Co-citation scientific maps: A case study of medical sciences in Iran

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ABSTRACT

Visualization of scientific maps enhances the awareness and general recognition of the scientific domains and their structures. It facilitates the study of the existing situation and planning of the future researches as well. The present study sought to discover and generate the scientific map of medicine in Iran between 2003 and 2007. It also aimed to determine the most effective medical subject categories in the map generated. The study follows a scientometrics trend in which all published articles of Iran indexed in the Science Citation Index Expanded (SCIE) between 2003 and 2007 were retrieved. Then, these articles were limited to medical subject categories through the result analysis section of SCIE and 10247 articles were retrieved in medical subject categories as research population. NWB (Network Workbench Tool) software and ISI medical subject category co-citation were used for analyzing the articles in medicine and generating scientific maps. The scientific medical map showed that there were 61 nodes and 164 links with a weight ranging from 101 to 591. 31 nodes depicted one medical subject category, while the other nodes covered non-medical, or a combination of medical and non-medical subject categories. Medical subject categories with the highest impact included general and internal medicine, pharmacology and pharmacy, biochemistry and molecular biology, neurosciences, and research and experimental medicine. The strongest links were visible in general and internal medicine, with public, occupational, and environmental health; general and internal medicine with pharmacology and pharmacy; and pharmacology and pharmacy with neurosciences. The quantitative growth in medical articles alongside their quality is effective in scientific maps. It is necessary to encourage the categories with more effective and support the subject categories with the least impact to publish more articles and get more citation.

Keywords: knowledge mapping; scientific maps; medicine; Iran; co-citation analysis; subject category; scientific products; citation analysis; Science Citation Index

INTRODUCTION

In any scientific field, the researchers have to utilize the literature available in order to enrich their researches. Moreover, a knowledge and general understanding of the specialized field under investigation and its structure is very important. Scientific maps and drawing of the structure of scientific fields, which are among the various parts of the scientometric studies, facilitate studying of the current production of science in the fields under investigation, as well as easing the planning and policy making for future investigations. Moreover, drawing of the scientific maps help us to show a picture of a domain and its related fields; otherwise, the situation in a field will not be easily visible. Such maps help us in an overall understanding of a domain or field, and reveal the links among the different fields.

Generating scientific maps is an inter-disciplinary field, showing the continuation of the efforts in quantitative and qualitative studies begun in the 19th century. It has also been in line with, or a continuation of discussions in scientometrics and bibliometrics, etc., all considered as part of the studies in the evaluation of science. As Small has

said "a map of science is a spatial representation of how disciplines, fields, specialties, and individual articles or authors are related to one another as shown by their physical proximity and relative locations"[1].

A number of methods are used in drawing the scientific maps, including co-citation analysis, analysis of bibliographic coupling, and word co-occurrence. Among these, the co-citation method has received the attention of many researchers; because Co-citation maps could depict subject relationships. The patterns of co-citation define the collective perceptions of citing authors and give rise to clusters of highly cited and co-cited works. Shift in highly cited articles are then used to study the rate of intellectual change. A sudden change in the co-citation patterns can signal a revolution in the field [1]. Garfield, who is the founder of the ISI, believes that the co-citation method is a unique method used in the study of cognitive structure of science, through which one can map the structure of specific research fields and all science. The utilization of this method as a way for recognizing the conceptual structure of a scientific field, dates back to the 1970s. In fact, Henry Small and Irena Marshakova-Shaikevich separately talked about the co-citation method in 1973. However, Small is famous for using this method in mapping the conceptual structure of scientific fields and analyzing the interdisciplinary relationships [1-5]. Co-citation analysis includes the investigation of the relationships between references of a document and is conducted at different levels, such as documents, authors, journals, and subject categories utilizing the reliable data bases, such as the ISI. In 1993 for example, Small drew the scientific map based on the articles published in the ISI for the period during 1983-1989. He scrutinized the changes occurred in the relationships of different fields during these seven years based on the maps he had drawn [4].

Small (1999) visualized a map based on ISI papers in 1996. Threshold was 5 citations for papers. In this study he used clustering and strong co-citation analysis to create pathways through the scientific literature. For example, a specific path was described starting in economics and ending in astrophysics traversing 331 documents. Implications of information pathways were discussed [3].

In 1999, the same researcher generated the co-citation map of the ISI articles published in 1995. It was based on a dataset of about 36000 documents. An overall map of science shows the multidisciplinary breath of the document sample [1]. Moya-Anegon et al.(2005) propose the use of ISI-JCR categories as units of cocitaiton and measurement for the construction of heliocentric maps. They generated the structure of Spain with this method [6]. Boyack, et al. (2005) drew the map of the whole science based on the articles indexed in the ISI in the year 2000 [7]. In an article in 2006, Vargas-Quesada, et al. concentrated on drawing the scientific maps of the USA utilizing the citation analysis of major subject categories [8]. In a study in 2008, Osareh & McCain drew the structure of Iranian chemistry using the co-citation analysis of the authors for the period from 1990 to 2006 [9]. Porter & Rafols (2009), in a new outlook, they investigated how the degree of interdisciplinarity has changed over six research domains. For this reason they used the scientific maps generated for the years 1975-2005 based on the ISI subject categories. They computed the number of cited disciplines and references per article and co-author per article alongside a new index of interdisciplinarity and a science mapping visualization method [10]. Small (2010) used maps of science to suggest possible interdisciplinary links analyzed by co-citation context analysis. His study was based on 22 subject categories of ESI between 2002 and 2008 [5]. Chen, Ibekwe-SanJuan and Hou (2010) used a multiple co-citation analysis method for characterizing and interpreting the structure and dynamics of co-citation clusters in the field of Information Science as defined by 12 core journals. They used both author co-citation analysis (ACA) and document co-citation analysis (DCA) [11]. Hassanzadeh (2011) investigated the status of Iranian publications on nanotechnology published in ISI journals from 1991 to 2010 and depicted co-citation among them as a social

network. Results showed an emerging tendency among authors towards multidisciplinary and multinational co-operations [12].

As medicine and its related fields have much importance in human health, the researchers have always paid attention to them; they are among the fields with a lot of investments for their research. In the SCIE data base, one can find 60 subject categories (out of a total 171 subject categories) related to medicine and its related fields, all of which are in line with the major or minor NLM classification.

In the present article, it was attempted to generate the scientific medical map of Iran in the period of 2003-2007 utilizing the category co-citation analysis bearing in mind the medical products of Iran indexed in the SCIE. The maps were drawn in two levels; in the first level, the general map is shown, which will in turn determine the most influential medical subject categories, while the second level characterizes a clear picture of the relationships among the different medical categories, so that they may help in future planning and policy making in these fields.

MATERIALS AND METHODS

In the present study, which is of scientometrics types, the study population included all medical papers of Iran between 2003 and 2007 indexed in SCIE, and their references. The number of the products was 10247 in 60 medical subject categories.

The data were extracted from SCIE. Having in mind the CU=Iran, as well as limiting the publication year of the articles to 2003-2007, all documents published from Iran during the above mentioned time, and indexed in SCIE, were retrieved. The targeted documents were also limited to the medical subject categories through the result analysis section of SCIE; all the records obtained were stored in a 'full record' and in the ISI format. Moreover, the data analysis section of that data base was used to answer some of the research questions in the present study. The ISI medical subject categories were used as the analysis unit, and the co-citation was used as the assessment unit. The frequency of co-citations as the evaluation standard was calculated by using the Network Workbench Tool (NWB) software.

The software, prepared in 2007 is a tool for network analysis, modeling, and visualization in social sciences, bio-medicine, and physics.

It is an open source software framework, for the easy integration and utilization of datasets, algorithms, tools and computing resources. This software enhances access to more than 80 algorithms and 30 sample datasets for the study of networks [13].

Due to the research conditions and populations in scientific maps, a threshold is considered in co-citation studies. In the present study, the documents with at least two citations were selected. The references in those documents were analyzed for co-citation analysis purposes. We had to impose some changes in the ISI retrieved records, as the NWB software performs co-citation analysis at the document level. For such a purpose, the subject category of each of the existing journals in the references were retrieved via JCR and replaced with the targeted reference. Naturally, the references not being covered by the JCR were omitted from our analyses.

RESULTS

As it can be seen in Table 1, the scientific products of Iran have had a growing trend in the SCI during the years under study. The numerical increase is also visible in the number of the medical documents. There is an increase in the ratio of the scientific medical products to the other scientific products in the SCI index during the years under our investigation as well, so that from 27.94 % in 2003 it has increased to 37.61 % in 2007. In general, 33.26 % of all scientific products of Iran are devoted to the scientific medical products.

Table 1. Frequency of the medical scientific products of Iran (from among all products of Iran) in the SCI during 2003 to 2007

year	Scientific product of Iran	Scientific product of medicine in Iran	
	number	number	percent
2003	3236	904	27.94
2004	4187	1236	29.52
2005	5560	1732	31.15
2006	7275	2408	33.10
2007	10547	3967	37.61
Total years	30805	10247	33.26

As it was noted earlier, we selected all documents which had received at least two citations during the years under our study. The number of such articles includes 4585 articles which covers up 44.74 % of all articles retrieved. The reports of the co-citation maps of these articles indicate 5766 nodes and 49276 links, with 4567 individual nodes. The link weight is ranging from 1 to 591. Due to the high density of the maps drawn without considering the co-citation threshold, and in order to show more powerful links, the authors decided to select the links with weights more than 100. In the maps drawn, the links between different subject categories based on their weight, are shown in light or dark colored lines. The stronger links are shown with darker and bolder lines, while the weaker links are drawn with narrower and less-lighter lines.

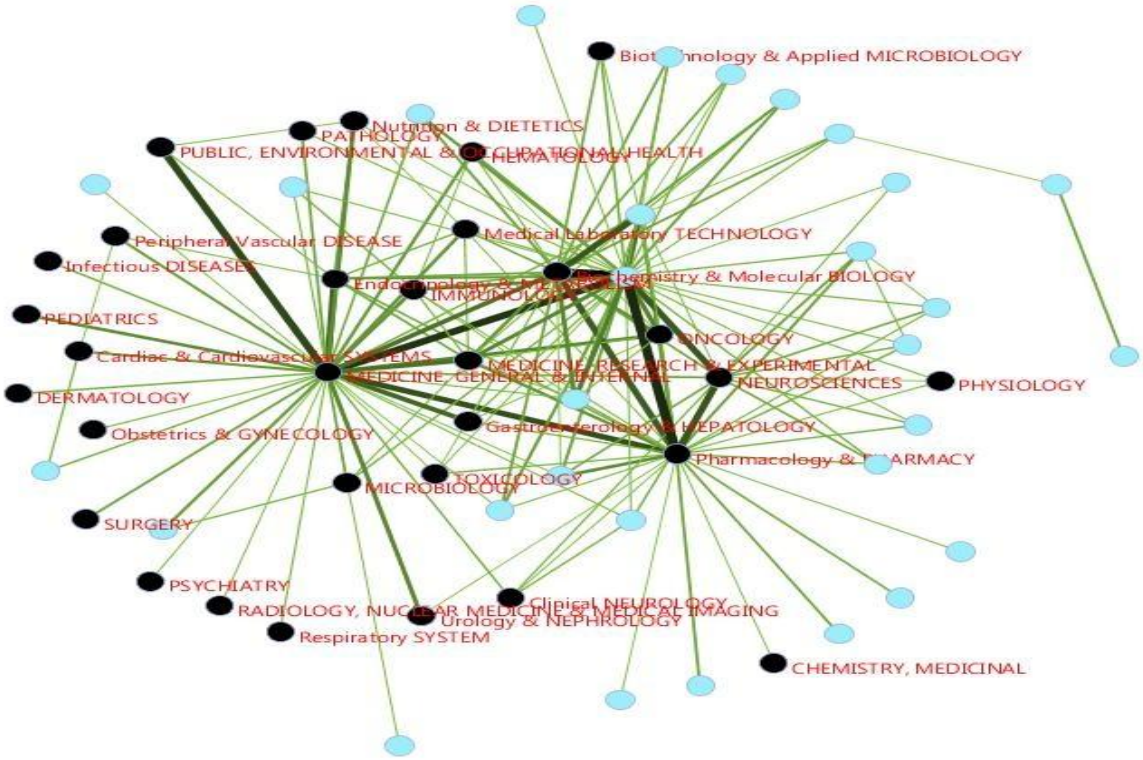

Figure 1. The scientific map of medicine in Iran during 2003-2007 (visualizing the nodes covering one medical subject category)

The reports on the generated map in Figure 1 show that there are 61 nodes and 164 links with weights ranging from 101 to 591. The study of the nodes shows that 31 of the nodes represent one medical subject category as follows:

1-Biotechnology & applied microbiology
2-Microbiology
3-Gastroenterology & hepatology
4-Biochemistry & molecular biology
5-Nutrition & dietetics
6-Medical laboratory technology
7-Dermatology
8-Psychiatry
9-Immunology
10-Physiology
11-Neurosciences
12-Pharmacology & pharmacy
13-Oncology
14-Medicine, general & internal
15-Endocrinology & metabolism
16-Hematology
17-Pathology
18-Chemistry, medicinal
19-Clinical neurology
20-Urology & nephrology
21-Radiology, nuclear medicine & medical imaging
22-Infectious diseases
23-Surgery
24-Respiratory system
25-Obstetrics & gynecology
26-Peripheral vascular disease
27-Pediatrics
28-Cardiac & cardiovascular systems
29-Public, environmental & occupational health
30-Medicine, research & experimental
31-Toxicology

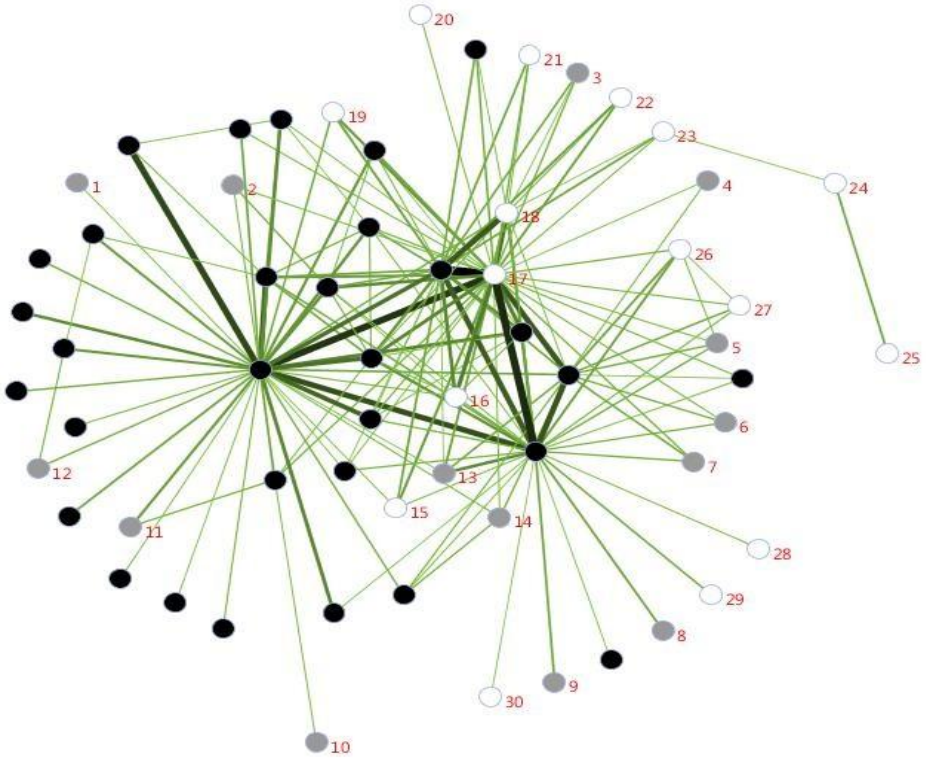

Figure 2 . Compound or nonmedical nodes in the scientific map of Iran from 2003 to 2007

As it can be seen from Figure 2, the gray nodes are combinations of two or more medical subject categories and as follows based on their numerical values:

1-Immunology ; infectious diseases
2-Immunology; medicine, research & experimental
3-Biochemical research methods ; biochemistry & molecular biology
4-Neurosciences ; physiology
5-Neurosciences; pharmacology & pharmacy ; psychiatry
6-Neurosciences ; pharmacology & pharmacy
7-Biochemistry & molecular biology ; neurosciences
8-Pharmacology & pharmacy ; toxicology
9-Chemistry, medicinal; pharmacology & pharmacy
10-Biotechnology & applied microbiology ; microbiology
11-Immunology; infectious diseases; microbiology
12-Cardiac & cardiovascular systems; hematology ; medicine, general & internal
13-Medicine, research & experimental ; pharmacology & pharmacy
14-Clinical neurology ; neuroscience

Moreover, in Figure 2, the nodes colored in white, visualize one non-medical subject category, or a combination of medical and non-medical subject categories, and based on their numerical values are as follows:

15-Cell biology
16-Biochemistry & molecular biology ; cell biology
17-Multidisciplinary sciences
18-Biochemistry & molecular biology; biophysics
19-Genetics & heredity
20-Biochemistry & molecular biology; biology; cell biology
21-Biochemical research methods ; biochemistry & molecular biology ; chemistry, analytical
22-Biochemistry & molecular biology; biophysics ; cell biology
23-Chemistry, multidisciplinary
24-Chemistry, analytical
25-Biochemical research methods; chemistry, analytical
26-Behavioral sciences; neuroscience; pharmacology & pharmacy
27-Behavioral sciences ; neurosciences
28-Chemistry, multidisciplinary; pharmacology & pharmacy
29-Chemistry, medicinal; chemistry, multidisciplinary ; pharmacology & pharmacy
30-Plant sciences ; chemistry, medicinal; integrative & complementary medicine; pharmacology & pharmacy

In the maps so far visualized, some medical categories are more influential than others. Such categories have more links with other categories and may be considered as the center of a small map, being surrounded with other subject categories. The most influential ones, which are extracted from Figure 1 and each with at least 10 links with other subject categories, are as follows:

1-Medicine, general & internal
2-Pharmacology & pharmacy
3-Biochemistry & molecular biology
4-Neurosciences
5-Medicine, research & experimental

As it was noted in the introduction part of the article, there are 60 subject categories in the SCI Index, which are also included in the NLM classification. However, in the map generated in the present study, 29 of the above subject categories are absent. In order to determine the least influential medical subject categories, another map was generated under the same method, but one which included the threshold links with weights of more than 30. It became clear that 15 of the following subject categories are absent. Therefore, the following may be considered as the least influential medical subject categories in the scientific map:

1.Anatomy & morphology
2.Allergy
3.Medical ethics
4.Rehabilitation
5.Tropical medicine
6.Orthopedics
7.Andrology
8.Substance abuse
9.Anesthesiology
10.Integrative & complementary medicine
11.Medical informatics

12.Medicine, legal
13.Health policy & services
14.Medical imaging
15.Clinical psychology

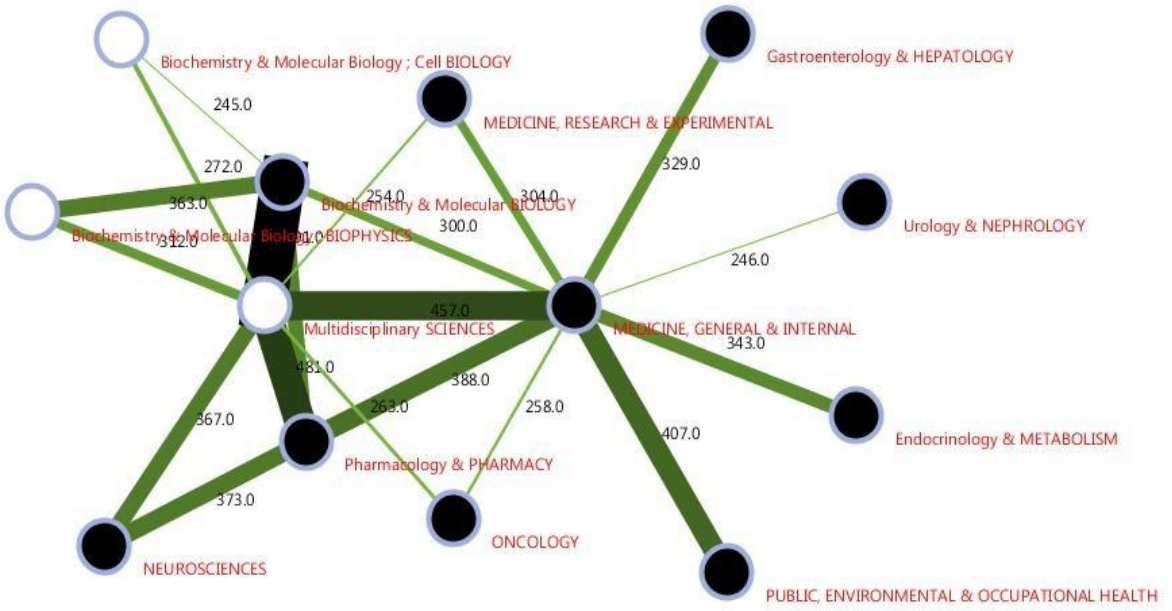

Figure 3. The 20 most outstanding links in the medical scientific map of Iran (2003-2007)

Figure 3, which is generated based on the 20 most outstanding links in the map for the years 2003 to 2007, visualizes the most important inter-disciplinary category links. Based on this figure, in which the weight of the nodes is represented, the most powerful links are between the following medical subject categories as follows:

1-Medicine, general & internal – Public, environmental & occupational health
2-Medicine, general & internal– pharmacology & pharmacy
3-pharmacology & pharmacy- neurosciences
4-pharmacology & pharmacy – biochemistry & molecular biology
5-Medicine, general & internal – endocrinology & metabolism

As it may be seen in Figure 3, there exists a powerful link between the category of multidisciplinary sciences and medical subject categories.

In the second section of the present article, the scientific maps are generated at the second level. Due to the importance of the of influential medical subject categories in the scientific map of Iran, the 5 most outstanding ones are depicted. In order to generate maps of the above-mentioned medical subject categories, one has to generate the overall map first. Next, after deleting the unrelated nodes and links, the map of the targeted subject category will be generated. However, for determining the most important links and a map showing them, and for the purpose of an easier analysis, the selected threshold for the weights of the links has to be increased. The weight of the links for the maps in the years under our investigation is a maximum of 591. The selected threshold for this purpose included as 100 for the weight of the links.

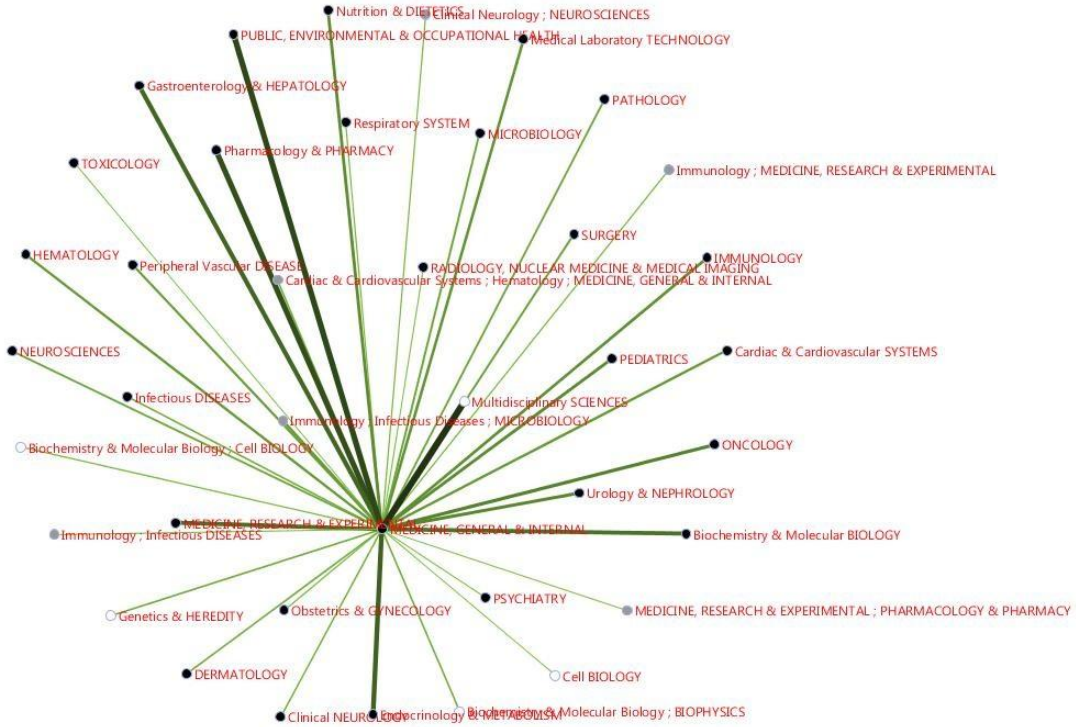

Figure 4. General & Internal Medicine in the scientific map of Iran (2003-2007)

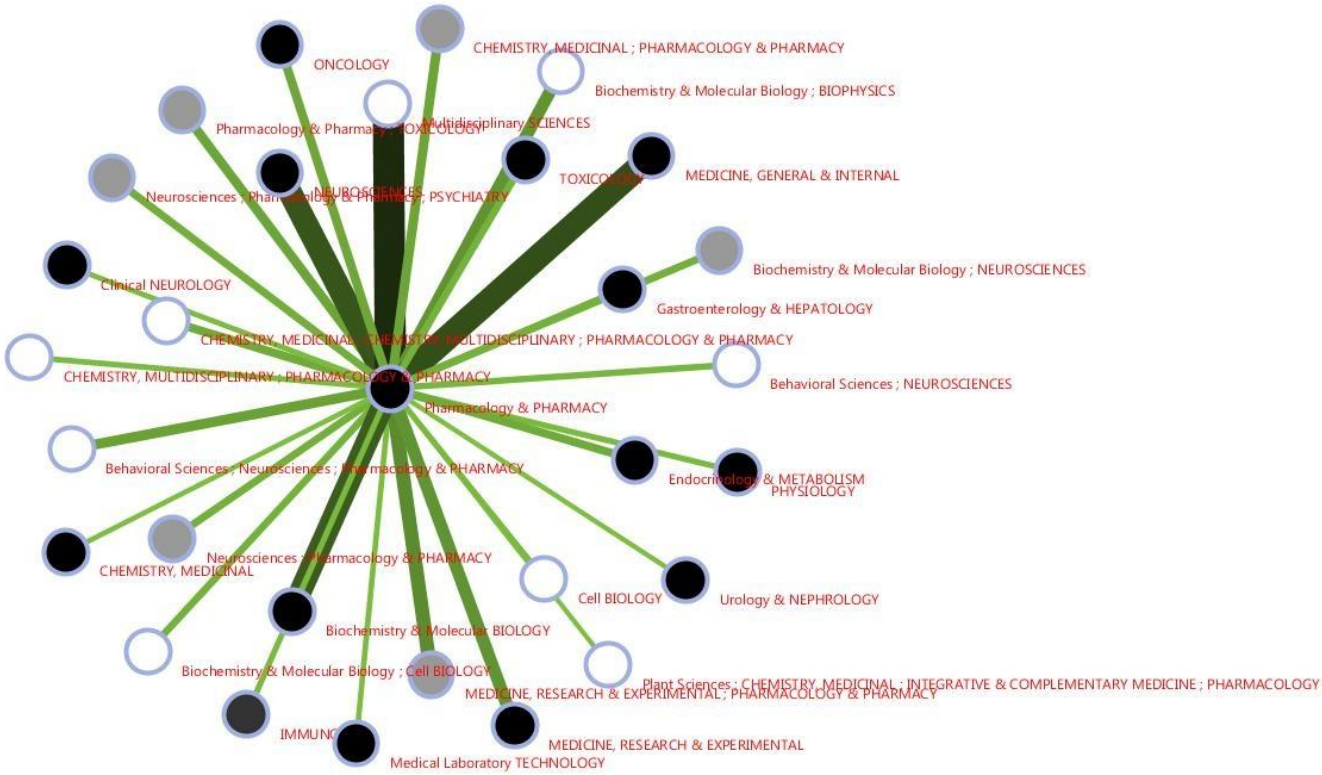

Figure 5. Pharmacology and Pharmacy in the scientific map of Iran (2003-2007)

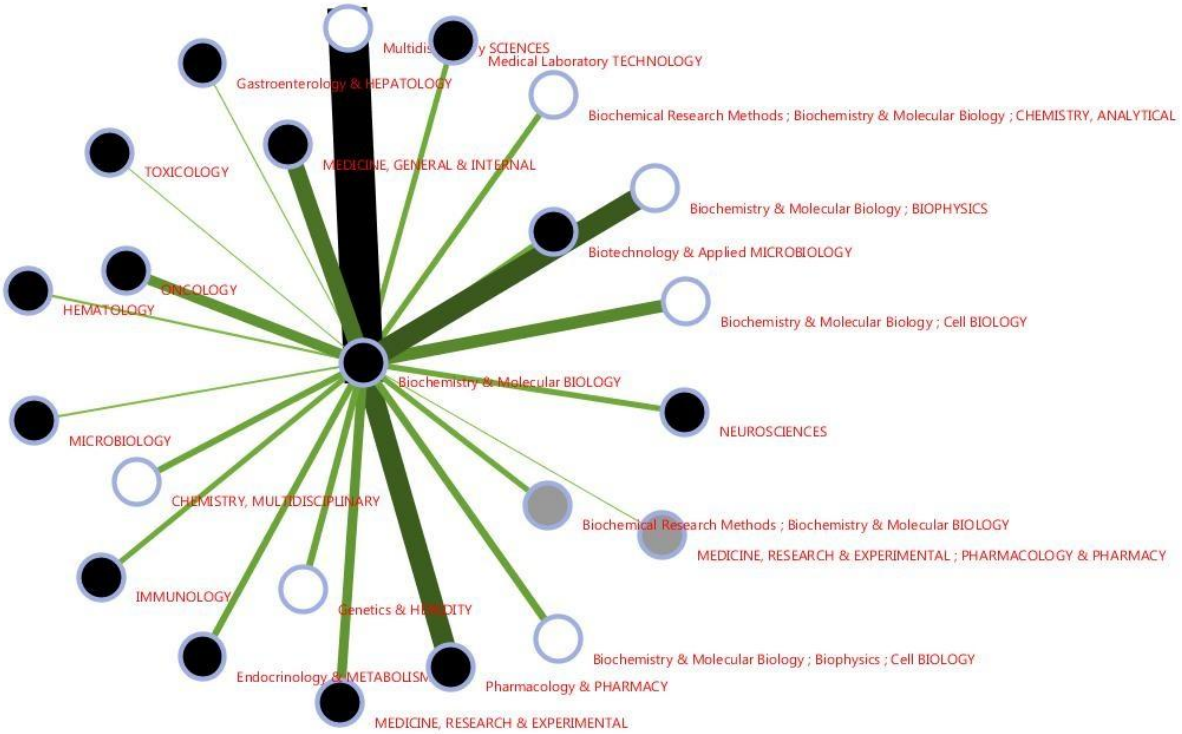

Figure 6. Biochemistry and Molecular Biology in the scientific map of Iran (2003-2007)

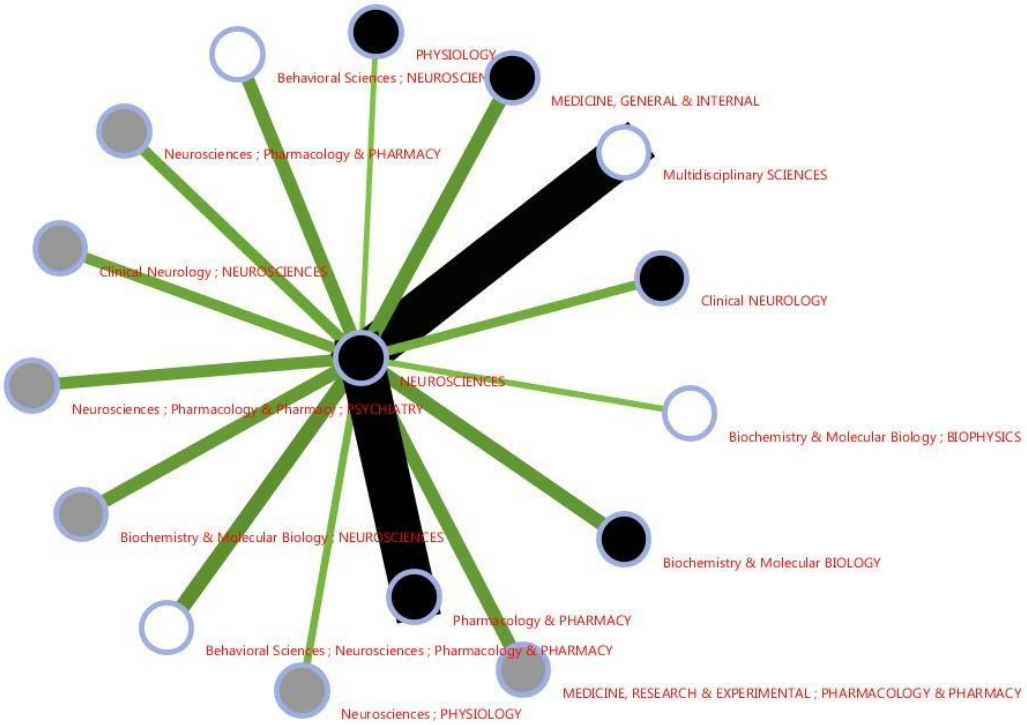

Figure 7. The Neurosciences in the scientific map of Iran (2003-2007)

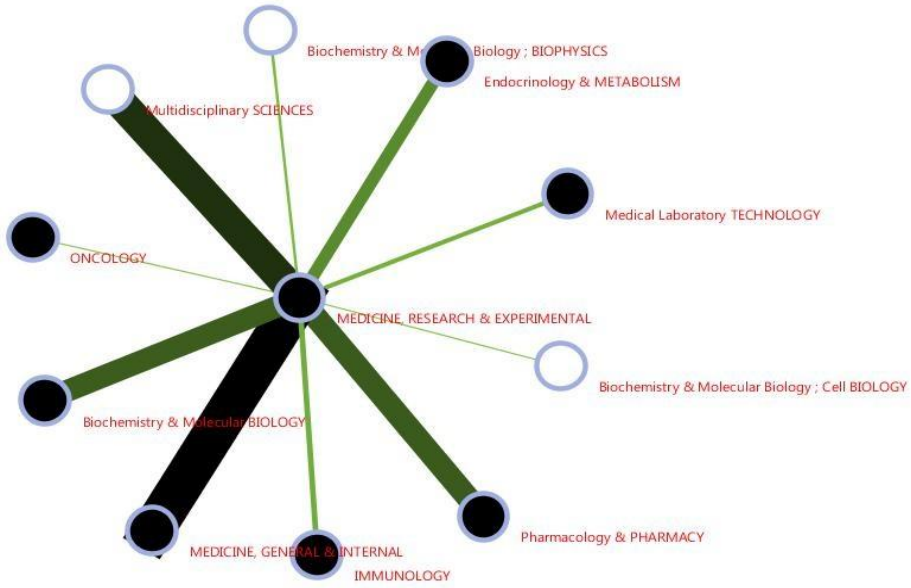

Figure 8. Research & experimental medicine in the scientific map of Iran (2003-2007)

In these maps, shown in Figures 4-8, each of the influential subject categories are depicted as the center of the map with the other subject categories surrounding them. These networks may be called the 'solar networks' or 'heliocentric maps'. Through these maps, one may well understand the relationships between one subject category and others. It is even possible to generate the maps in this section with various thresholds; however, in this article, only a few are noted. Moreover, from the maps 4-8, we can learn the importance of different domains, and their being inter-disciplinary. In the 5 domains investigated, we may conclude that general and internal medicine (followed by pharmacology and pharmacy) are more inter-disciplinary due to the amount of their relationships with other domains.

DISCUSSION

A growing rate in the medical sciences products of Iran as well as its percentage growth with respect to the total amount of the scientific products of the nation during the years under this study can be seen.

In line with this, in a study conducted by Mohmmad Hassanzadeh, et al. (2010) on investigating the 30-year medical products of Iran indexed in the SCI, it became clear that from 1983 till 2007, a growing trend could be observed in the scientific medical products of Iran. The highest number of Iranian published documents in the above database had been during 2003-2007 [14]. The present study too, studied co-citation during the same period.

It may be expected that the growth continues, considering the expectations of the Ministry of Health, and Medical Education in obtaining increases in scientific medical products of Iran, as well as the reiterations of the Comprehensive Scientific Health Map [15] in achieving the highest number of scientific products in the region.

This increase could be seen in the article by Imami (2010) which pointed to the scientific products of Iran in 2009 compared to its previous year [16].

Moreover, the report by the director of the Islamic World Science Citation database (ISC) pointed to an 18 % increase in the scientific products of Iran

in the SCI in 2011. Based on that report, Iran's rank in producing valid international articles during 2000-2011 was upgraded from 48 to 30 [17].

In the report by the Ministry of Health and Medical Education (2010), we saw the increase in the scientific medical products of Iran during 2000-2009. In that report, Iran had had the highest growth in producing science, ranking 26 internationally, while Turkey had been 4 in that respect [18].

This trend was continued till 2011 when Iran's rank was upgraded to 20, occupying 1.44 % of the ISI scientific articles, while except for China, the trend for the countries ranking 1 to 30, the trend had not been ascending [19].

Medicine accounts for ⅓ of all researches in Iran. It shows the scientific power of this domain in Iran. Thus, the results of this section may be used by the scientific community, especially by those in medicine. It may be also influential in policy making in the medical field.

Though with a growing trend in scientific products, in order to fill the gap with the developed nations, Iran would need to use more efforts, and empowerment in the medical field would demand planning and more investments.

As it was noted before, 44.74% of all articles was chosen for co-citation analysis. Therefore, the number of citations received by an article, which is one of the standards of quality assessment of the scientific products, is also of vital importance in scientific maps. If a document remains without any citations, it will be deleted from the science circle and from the scientific co-citation maps after a while.

As there has been no attempt in mapping the medical sciences in Iran, and as the present study has been the first, one may compare the results of the present study with those generated the overall scientific map of the world in which medicine is one of the most important clusters. For example, by extracting data from JCR 2006, Leydesdorff & Rafols (2009), generated the scientific map of the world, based on the ISI subject categories. In their study, medical subject categories were divided into 5 general categories including bio-medicine, neurosciences, infectious diseases, clinical medicine, and general medicine and health. There were sub-categories within the categories as well. All the 5 categories were related to each other. Bio-medicine formed a big nucleus, encompassing pharmacy and pharmacology and general and internal medicine were sub-classified into the category of general medicine and health. The results of their study confirm the results we found in our research. As for non-medical subject categories, both researches indicate a relationship with the chemistry. But in Agriculture, which in the study by Leydesdorff & Rafols a relationship with 5 general categories had been found, no relationship was found in the present study [20].

The scientific maps of Spain showed the relationship between pharmacology & pharmacy and General & internal medicine was very strong [21]. A similar relationship existed in the present study.

A scrutiny on the maps drawn showed that the relationship between pharmacology & pharmacy with general & internal medicine and neurosciences is very strong. The relationship between general & internal medicine with public, environmental & occupational health, as well as with endocrinology & metabolism is remarkable. These strong relationships indicate that such subject categories are conceptually very close and have impacts upon each other. Moreover, it shows the researches which are combination of different subject categories, or collaboration of researchers from different subject categories.

The same concept was found in a study by Hassanzadeh (2011). The results of that research indicated that there existed complex relationships for the clusters formed from the articles in Nano-technology of Iran as regards to multi-disciplinary collaborations. It showed that the authors had a tendency towards international and multi-disciplinary fields [12].

A point worthy of consideration in the generated maps is the presence of non-medical subject categories in the scientific medical map of Iran. This is due to the relationships between different scientific fields and the sciences becoming more inter-disciplinary, so that in writing an article or any other scientific text, the literature of other fields is being used as well. The presence of non-medical subject categories in our map shows the attention of the medical specialists to the non-

medical categories, as well as the collaboration of the specialists of different fields in conducting scientific researches. As Small (2010) has noted if scientists from different fields come together to work on a project, they use papers form different subjects. In other words, the reference list of a scientific paper can be interdisciplinary, if it cites literature in different disciplines [5]. As co-citation maps are based on references, it can be said such maps can visualize interdisciplinary relations in scientific domains.

Among the combined subject categories, there are categories made from biochemistry with biophysics, and cell biology. Moreover, the compound category of pharmacology & pharmacy with toxicology has an important impact on the maps. This signifies resources which have inter-disciplinary features being used by many researchers.

In the map generated by Small using the ISI article co-citation method in 1995, medicine is one of its clusters, within which subclusters such as cardio-vascular diseases and CNS are present. Moreover, radiology, transplantation, toxicology, fertility, etc. are visible, and this branch has a close link with the cluster of biology [1]. Also, in the present study, some non-medical subject categories such as cell biology are present in the map generated. This category has a relationship with medical subject categories. The other non-medical categories such as genetics & heredity, Multidisciplinary chemistry, and analytical chemistry are also present in the map of medical sciences. However, the most important subject category is the category of multidisciplinary sciences whose colorful presence, and its strong link with other fields is worthy of consideration. As Moya-Anegon, et al.[6] has noted, one may conclude that all subject categories possess strong links with the category of multidisciplinary sciences, because in the journals such as Science, and Nature, which are categorized in this field, articles related to all scientific domains are published, and the amount of citations to these articles is very high; therefore, the powerful presence of this subject category in category co-citation maps seems quite logical.

The 5 most influential medical categories were determined based on the general map generated. The number of links connecting these categories to others is more than the others. The subject categories of general & internal medicine, pharmacology & pharmacy possess most links. Biochemistry & Molecular Biology, Neurosciences and Research & experimental medicine possess considerable links as well. This might be due to the fact that such categories are more inter-disciplinary. As Small has noted, the study of inter-disciplinary links is one of the applications of the scientific maps [5]. In the maps generated for the influential categories, one can easily follow such links. As Moya-Anegon, et al. has noted, in the study of heliocentric maps by following the links between the centers in the map with the categories surrounding it, one may be able to determine how much inter-disciplinary a category is [6].

Some of the medical subject categories in the map generated in the present study have had no presence; therefore, we may consider them as the least effective categories in the scientific medical map. These categories appear to be the gaps in the medical research. This may be a guide for researchers and policy makers in medical subject categories to plan for the future researches.

Based on what has been found in the present study, the authors suggest that a committee be established in the Ministry of Health and Medical Education of Iran, which could be in charge of preparing and generating large scientific maps; so that such maps be available, like the maps of the other countries in the Atlas of Sciences which are accessible in the internet [22], so that all specialists and students, and decision makers may be able to use them. Departments of Medical Library & Information sciences and specialists in scientometrics should be in the center of this committee and specialists from other disciplines such as computer sciences and statistics should help them. This committee could lead individual researchers in their projects related to various domains.

It is necessary to encourage the categories with more effective and support the subject categories with the least impact to publish more articles and get more citation. It is recommended that the committees or the groups which are the responsible for the least impact subject categories

in the Iran Ministry of Health and Medical Education prepare the programs for the reinforcement of these fields and improvement of their relations with other categories.

The scientific maps have to be generated in different eras under various methods and techniques, so they can offer a clear visualization of the scientific products of different fields, authors, publications, etc. to the users. Moreover, generating and comparing the scientific maps of different countries are suggested.

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