

Research networks evaluation: indicators of interactive and formative dynamics

Avaliação de redes de pesquisa: indicadores de interação e formação

Evaluación y redes de investigación: indicadores de interacción y formación

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Abstract

This study, supported by CNPq, aimed to elaborate markers for the evaluation of interactive processes work in research networks. It is grounded on the understanding that a research network is established when a group collaborates with the intention of producing knowledge. From the theory, a methodology was developed to explore the curricula of researchers employing software to build spreadsheets, count co-authorships, and analyze social networks. The researchers' bibliographical production was examined through graphs representing their research collaboration networks and a protocol was built to evaluate them. The results identify 10 markers, qualitative and quantitative indicators for evaluating research processes on networks, which have been tested and validated in the context of application.

Keywords: Evaluation. Research networks. Scientific collaboration. Indicators.

Resumo

Este estudo, apoiado pelo CNPq, objetivou elaborar marcadores para a avaliação de processos interativos de trabalho em redes de pesquisa. Ele se baseia no entendimento de que este tipo de rede se estabelece quando um grupo colabora com a intenção de produzir conhecimento. A partir da teoria, desenvolveu-se uma metodologia de exploração de currículos de pesquisadores com uso de softwares para construção de planilhas de dados, contagem de coautorias e análise de redes sociais. A produção bibliográfica dos pesquisadores foi examinada através de grafos representando suas redes de colaboração em pesquisa e um protocolo foi construído para avaliá-las. Os resultados identificam 10 marcadores/indicadores quali-quantitativos para avaliação de processos de pesquisa em rede que foram testados e validados em contexto de aplicação.

Palavras-Chave: Avaliação. Redes de pesquisa. Colaboração científica. Indicadores.

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Resumen

Este estudio, apoyado por el CNPq, tuvo como objetivo elaborar marcadores para la evaluación de procesos de trabajo interactivo en redes de investigación. Se basa en el entendimiento de que este tipo de red se establece cuando un grupo colabora con la intención de producir conocimiento. Desde la teoría, se desarrolló una metodología de exploración de currículos de investigadores con el uso de softwares para crear hojas de cálculo y contar coautorías y realizar análisis de redes sociales. La producción bibliográfica de los investigadores fue examinada por grafos que representan sus redes de colaboración en investigación y un protocolo fue construido para evaluarlas. Los resultados identifican 10 marcadores/indicadores cualicuantitativos para evaluación de procesos de investigación en red que fueron testados y validados en el contexto de aplicación.

Palavras Chave: Evaluación. Redes de investigación. Colaboración científica. Indicadores.

1. INTRODUCTION

Nowadays researchers and teachers are being evaluated by the metrics of their bibliographic production. Bibliometric indicators accomplish and comply with this purpose. They are being applied as instruments for detecting knowledge production and for research results communication. But, as argues Van Raan (2006, p.409), (...) “the conventional bibliometric indicators may fail to account for this nonlinearity between size – measured by number of publications – and impact – measured by number of citations – and could result in an over or underestimation of research performance”. (RAAN, 2006, p. 409)

The productivity measures – mainly based on number of publications in international journals – make up the indexes that will accredit and classify undergraduate and graduate higher education programs in Brazil, and are tasks carried out, respectively, by the National System of Higher Education Evaluation (Sinaes) and by the Coordination for the Improvement of Higher Education Personnel (Capes).

In Brazil, graduate programs and individual researchers, both are evaluate by Capes and by the National Council on Scientific and Technological Development (CNPq). Evaluation guidelines are given in the decennial National Plan for Postgraduate Education (PNPG) 2011/2020. Among the parameters, are the internationalization and relationship with the extra-academic sector, conditions for the classification of graduate programs at a level of international excellence, scores 6 and 7 (scale from 1 to 7). The guidelines appraise ‘parameters that are not exclusively those of the basic and academic fields’. The evaluation of applied programs includes incentives to form partnerships for the purpose of generating technology and training professionals for the entrepreneurial sectors. The guidelines consider the weighting of articles and books published, theses and dissertations advising, which adjust

to external demands. The type of individual production to be considered includes bibliographic, cultural and technical production, patents requested, patents that are commercially exploited, software, prototypes and others. Therefore, they contribute to the reputational concepts given to higher education institutions. Such indexes and concepts are, indeed, mathematic formulations, but they validate the research activity in the microinstitutional context, locus of individual career and group activities. They can acquire an extreme and unique importance because they reverberate in international university rankings and, in order to do that, change the focus of research practices towards a sometimes sterile productivity.

Unfortunately, evaluation procedures restrained to measurements do not consider the collaboration that occurs inside research networks and groups. By the way, research networks and collaboration have been taken by the prestigious Nature as the success marker for universities of the future (ADAMS, 2012) and as trampolines to the knowledge economy by a special edition of Studies in Higher Education (KEARNEY; LINCOLN, 2013). Despite of it, in the acknowledged evaluation systems, the products are measured, but the processes through which they have been conceived remain mostly unknown.

Therefore, the study to be presented is part of a larger project aimed at exploring the relations inside the generating processes of knowledge production, e.g. inside research groups and to build markers to assess interaction in research networks.

2. APPROACHES FROM THEORY

We understand that in science, as in other human activities, “a network community can be defined as a group of people who are more connected among themselves than they are in relation to other groups of people” (CHRISTAKIS; FOWLER, 2010, p. 8). A research network is a web of connections among scientists whose relations, on creating co-authorships interactions, produce knowledge circulation and innovation.

Therefore, for each new research project inside a research group, a new network is formed, maybe a different web. For each circumstance, time and place, a special web will be weaved. These webs may produce different results and “despite the ubiquitous nature of collaboration in science, the benefits of collaboration are more often assumed than investigated” (LEE; BOZEMAN, 673).

A simple way for understanding collaboration nets in research is given by Newman: “I study networks of scientists in which two scientists are considered connected if they have coauthored a paper” (NEWMAN, 2001, p. 404). Therefore, in the study presented here, we focused only on collaboration as it can be perceived through co-authorship in scientific publication.

We acknowledge there “are many variants of research collaboration that are not covered by co-authorships” (LAUDEL, 2002, p. 4). However, co-authorship is still being used as the main measure of connection within academic networks (GLÄNZEL; SCHUBERT, 2005). It is based on the analysis of co-authorship network, which examines authors as nodes in a research network defined by collaboration (SUN; MANSON, 2011). Yet, collaboration networks in research can be highly complex when their specificities, differences, territories and frontiers among disciplinary areas are observed (CLARK, 1998; BECHER; TROWLER, 2001; NEWMAN, 2001; 2003).

As for frontiers, it is important to highlight that interest and communication strategies tend to minimize conflicts and predicaments. Paradigms and methodologies can be shared, stimulating intergenerational learning. Stoer and Magalhães (2003) have considered that networks are established on the principle of partnership. Cooperation and interactions in networks enhance theoretical and methodological research references and bring resources from different orders into the groups. Research networks show, in a beyond competition manner, the “brand” of different research territories, their own ways of researching and publishing results and/or of delivering patents and prototypes.

According to Watts (2004), there would be a “new science of networks”. One would need to understand its multidisciplinary and innovative agendas under constant construction (MOLINA; MUÑOZ; DOMENECH, 2002). As Leung (2013) says, the functioning of the research networks resembles the “sponge” metaphor or the communicating vases. For the nanotechnology author, groups operating in networks produce innovation when acting in “spongelike” networks, whose flexible structures absorb constructive efforts from partners and squeeze useful material at the right moment.

Other views define the studies about networks and capture research networks in different disciplinary areas, investigate and analyze co-publications, with procedures and tools based on Social Network Analysis (SNA) and scientometric techniques. Among these authors, are: Balancier and colleagues (2005), Maia and Caregnato (2008), Fiorin (2007), Oliveira,

Santarem and Santarem Segundo (2009), Vanz and Stumpf (2010), Hayashi and Amarílio Junior (2010).

The evaluation of research network interaction, nevertheless, seems to be still an object of desire, given the difficulty to capture the inside, internal elements of collaboration. A reduced number of studies about evaluation of research networks can be found in the literature (VAN RAAN, 2012; WIXTED; HOLBROOK, 2012). Studies about the thematic come across in articles and reports of the Organization for Economic Cooperation and Development (OECD) and Simon Fraser University (SFU). OECD points out the need to evaluate collaboration since the beginning of a given project/program. It is understandable that the outcomes of evaluation should be publicized to the policies responsible and to the general public. In capturing the outcomes and impacts of publicly funded research, Cressman and collaborators (2009) state that the tools for evaluating networks are in their infancy; that there is an absence of specific vocabulary to describe networks; and that the language used to describe network studies is a complex mathematics language, difficult to understand in its senses.

For Shin, Lee and Kim (2013), the collaborative activities are discouraged at times because evaluation systems only count publications and citation of researchers. In some systems, these metrics can be negative to collaboration, since they discount points from authors whose publications have been coauthored. Tensions and conflicts occur because the counting of points from publications is fractionalized and the credit among the authors, divided.

We base our studies upon the consideration that research collaboration is traditionally measured by number of co-authorships extracted from publications. In individual level it examines authors as nodes in a research network defined by collaboration (SUN; MANSON, 2011). We also acknowledge that, despite the incommensurable number of applications already developed, there are still many variants not covered (BARABASI et al., 2002; LAUDEL, 2002). Explicit or visible forms of collaboration are easy to measure, but they are only a small part of the collaboration iceberg. As such, co-authorship and citation data analyses identify the connectivity among different nodes/actors (e.g. individuals, organizations and institutions) and their characteristics. They allow us to see some pathways and trends according to which knowledge is built and flows.

Other issues related to networks indicators is the need to critical analyses of some data problems. For example, sometimes bibliometric data present consistency troubles, such as

incongruences in authors' and institutions' names. This fact points out to the necessity of standardizing and cleaning data (MAIA; CAREGNATO, 2008; VANZ; STUMPF, 2010). Selection of the best indicators for a research networks system must take in account cost of collecting data. Systems must be built on simplicity and reliability criteria, taking care to select appropriate indicators in order to avoid information overload.

The reviewed literature casts doubt about who collaborates, why and how they collaborate, not answering the classic evaluation questions: know what, know how, know why, know who and know who knows to do what. Many indicators can be used on analyzing and evaluating networks: as Airoidi and colleagues (2011) said, “there are 47 network metrics widely adopted in the social and physical sciences”, and they give some examples of popular network metrics such as a variety of centrality measures, clustering coefficients, connectedness, hierarchies, and average distances. Thus, selecting which dimensions and indicators are the best suited to answer the research questions one has in mind is a key step on research network evaluation. The study hereby presented defines as its objective to understand the interaction processes that occur inside research networks and proposing an evaluation of collaboration processes.

3. DATA COLLECTION AND METHODOLOGY

As criteria for choosing the investigated subjects, the search focus was set on the top career positions on the areas of Education, Production Engineering and Physics. To meet the first criterion, the sample was drawn from scholars considered of excellence by the Brazilian National Council for Scientific and Technological Development (CNPq), under the 1A classification. To be part of the study, each researcher must have been leader of research groups with a 10-year-old network of collaborators. Data was collected by combining and cross-checking information from CNPq's Lattes Platform of Curricula Vitae and of Brazilian Directory of Research Groups (DGPB/CNPq). Each research group in Brazil registered in this database has one leader, its main researcher, an ego around which the network is developed. As we gathered collaboration information only from the curricula of the leaders, we obtained egocentric networks, patterns that emphasize the role of the leader in the knowledge flow.

The methodology included: (a) data collection from 1A researchers' curricula, CNPq Lattes Platform and DGPB/CNPq databases; (b) compilation of data on authors and co-authorships; (c) construction of graphs representing the collaboration on articles, books and

chapters published in 10 years by each subject; (d) interviews (not explored in this article); and (e) development of a pilot study.

The pilot study was carried out by reviewing the curriculum of a researcher from our research group who comprised the same characteristics of the group selected for analysis. These data, however, was not included in the sample described here (MIORANDO, 2011; MIORANDO; LEITE, 2012).

The final sample was integrated by 10 Education researchers; 6 Production Engineering researchers (only 8 at the top of the career and 2 between them without a research group); 10 Physics researchers. These fields were considered in accordance with CNPq's table of areas of knowledge. They were also chosen in continuity with the selection adopted in former studies (CUNHA; LEITE, 2009), using the classification of academic areas according to the epistemological status and the labor and employment conditions of the careers to which they train (Table 1).

Table 1 – Knowledge areas and selected careers.

Great Area	Area	Career
Human Sciences	Education	semiprofession
Exact and Earth Sciences	Physics	profession
Engineering	Production Engineering	liberal profession

Source: Author: based on CNPq – Table of Knowledge Areas (extracted from <http://200.17.161.80/prppg/projetos/tabela-areas-do-conhecimento-cnpq.pdf> in May, 3rd, 2013) and on Cunha and Leite (2009).

Therefore, 26 researchers were selected for the study and their production in articles, books and chapters made up the main corpus of the collected data. For ethical reasons, the data of one subject was disposed of. Thus, the results concern the networks of 25 researchers. The data coming from public curricula, Lattes Platform, were collected at established and fixed dates, and they comprise the production from years 2001 to 2010, period of time representing an expressive exposition of researchers to public policies of incentive to publication and to research group formation, induced by CNPq.

4. RESULTS

Based on the reviewed literature, the pilot study, the interviews with groups' leaders (which are not discussed in this text) and on the collected and analyzed data about the scientific

production of the researchers acting in research networks, a synthetic protocol of evaluation criteria and markers was conceived and applied to each of the subjects' networks.

The protocol was formulated from the compilation of all kinds of data constructed from the curriculum of each researcher and analyzed through the employ of a spreadsheet application (Microsoft Excel) and a SNA software (Pajek). It was designed to provide an overview of network activity in the production of an author, combining elements in a set and allowing further interpretation. Protocols were made out of three sections: identification data (subject information); network structure (graphs from scientific publication and analysis of ego's co-authorship relations); frequencies of ego and co-authors publications.

Consequently, 25 individual protocols and 25 networks were designed and submitted to a practical application. The networks showed ten years of production and, combined, made up tallies of 970 articles, 325 book chapters, 53 whole books and 918 co-authors. Furthermore, protocols were compared within and among the three knowledge areas. The comparative results make it possible to identify quali-quantitative indicators for evaluation of network research processes.

The markers obtained, as the name suggests, intend to mark or indicate interaction processes, collaboration and co-authorship inside research networks. They are designed to shed light on egocentric networks such as the ones we constructed and analyzed. They refer to (A) network's actors, partners of the leader/ego in co-authoring scientific publications; (B) position of the leader/ego in the network and its power distribution; (C) national/international range of the network's output; (D) power of the leader/ego (Table 2).

Table 2 – Selected markers or indicators.

Reference	Marker/Indicator
A. Network actors (leader/ego's partners)	(1) network authors: intra and extra group in-country and abroad; (2) vertices groupings which situate individuals linked to the leader/ego or to more network actors; (3) authors' institutions: in-country or abroad, academic or extra-academic.
B. Leader/ego's position and network's power distribution	(4) leader centralization: pure or interconnected forms; (5) publications by number of authors.
C. Network production's national/international range	(6) publications by geographic insertion: national, international; (7) periodicals by geographic insertion.
D. Leader/ego's powers	(8) degree of centralization; (9) group/network leader's power; (10) collaboration intensity.

Source: Authors (2014).

Markers can also be rearranged as they beacon the interaction processes – leader power, intensity of collaboration, number of participants in the network; the movements of the network – publication inside and outside the country, national and international partnerships; and the different agencies integrating the network – seen through research group and institutional affiliation of authors to universities, corporations and foundations. They offer insights on the size, reach and dynamics of a research collaboration network.

The markers obtained by observation of the combination of factors analyzed can also be seen according to the disciplinary area of knowledge investigated. For instance, the fields included in this study present different behaviors when it comes to their publication practices. It was possible to notice that the collaboration in the networks also varies according to the vehicle used, i.e., the publication media, such as journals, whole books or book chapters. Collaboration thresholds for the three areas converge when it comes to books and chapters, pointing out that the differences among areas can be measured from the data on articles' authorship.

Thus, it is possible to draw a few conclusions on the networks' interaction processes when analyzing e.g. articles production in ten years. Education authors have published only part (42.6%) of their works in collaboration with colleagues, while Physics and Production Engineering researchers publish preferably with partners, they coauthored more than 95% of their outputs (marker B5). Likewise, when taking the case of collaboration, Education has a share of 46.5% of coauthors –ego plus one - that connect exclusively with the leader, while in Physics 85.3% of collaboration results of the linkage of three or more authors, and in Production Engineering 42.7% had collaborated with at least two other researchers (marker A2). This leads to the conclusion that Physics has bigger research collaboration networks with a greater connectedness and degree of collaboration, while in Education group leaders have a higher degree of centrality and construct and interact with smaller networks. Production Engineering occupies an intermediate position (markers B4, D8, D9 and D10).

When it comes to the movements of the network, the internationalization of scientific production is demonstrated. Physics authors had 96.5% of their articles published abroad, while in Production Engineering the share was of 55.7% and in Education, 14.4% (markers C6 and C7). On all three areas, co-authorship is based, in its majority, in Brazil, but Physics has shown the singularity that almost one third of the researchers involved in the subjects' network work abroad (marker A3).

Considering the agencies integrating the network, Physics shows again a greater internationalization and relations with variety of institutions, having more foreign and extra-academic authors' presence in their networks (marker A3). On other hand, Education has the greatest amount of endogenous collaboration, inside the research group led by the network's ego (marker A1).

5. CONCLUDING REMARKS

Since the end of the 20th century, the university has been at the heart of many demands. Some of these demands were imperatives of evaluation and they can influence the institutional forms of knowledge production. Challenges and conflicts (BECHER; TROWLER, 2001; WEILER, 2006) mark the context of production and reveal the orthodoxies of knowledge in different fields. Among the orthodoxies is the demarcation of the production of each unique mind (SÁBATO, 1975) by printed and on-line publications. These publications inform research results and, at the same time, they mark the national and/or international acknowledgment of the researcher. In this sense, the quantity and quality of production should be interdependent variables but what is measured is the impact factor of the journals in which they are published, the number of citations, the h-index that testifies the citations' circulation of each researcher.

On the other hand, among the orthodoxies of knowledge produced in the institutional sphere of the university, identified by the expression 'academic science' (SLAUGHTER; LESLIE, 1997), is the associated function of seeking innovation. It is not enough for the contemporary researchers to do academic science, they must produce knowledge *plus* innovation. In the case of Latin America, one should recall Sábato who, in 1975 (p. 143), said that "scientific-technological investigation is a powerful tool to transform a society" and, therefore, presupposes decisive action in the field of investigation. Sábato, back then, discussed the efficiency of the innovation process based on the triangle of relationships that exist between government, scientific-technological infrastructure and the production sector.

Years later, Henry Etzkowitz and collaborators (2000) would discuss the entrepreneurial university and the 'triple helix', relations among government, university and production sector. In both works, the university plays an outstanding role in innovation and knowledge production. Therefore, investigators take on decisive roles because they are at the vertex of the scientific-technological infrastructure (SÁBATO, 1975). The individual creative

capacity should have the conditions to produce knowledge and innovation. Sábato advised, back in the 1970s, in anticipation, that the efficiency of this vertex would consolidate teamwork, since it generates an abundance of resources, increases efficiency and leverages creativity: “team work, and work with abundant resources increases efficiency and stimulates creation” (SÁBATO, 1975, p. 148). Groups and networks are perfect shelters to unique and creative minds.

In addition, however, we believe that scientific, technical, operational knowledge cannot sustain itself without breakthrough educational and pedagogical interaction. In other words, there is a ‘new’ epistemological condition to place human beings at the center of the educational process of research relationships. Under interdisciplinary contexts, this condition could possibly institute sustainability and the research future.

When thinking about production of knowledge at university, and the way in which the researchers are performing academic science and innovation, we see the multiplying effect of the research, collaboration and co-authorship networks (KATZ; MARTIN, 1995; BECHER; TROWLER, 2001; NEWMAN, 2001; HE; GENG; HUNT, 2009; SANTIAGO; CARVALHO, 2011; ADAMS, 2012). If there are disputes among field workers, among tribes and their territories, the networks appear to be diluting the differences and increasing the amount and quality of knowledge production and the extent reached by the results and their dissemination through the intensive use of informational and communicational tools and languages. And, the pedagogical innovation is the interactional and formative process of researching in a collective way.

The specificity of the studies on research networks has been expanding. Outstanding among them is the importance of authorships and co-authorships in publications, because they constitute indicators of the individual production of researchers and positional indicators of an institution contributing to their insertion in national and international rankings.

On surveying a researcher’s production, we automatically compute the number of products. However, this accounting procedure is not sufficient to evaluate research and collaborative networks. So, as this research showed, collaborative networks appear as an effective strategy to produce knowledge. Networks are setters of a cultural and informational capital in which knowledge changes its nature and begins to circulate speedily in bytes, bringing together researchers from the most distant points of the world at the velocity of gigabytes per second and synchronous time. They are “driving the creation of knowledge and

the innovation processes resulting from the exchange of information” (BALANCIERI et al., 2005, p. 1). At the same time they are driving the emergence of new values in the academy and interfering in the way individualized production is performed. As Adams (2013) says, a new age of research is rising.

The results show that there is much to know about collaboration practices in research from interaction and sharing of experiences. The indicators constructed and exposed in this study were based upon some of the many suggestions available from the literature. We believe that these markers may be used by research groups, universities’ research departments and funding agencies to better understand the pedagogical interactive process of collaboration inside networks. In times when higher education and research face transitions, entering a new age of research, new evaluative focus, criteria and procedures on networks scientific collaboration can be useful tools. These markers intentionally set the evaluation focus on research *processes*, not in productivity results or researchers’ individual productivity. Then, the networks evaluation’ may be understood as participative possibilities through which metrics fit the purpose of auto, hetero and communal evaluation.

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