all pairs of nodes.

- **Ego network:** Also known as a personal or egocentric network, this refers to the social relationships of a single actor. The data is analyzed by summarizing the characteristics of the individuals in that network in order to correlate the aggregated characteristics with the individual characteristics of those involved. This type of data allows researchers to study topics such as the characteristics of social support networks,

1. The root "eigen" comes from German and means "own" or "proper." Eigenvectors are also known as proper vectors or characteristic vectors of a linear transformation or a matrix (Larson, 2015, p. 342).

variations in social support after a natural disaster, the influence of networks on adolescent behavior, the relationship between intravenous drug use and HIV transmission, or the effect of personal networks on voting behavior (McCarty, 2010, p. 243). These networks are also a result of the forces that society reproduces: social and economic organization, cultural institutions, and the intentional and unintentional actions and outcomes of its individuals (Giddens 1967, 1987, as cited by Molina *et al.*, 2008, p. 36).

- **Cluster** analysis is used to find groups within the network based on their relationships (Kuz *et al.*, 2016, p. 92). This analysis is a set of multivariate techniques used to classify a group of individuals into homogeneous groups (University of Valencia, n.d., p. 1).

Indicators of Scientific Collaboration and Network Analysis

From a bibliometric perspective, the co-authorship index and the collaboration index provide an initial look at collaborative behavior (González de Dios *et al.*, 1997; Mora Valverde, 2019). Furthermore, two-dimensional indicators allow for the observation of knowledge concentration and network stability (Ibáñez-Cubillas, 2016; Rodríguez Treviño, 2013).

Social Network Analysis (SNA) complements this view with structural metrics like degree, centrality, closeness, betweenness, density, and modularity (Molina *et al.*, 2008; Pérez Beltrán *et al.*, 2015). When combined with bibliometric indicators, these metrics allow us to understand not only the amount of knowledge produced but also how that production is structured and distributed within the scientific community (Brand and Gómez, 2009).

In my opinion, integrating quantitative (bibliometric) indicators with relational SNA metrics not only improves the quality of the analysis but also enables a more strategic interpretation of the results. This duality makes it easier to provide informed recommendations to editorial teams, research centers, and institutional authorities. It allows us to go beyond simple counting and evaluate how knowledge actually circulates, who the leaders are, and what power or exclusion structures might be operating within the networks.

Technological Tools for Network Analysis

Technological tools facilitate network analysis for both methodologies. Among the most widely used software that does not require programming are Gephi, VOSviewer, Pajek, and Ucinet (Amat, 2014; Brand & Gómez, 2009). For programmable environments, notable libraries include NetworkX, igraph, and statnet (Pérez Beltrán *et al.*, 2015). These tools enable the representation of networks, the application of analysis algorithms, and the export of visual results that aid in interpreting complex collaboration data (Rodríguez-Faneca *et al.*, 2021).

From an applied perspective, I believe that the current availability of accessible and powerful tools for network and bibliometric analysis opens up new possibilities for democratizing these methodologies in Latin American research. I think it's crucial to promote the use of these technologies in academic training. They not only help produce more precise and complete results but also generate useful evidence for formulating concrete recommendations for editors, researchers, and those who evaluate scientific production.

Proposal

Based on the analysis presented in this essay, I propose that the academic community, particularly in the field of librarianship and information science, more decisively promote the methodological integration of Social Network Analysis (SNA) and bibliometrics as complementary tools for research, evaluation, and management of scientific output.

In academia, this proposal means including training in both methodologies across undergraduate and graduate programs in librarianship, information science, education, and scientific research. This would not only strengthen the analytical skills of students and faculty but also foster a research culture that is more critical, empirical, and focused on continuous improvement.

Within the scientific community, the proposal aims to encourage the combined use of these methodologies in studies that evaluate journals, analyze institutional collaboration, visualize disciplinary networks, and diagnose research systems. This integration would allow us to not only measure scientific production in quantitative terms but also to identify patterns of connection, leadership, exclusion, and strategic opportunities for growth and cooperation.

To achieve this, I recommend the following:

- Establish basic methodological guidelines to direct the combined use of SNA and bibliometrics in scientific research.

- Encourage the creation of interdisciplinary teams that include specialists in quantitative analysis, data visualization, and editorial management.

- Promote the use of accessible and free technological tools, along with open data repositories, to facilitate reproducible analysis.

- Drive regional or inter-institutional research that uses this methodological combination to analyze production networks in Latin America, making local dynamics visible that are often overlooked in global studies.

I believe that taking this proposal seriously would contribute to a broader and deeper understanding of science as a collaborative social practice, and would enable the construction of more solid, inclusive, and strategic academic networks.

Conclusions

The combined analysis of Social Network Analysis (SNA) and bibliometrics allows for the observation of both the quantity of scientific production and its relational structure. This methodological complementarity strengthens the understanding of academic collaboration and enables more informed decision-making in evaluation processes, editorial management, and scientific policies (Brand & Gómez, 2009; Ibáñez-Cubillas, 2016; Molina *et al.*, 2008).

The availability of technological tools has democratized their application, and their inclusion in library and information science studies can foster a more reflective, strategic, and collaborative research culture (González Alcaide & Gómez Ferri, 2014; Rodríguez-Faneca *et al.*, 2021).

In summary, I firmly believe that integrating SNA and bibliometrics as complementary methodologies not only offers a more complete understanding of scientific collaboration but also provides a richer empirical foundation for generating recommendations aimed at improving academic production. This combined perspective allows stakeholders in the scientific ecosystem—researchers, editors, and institutions—to make more informed, fair, and strategic decisions.

Given the potential of these methodologies to reveal hidden structures in scientific production, it is recommended to promote research that combines bibliometrics and social network analysis in different contexts: higher education, applied research, public policy, and knowledge management. It is also relevant to explore the use of emerging technologies, such as artificial intelligence, to automate the identification of collaborative patterns and suggest new strategic alliances between researchers or institutions.

This essay, which is theoretical and exploratory in nature, has several important limitations that must be considered. First, the discussion is based exclusively on a literature review and does not empirically apply the methodologies of social network analysis (SNA) and bibliometrics to a specific body of scientific data. This means that the advantages and complementary potential of both methodologies are addressed on a conceptual level rather than through results supported by quantitative evidence. Second, the analysis is focused primarily on the Latin American context. While frameworks applicable on a global level are presented, there is no in-depth discussion of regional comparisons that could enrich the conversation about scientific collaboration.

Despite these limitations, the essay opens avenues for future research by identifying the need for mixed-methods studies that combine quantitative analysis (bibliometrics) with network visualizations (SNA), applied to specific scientific journals, academic communities, or emerging knowledge areas. It also suggests the importance of developing common methodological protocols to guide the integration of both techniques, as well as building open data repositories that facilitate reproducible analysis and broaden the scope of comparative studies. Overcoming these gaps would not only empirically validate the benefits of methodological complementarity but also provide more solid evidence for improving editorial, scientific, and institutional policies.

In conclusion, this essay presents limitations that create opportunities for future research. As a theoretical reflection based on a documentary review, the methodologies were not empirically applied, so their contributions are centered on the conceptual plane. Likewise, the focus was limited to the Ibero-American context, without incorporating comparisons between regions or specific case studies. These limitations offer opportunities to advance toward mixed-methods research that combines bibliometric and social network analyses on real data to empirically validate the benefits of their integration. It is also necessary to develop shared methodological protocols, strengthen access to open data, and encourage collaborative studies that can close gaps in the understanding of scientific production and its relational structure. Addressing these lines of inquiry would contribute to a more robust, inclusive, and strategic vision of academic work.

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