BIBLIOMETRIC SCIENCE MAPPING AS A POPULAR TREND: CHOSEN EXAMPLES OF VISUALISATION OF INTERNATIONAL RESEARCH NETWORK RESULTS

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ABSTRACT

The authors of the article describe the popular trends and methods as well as ICT tools used for the mapping and visualization of scientific domains as a research methodology which is attracting more and more interest from scientific information and science studies professionals. The researchers analysed Pajek, one of the programs used for the processing and visualization of bibliographic and bibliometric data, within the framework of the implementation of IRNet research network project and activities, and presented several examples of visualisation.

KEYWORDS

Networking, Bibliographic and Bibliometric Data, Mapping, Visualization, Applications

1. INTRODUCTION

Modern science is undergoing enormous changes and transformations. Science 2.0 is a term used to refer to processes, trends and phenomena related to the use of new technologies and information and communication technologies in science, and in particular, tools, services, publications and online resources. This trend stresses the benefits of increased collaboration and cooperation between researchers and scientists. However, it refers primarily to the consequences of using these technologies.

At this stage of Web 2.0 development a popular trend has emerged whereby knowledge resources are mapped from public web services. For example, a map of English Wikipedia articles was generated using a measurement registering common categories of articles (Holloway, Božicevic, Börner, 2007). User activity specialist services also inspire analysis and mapping of data such as blogs and forums, users' logs (Bollen, Van de Sompel, Hagberg, Bettencourt, Chute, Rodriguez, Balakireva, 2009) etc. The concept of the mapping and visualization of scientific domains as a research methodology is presented in Figure 1.

Scientometric and bibliometric approaches are being increasingly used by some authors to assess the evolution and structure of scientific knowledge and R&D output (e.g., Meyer, M. (2004), Wagner, C. S., and Leydesdorff, L. (2005), Dietz, J. S., and Bozeman, B. (2005), Adams, J. D. (2006), Hussler, Caroline, and Ronde, Patrick (2007)). Normally, studies within this research field (Meyer, M. (2000b), Meyer, M. (2004), Wagner, C. S., and Leydesdorff, L. (2005)) aim to appraise the scientific output of individuals, journals and even organizations (e.g., effective publication in internationally refereed journals, high citation scores) by surveying and analyzing co-authorships and citation indexes.

2. SCIENCE MAPPING OR BIBLIOMETRIC MAPPING

The existing methods of information visualization have been successfully adapted in a network environment where websites, with some approximation, can be regarded as scientific articles, and hyperlinks as quote links. This approach has promoted the rapid development of Webometrics (Zhao, Strotmann, 2008), Osińska, 2010).

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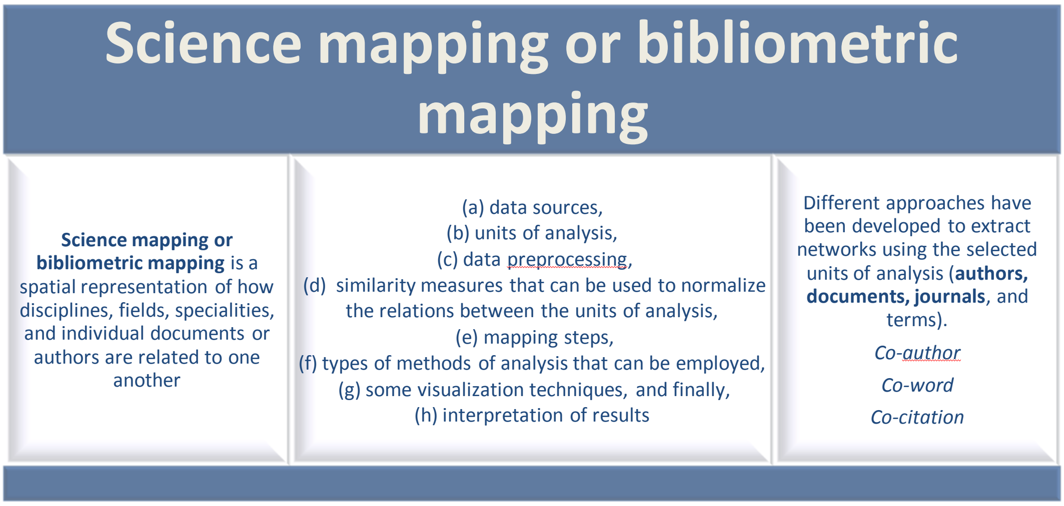

Figure 1. Science Mapping Concept

According to (Wagner, Leydesdorff, 2005), authors within this research field are interested in the increase of the interconnectedness of scientists (e.g., Okubo, Miquel, Frigoletto, and Dore, 1992), Luukkonen, Tijssen, Persson, Sivertsen, 1993; Zitt, Bassecoulard, Okubo, 2000; Glanzel, 2001; Cantner, Graf, 2006), in figuring out patterns of collaboration in general (e.g., Chung, Cox, 1990, Gibbons, Limoges, Nowotny, 1994; Katz, Martin, 1997; Dietz, Bozeman, (2005), Hussler, Ronde, 2007, and of international linkages in particular (e.g., Stichweh 1996, Schott, 1998) and further analyzing implications of linkages for funding and outcomes (e.g. Van Den Berghe, Houben, De Bruin, Moed, Kint, Luwel, Spruyt, 1998; Wagner, Yezril, Hassell, 2000; Sequeira, Pacheco, Teixeira: p. 8-16).

To better understand the structure and dynamics of the development of individual science departments and to find a way to identify thematic trends, researchers analyze literature and the paths to cite individual publications. Analytical citation has been used in bibliometrics for a long time. The term developed by KDViz (Knowledge Domain Visualization) was coined by Ch. Chena in 2001, editor of the leading information visualization magazine Information Vizualizatiorf (common abbreviation: InfoViz). Because these methods lead to the generation of graphical maps, another name is used in parallel: Mapping Science or, less often, scientography. This last one was introduced in 1960 by E. Garfield, founder of the Institute for Information Science in Philadelphia (ISI). Over the past 10 years, the domain knowledge visualization research has been extended to include information retrieval tasks (Osińska, 2010).

3. SCIENCE MAPPING

Science mapping or bibliometric mapping is a spatial representation of how disciplines, fields, specialties, and individual documents or authors are related to one another (Small, 1999). It is focused on monitoring a scientific field and delimiting research areas to determine its cognitive structure and its evolution (Noyons, Moed & Van Raan, 1999). There are different important aspects to a science mapping analysis, such as: (a) data sources, (b) units of analysis, (c) data pre-processing, (d) similarity measures that can be used to normalize the relations between units of analysis, (e) mapping steps, (f) types of methods of analysis that can be employed, (g) some visualization techniques, and finally, (h) interpretation of results.

Different approaches have been developed to extract networks using selected units of analysis (authors, documents, journals, and terms). Co-word analysis (Callon, Courtial, Turner & Bauin, 1983) uses the most important words or keywords of the documents to study the conceptual structure of a research field. Co-author analyzes authors and their affiliations to study the social structure and collaboration networks (Gänzel, 2001); Peters & Van Raan, 1991).

Finally, the cited references are used to analyze the intellectual base used by the research field or to analyze documents that cite the same references. In this sense, bibliographic coupling (Kessler, 1963) analyzes citing documents, whereas co-citation analysis (Small, 1973) studies cited documents. Other approaches such as author bibliographic coupling (Zhao & Strotmann, 2008), author co-citation White & Griffith, 1981), journal bibliographic coupling (Gao & Guan, 2009; Small & Koenig, 1977), and journal co-citation (Mccain, 1991) are examples of macro analysis using aggregated data (Cobo, López-Herrera, Herrera-Viedma, Herrera, 2011: 1382).

Interesting research results were received by Spanish authors (Gomez, Ignacio; Vazquez-Cano, Esteban; Lopez-Meneses, Eloy, 2016). According to their research, Spain was in 2013 the leading European country in MOOC course offerings and is in a leading position worldwide in the number of massive courses offered in 2014. This prolific activity is being transferred to the educational and scientific world in the form of posts in blogs, social networks and web pages, as well as scientific papers and books that attempt to analyze the movement from different methodological approaches. To date there is not any research that analyzes the bibliometric impact of MOOC movement in the Spanish scientific community. Therefore the objective of this research is to perform a bibliometric study of the scientific impact in the form of scientific article or research book in journals and Spanish publishers from January 2010 to June 2014. The study was approached from a descriptive and quantitative methodology, taking as reference bibliometric indicators of production, number of citations, and indicators of visibility according to their impact on different databases: WoS / Social Science Citation Index, Scopus, In-Recs, Google Scholar and categorization of Spanish scientific journals (ANEP / FECYT). The results show that the impact of the Spanish scientific production in the form of books and scientific articles in prestigious international databases (WoS-SSCI / Scopus) is very low, although the national impact categorization according to ANEP / FECYT and In-Recs is moderately high (Gomez, Ignacio; Vazquez-Cano, Esteban; Lopez-Meneses, Eloy, 2016).

Mapping and visualization on the TimeLine is comprehensively described and presented in Vieslava Osińska (2016).

The following software products are used for processing of bibliographic and bibliometric data:

- CiteSpace, CiteSpace II
- Bibexcel
- Pajek
- VOSViewer
- HistCite
- XLSTAT
- Publish or Perish
- VantagePoint
- Sci2 Tool
- UCINET

Applications used for a typical statistical analysis of large data sets include Statistica, Origin, Matlab, Mathematica. In the list above, special note should be made of CiteSpace – a continuously developed complete tool supporting all stages of the visualization process from data extraction to validation of the resulting graphic configuration.

4. MAPPING AND VISUALIZATION OF IRNET PROJECT NETWORKING ACTIVITIES

Within the framework of the IRNet project (www.irnet.us.edu.pl) research is being conducted in several WPs which are separate, yet simultaneously connected through interrelated stages, which roughly address our several research questions.. A bibliographic database was created containing all the published articles, books from 2014 to date by all IRNet researchers (178 publications) according to the following rubrics: names and surnames of (co)authors, affiliation, title of publication, type (article, chapter, book, etc.), where published (conference proceedings, monograph, journal, etc.), year key words, indexing.

This database also includes information regarding the number of authors, authors' affiliation, country, year, research areas, keywords, the source of publication (e.g. journal, book, etc.) and certain other data. Consequently, this dataset enables us to assess the main trends in IRNet scientific publications production. The time frame of the analysis is the last 4 years of IRNet existence, in which we have been able to trace its knowledge production and dissemination.

Based on the dynamics of international co-authorships, we will be able to map and trace international collaboration patterns and thus infer IRNet geographical influence scope, i.e. its international influence (Research Question).

By means of additional research utilizing information available in the Institute for Scientific Information (ISI), namely in the Science Citation Index (SCI), we assess the geographical pattern of the citations of IRNet scientific activities, publications, production. This enables us to evaluate to what extent IRNet project

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scientific production has been cited at the European and world level.

As the subject matter of the project is related to educational technologies or, to be more precise, to e-learning technologies, which is reflected in the participants' publications, one can assume that an analysis of international collaboration and the degree of participants' involvement in various countries etc., will indirectly allow for an evaluation of the objectives of e-learning technology development in each partner country and institution.

5. METHODOLOGY OF RESEARCH

Among the main indicators of research effectiveness - bibliometric indicators - is a powerful information tool to support the development of science. Practical research methods were prepared using the programs: Bibexel (metadata analyses), and program Pajek: graph editing and visualization of the graph structure of co-authorship – using the method of Kamada-Kawai (Tomihisa Kamada & Satoru Kawai).

For the study of science as a process of scientific communication, which is relevant to this study, one can use the tools of network analysis. As a tool for analysis and visualization of large scale networks we can recommend Pajek (Pajek, 1996). However, for complex types of analysis, one must have competencies helping one to work with specialized products and to develop programming skills.

To carry out a network analysis of participants of the project, we will build a network of co-authorship for research activity and presentation of results in scientific publications.

Analyses of data for the purpose of network analysis were performed using Bibexel, starting with obtaining initial data for this program. These data (up to the end of 2016) were assembled using built-in tools of the scientometric database Web of Science. Data for each participant in the project IRNet are files with the extension .txt which were combined using the program Bibexel: in the new window "Type new/file name here", one should enter name which needs to have the merged file, select all the files one wants to merge, and run Files -> Append all selected files to another.

For building a graphics editing program Pajek (http://mrvar.fdv.unilj.si/pajek//) the following objects were used:

1. Networks are the main objects (vertices and lines), and the default extension is: .net. In this case, the created file is Analiz.net of the 83 vertices – authors' articles and links between them, reflecting the co-authorship in publications. The file specifies an additional property of vertices – the identity of the authors who analyzed the participants of the project (diamond).

*Vertices 83

1. 1 "Kommers P." diamond
2. 2 "Smyrnova-Trybulska E." diamond
3. 3 "Morze N." diamond
4. 4 "Noskova T." diamond
5. 5 "Pavlova T." diamond
6. 6 "Yakovleva O." diamond
7. 7 "Sekret I." diamond
8. 8 "Zavgorodnyi V." diamond
9. 9 "Yalova K." diamond
10. 10 "Yashina K." Triangle

…

*Edges

1 2 10

1 3 8

2. Vectors – file Analiz.vec, contains 83 entries, where for each vertex (author) its quantitative characteristic (real number) – the number of publications is indicated. *Vertices 83

1 12 2 58 3 53 4 27 5 30

3. Partitions – file Analiz.clu, where for each vertex the class is defined to which it belongs. In this case, there are 10 classes, in line with the countries' mission project participants:

1- Australia, 2- Czech Republic, 3 – Netherlands, 4 – Poland, 5- Portugal, 6 – Russia, 7- Slovakia,8- Spain, 9 –Turkey, 10 – Ukraine.

*Vertices 83

3 4 10 6 6 6

To build a network visualization of co-authorship in the program Pajek, it is necessary to download the file Analiz.net in the Networks field. Vectors – Analiz.vec Partitions – file Analiz.clu, and select Draw -> Network + First Partition+ First vector.

As for building the visualization of networks linking scientists with special software and settings, the project participants' "labeled" rectangles (diamond) and the corresponding vertices have the signatures – the names of the scientists, not the participants – triangles (Triangle); shapes-marks are of different colors depending on the country, which represent the authors, and the size that is determined by the number of each author's publications. As can be seen in Figure 2, the scientists have different publication activity, some who are not the participants of the project have a greater number of publications than some of the participants. The latter can be considered as a basis for widening the circle of participants or an invitation of active scientists to other projects. The window where in the text file the relationships of a particular author (co-author) is described, can be called using the right mouse button for the selected node.

As a result of the visualization of the graph structure of co-authorship we have obtained a Kamada-Kawai layout (Tomihisa Kamada & Satoru Kawai) (Figure 2).

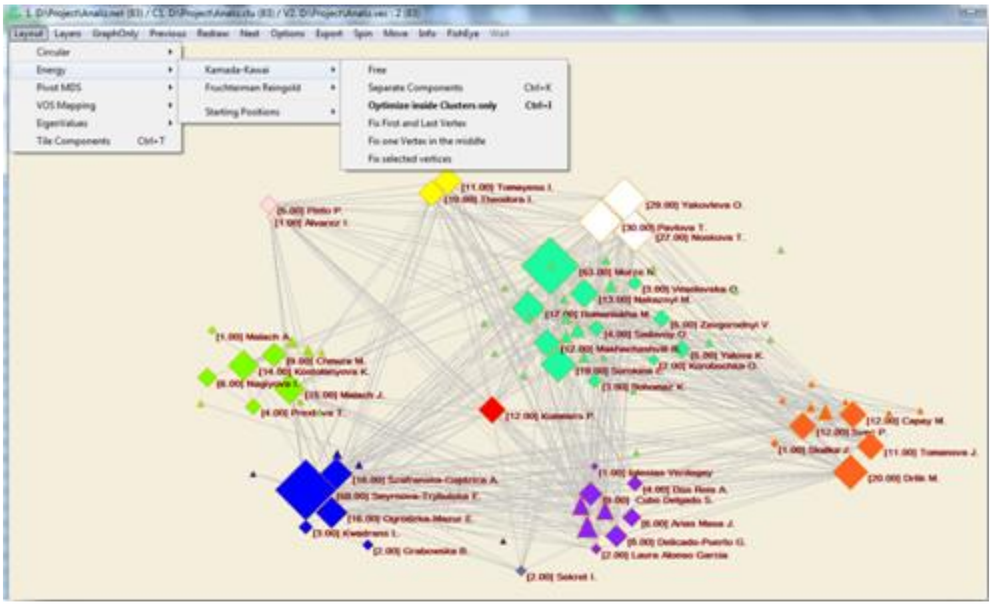

Figure 2. Example of Visualization of Co-Authorship with the Countries' Mission of Project Participants Kamada-Kawai Layout

This made it possible to analyze the contribution (number of publications) of the project participants and their collaborators within each country. For example, the largest representation of scientists are from Ukraine, representatives from Russia (3 participants) did not attract other sponsors from their country, but their activity was high, and there are countries, represented by one party such as Turkey (Sekret I.) and the Netherlands (Kommers P.), but the representative from the Netherlands cooperated with other project participants actively.

However, it should be noted that visualization network analyses are often unreadable because they contain a large number of nodes with one or two connections.

The concentration of connections allows for visually accentuating the centers of the analyzed activity, but it complicates general perception and makes the label unreadable. To view maps based on the results of the network analysis, it is recommended that the concentration of connections be reduced. Therefore, by means of the program Pajek a subnet was created consisting only of participants of the project (Operations/Network+Partition/Extract SubNetwork). When one starts this, first it is necessary to create a file – Part.cls where the elements of the desired cluster should be grouped. In this case it is 42 participants. Such a file can be generated automatically, if necessary, changes can be made manually.

For a network that contains only the data about participants of the project, files and partition vectors are formed. You can optionally save this data as separate files or a network in general - with the file extension .paj (file/ Pajek project file /save).

As a result of visualization of the graph structure whose vertices became only the authors of the project, we obtain a Kamada-Kawai layout in which the data are not grouped with representation (Figure 3).

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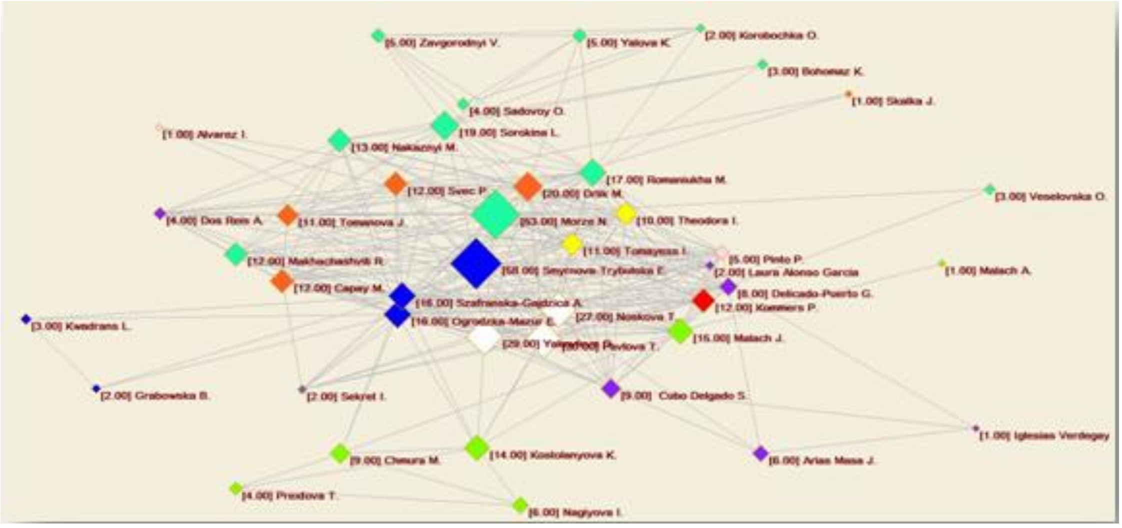

Figure 3. Example – The Visualizing of the Graph Structure of Co-Authorship of the Project Participants Kamada-Kawai Layout

As can be seen from Figure 3, the distribution of the contribution of the project participants by the number of posts is not uniform: the center is represented by more active members. For each network node the author's name and the number of publications are added (which also affects the size of the geometric area). The color is also allocated to the country offices participating in the project.

It should be noted that the visualization, basically, is a brief synthesis of the results of the analysis that allows us to understand the context of the transition to the data that underpin it. The credibility presented in the form of a visualization of the analysis results will be high, if there is a verification of the results of the analysis, that is, all the visualization elements retrieved can be traced back to the primary data and methods of their processing.

The results of this visualization can be used to make optimal decisions on the management of information resources with the aim of improving processes of scientific communication and the evaluation publications contribution of each participant. To determine the scientific impact of the project participants in the development of pedagogical science an additional analysis needs to be conducted.

6. CONCLUSION

This publication is devoted to the one of the popular trends referred to as mapping of scientific domains and visualization of research results in international networks. It can be considered as a research methodology which is gaining more and more popularity among scientific information professionals and specialists from different disciplines.

There is an extensive offering of various types of software for processing of bibliometric data - open source license as well as commercial license programs.

The authors of the article, who are researchers of the European IRNet project and international research network, described and analysed certain bibliographic results of these activities using methods of mapping and visualization of scientific domains.

The methods for visual representation of scientometric information can serve as a basis for formulating preliminary working hypotheses in scientometric data analyses and for presenting the final results of analyses, in this case being a statistical analysis (a scholar's profile), a geospatial analysis (of member states) and a network analysis (participation in the project). Scientometric information mapping is closely related to the task of preparing forecasts of science development and improving the quality of existing forms of collaboration as well as developing new ones. The results obtained give grounds for supposing that the development of science branches and disciplines depends, to a large extent, on the existence and development of human capital and collaboration forms (we examined collaboration on this project only, but collaboration as such is limited to that) and, to a lesser extent, on identifying prospective fields of study and areas of technology. Further research will be pursued, among other things, to design a thematic-based collaboration model (constructing scientific e-communication models) and to assess the effect on scientists (and individual scientists) and science in general.

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REFERENCES

Adams, J. D. 2006. Learning, internal research, and spillovers. *The Economics of Innovation and New Technology*, 15, pp.5-36.

Akoev M.A., V.A. Markusova, O.V. Moskalev, V.V. Pislyakov; [Edited by M.A. Akoev]. Guide on scientometrics: Indicators of development of science and technology: [monograph] / M.A. Akoev, V.A. Markusova, O.V. Moskalev, V.V. Pislyakov; [Edited by M.A. Akoev]. - Ekaterinburg: Publishing House of the Ural Mountains. University Press, 2014. - 250 p. ISBN 978-5-7996-1352-5 DOI 10.15826 / B978-5-7996-1352-5.0000 [In Russian]

Barreiro E. W. Using HistCite software to identify significant articles in subject searches of the Web of Science. [online] https://arxiv.org/ftp/arxiv/papers/1512/1512.07069.pdf [available 18.02.2017]

Bollen J. Van de Sompel H., Hagberg A., Bettencourt L., Chute R., Rodriguez M. A., Balakireva L., 2009. Clickstream Data Yields High-Resolution Maps of Science. *PLoS ONE*. 2009 vol. 4 no. 3. [online], [available: 30.06.2017]. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0004803 >.

Callon, M., Courtial, J.P., Turner, W.A., & Bauin, S., 1983. From translations to problematic networks: An introduction to co-word analysis. Social Science Information, 22(2), pp. 191–235.

Cantner, U., and Graf, H. (2006), "The network of innovators in Jena: An application of social network analysis, *Research Policy*, 35, 463-480.

Chen Ch., Ibekwe-SanJuan, F., & Hou, J., 2010. The structure and dynamics of co-citation clusters: A multiple-perspective co-citation analysis. *Journal of the American Society for Information Science and Technology,* 61(7), 1386-1409.

Chung, K. H. and Cox, R. A. K., 1990. Patterns of Productivity in the Finance Literature: A Study of the Bibliometric Distributions, *The Journal of Finance*, 45, pp.301-309.

Cobo M.J., López-Herrera A.G., Herrera-Viedma E., and F. Herrera. 2011. Science Mapping Software Tools: Review, Analysis, and Cooperative Study Among Tools *Journal of the American Society for Information Science and Technology*, 62(7):1382–1402, 2011

Dietz, J. S., and Bozeman, B., 2005. Academic careers, patents, and productivity: industry experience as scientific and technical human capital, *Research Policy*, Vol. 34, pp. 349-367.

European Association of Science Editors statement on impact factors, [online], [available: 31.08.2010]. <http://www.ease.org.uk/statements/EASE_ statement_onJmpact_factors.shtml. Retrieved, 2009-03-25>.

Gänzel, W., 2001. National characteristics in international scientific coauthorship relations. *Scientometrics*, 51(1), 69–115.

Gao, X., & Guan, J., 2009. Networks of scientific journals: An exploration of Chinese patent data. *Scientometrics*, 80(1), 283–302.

Garfield E. 1994. Scientography: Mapping the tracks of science. *Current Contents: Social & Behavioural Sciences*, 1994, no. 7(45), pp. 5-10.

Garfield E.: Essays/Papers on Mapping the World of Science. Eugene Garfield, Ph. D. Home Page, [online], [Accessed at 31.08.2010]. Available at: <http://garfield.library.upenn.edu/ mapping/mapping.html>.

Gibbons, M., Limoges, C. and Nowotny, H., 1994. The new production of knowledge: The dynamics of science and research in contemporary societies, *Sage Publications: London.*

Glanzel, W. 2001. National characteristics in international scientific co-authorship relations, *Scientometrics*, 51, pp.69-115.

Gomez, Ignacio; Vazquez-Cano, Esteban; Lopez-Meneses, Eloy 2016): The Bibliometric Impact of MOOC Movement in the Spanish Scientific Community Aguaded EDUCACION XX1 Volume: 19 Issue: 2, pp. 77-103

Herr II, Bruce W., Weixia (Bonnie) Huang, Shashikant Penumarthy, Katy Börner, 2007. Designing Highly Flexible and Usable Cyberinfrastrucutres for Convergence. In William S. Bainbridge & Mihail C. Roco (Eds.), Progress in Convergence: Technologies for Human Wellbeing (Vol. 1093, pp. 161-179). Boston, MA: Annals of the New York Academy of Sciences.

Holloway T., Božicevic, M. and Börner, K., 2007. Analyzing and Visualizing the Semantic Coverage of Wikipedia and Its Authors. *Special Issue: Understanding Complex Systems. Complexity.* 2007, vol. 12, no. 3, pp. 30-40.

Hussler, C., and Ronde, P., 2007. The impact of cognitive communities on the diffusion of academic knowledge: Evidence from the networks of inventors of a French university, *Research Policy*, 36, pp.288-302.

Katz, S. and Martin, B. R., 1997. What is 'research collaboration'?, *Research Policy*, 26, pp.1-18.

Kessler, M.M., 1963. Bibliographic coupling between scientific papers. *American Documentation*, 14(1), pp.10–25.

Luukkonen, T. Tijssen, R. J. W., Persson, O., and Sivertsen, 1993. The measurement of international scientific collaboration, *Scientometrics*, 28, pp.15-36.

McCain, K., 1991. Mapping economics through the journal literature: An experiment in journal co-citation analysis. *Journal of the American Society for Information Science*, 42(4), pp.290–296.

Meyer, M., 2000. What is special about patent citations? Differences between scientific and parent citations, *Scientometrics*, 49, pp.93-123.

Meyer, M., 2004. Measuring the Impact of Science, 2004 International Engineering Management Conference Proceedings, 2004 IEEE, Vol. 1, pp. 377-381.

Noyons, E.C.M., Moed, H.F., & van Raan, A.F.J., 1999. Integrating research performance analysis and science mapping. *Scientometrics*, 46(3), pp.591–604.

Okubo, Y., Miquel, J. F., Frigoletto, L., and Dore, J.C. 1992. "Structure of international collaboration in science: Typology of countries through multivariate techniques using a link indicator, *Scientometrics*, 25, pp.321-351.

Osińska V., 2010. Rozwój metod mapowania domen naukowych i potencjał analityczny w nim zawarty. *Zagadnienia Informacji Naukowej* [on-line] *2010*, vol. *2* (*96*), *s. 41-51 [on-line]* http://repozytorium.umk.pl/handle/item/463 [accessed: 10.07.2017]

Osińska, V. 2016. Wizualizacja informacji. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, 2016. 187 s.

Peters, H.P.F., & van Raan, A.F.J., 1991. Structuring scientific activities by co-author analysis an exercise on a university faculty level. *Scientometrics*, 20(1), pp.235–255.

Schott, T., 1998. Ties between centre and periphery in the scientific world system: accumulation of rewards, dominance and self-reliance in the centre, *Journal of World Systems Research*, 4.

Sequeira J. A. Pacheco, Teixeira A. Assessing the influence and impact of R&D institutions by mapping international scientific networks: the case of INESC Porto In: *Economics and Management Research Projects:* An International Journal, 1(1), An International Journal – Open Access International Journals Publisher ISSN: 2184-0309, p. 8:19 (https://www.researchgate.net/publication/227355179) [accessed: 10.07.2017]

Small, H., 1973. Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science,* 24(4), pp.265–269.

Small, H., 1999. Visualizing science by citation mapping. *Journal of the American Society for Information Science*, 50(9), 799–813.

Small, H.,&Koenig, M.E.D., 1977. Journal clustering using a bibliographic coupling method. *Information Processing and Management*, 13(5), pp.277–288.

Smyrnova-Trybulska E., 2017. Mapping and Visualization of Scientific Bibliometric Domains and Research Network Activities In: *DLSC2017 Conference Proceedings*, ed. by Miroslav Hruby, Brno: University of Defence, pp. 301-308. ISBN 978-80-7231-416-4

Stichweh, R., 1996. Science in the system of world society, *Social Science Information,* 35, pp.327-340.

Van den Berghe, H., Houben, J. A., de Bruin, R. E., Moed, H. F., Kint, A., Luwel, M., and Spruyt, E. H. J., 1998. Bibliometric Indicators of University Research Performance in Flanders. *Journal of the American Society for Information Science,* 49, pp. 59-67.

Wagner, C. S., and Leydesdorff, L., 2005. Mapping Global Science Using International Co-authorships: A Comparison of 1990 and 2000, *International Journal of Technology and Globalization,* 1, pp.185-208.

Wagner, C. S., Yezril, A. and Hassell, S., 2000. International Cooperation in Research and Development: An Update to an Inventory of U.S. Government Spending, Santa Monica: RAND

White, H.D.,&Griffith, B.C., 1981. Author cocitation: A literature measure of intellectual structure. *Journal of the American Society for Information Science*, 32 (3), pp.163–172.

Zhao D., Strotmann A., 2008. Information Science during the first Decade of the Web: An enriched author cocitation analysis. *Journal of the American Society for Information Science and Technology* 2008, vol. 59(6), pp. 916-937.

Zhao, D., & Strotmann, A., 2008. Evolution of research activities and intellectual influences in information science 1996–2005: Introducing author bibliographic-coupling analysis. *Journal of the American Society for Information Science and Technology,* 59(13), pp. 2070–2086.

Zitt, M., Bassecoulard, E., and Okubo, Y., 2000. Shadows of the past in international cooperation: Collaboration profiles of the top 5 producers of science. *Scientometrics*, 47, pp. 627-657.