# The scientific map of medicine in Iran: Category co-citation analysis*

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## ABSTRACT

*Recognition and having a general outlook of the researches performed, as well as the links among various fields, and also having awareness of the developments and progression of such fields in time are among the objectives of scientific maps. The goal of the present study is to discover and draw the scientific map of medical domains in Iran during 2003-2007. For such purposes, we sought to utilize the subject category co-citation analysis. In line with this, the most productive, effective and the most cited medical subject categories in the period under investigation were determined. The study population included all scientific papers published by Iranians in medical subject categories, as well as their references, which have been indexed in Science Citations Index Expanded (SCIE). Data analyses and mapping were performed using Network Workbench (NWB) tool. The findings show that Iranian medical scholarly publications have been increasing compared with its total scientific products. The mappings reveal more density in the maps of each successive year under study. It can be said that subject categories such as Medicine, General & internal, Pharmacology & pharmacy, and Biochemistry & molecular biology are among the most productive categories as they have more relations with other categories. There is a significant difference between the quantity of scientific products and the amount of citations garnered by effective categories and other medical categories. However, no significant difference is found between the mean received citations per article in effective medical categories and other categories. The authors recommend more attention be paid to the scientific mappings using various techniques applied in different years in Islamic countries.*

**Keyword:** Scientific maps; Knowledge mapping; Medicine; Scientometrics; Category co-citation analysis.

## INTRODUCTION

Scientometric researches are so important in information science, that Hjorland (2002) has introduced it as one of the eleven approaches of domain analysis in Library and Information Science. Scientific maps and drawing the structure of scientific domains is one aspect of scientometrics. The mapping of the scientific domains structures provides grounds for studying the current status of scientific production in the domains under investigation. It can also pave the way for planning of the future research protocols. Such scientific mappings will also help present an image of a domain and its related fields; an image, which will be impossible to easily visualize. These maps help in understanding the domains, and will reveal the connections among the fields, though they may not be apparently recognizable.

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Scientific maps are similar to geographical ones, which help in understanding our surroundings; the scientific maps too, follow the same functions in a scientific environment. It can be used to identify major areas of science visually; their size; similarity, and interconnectedness and help understanding a scientific domain and its related fields (Boyack et al. 2005). Analogous to the way geographic maps show the relationships of political or physical features on the Earth, a map of science is a representation of how disciplines, fields, specialties, and individual papers or authors are related to one another as shown by their physical proximity and relative locations (Small 1999).

Mapping knowledge domains is a new trend in science with an intermediary nature whose aim is drawing graphs, extracting and analyzing data, sorting, and navigating and displaying the science. In fact, the purpose of scientific maps ranges from facilitating information access and making evident the structure of knowledge to helping knowledge seekers in discovering and recognizing knowledge. This method is used in studying scholarly communities and networks, as well as in examining dynamic changes such as speed of growth and evolution of fields, the diffusion of previous research topics, authors, and organizations (Borner et al. 2003; Shiffrin and Borner 2004).

Co-citation analysis is one of the methods of drawing scientific maps. It is one of the accepted methods widely used in mapping knowledge. Its usage is thought of as a route in understanding the conceptual structure of a scientific domain, which dates back to the 1970s. In fact, it was in 1973 when Henry Small and Irena Marshakova-Shaikevich separately introduced the idea of co-citation analysis. Small noted to the method in mapping the conceptual structure of scientific fields, and showed the idea of co-citation in two documents in publications related to quantum physics. Following Small, Eugene Garfield, at the Institute of Scientific Information (ISI) showed, through maps, the links among documents using the co-citation method (Garfield 1993; Mohammadi 2008). Moya-Anegon et al. (2004; 2005) suggested using co-citation analysis in ISI subject categories as a a technique in analyzing, visualizing and mapping large scientific domains.

Medicine and its related sciences have always been the focus of attention among researchers due to their importance in human health. They have been among the fields with the devotion of a large amount of capital investment in their research. The prevalence of the many specialized databases is a clear evidence for such a claim. In the Science Citation Index Expanded (SCIE), from among 171 subject categories there are 60 subject categories devoted to various medical fields, all being consistent with the National Library of Medicine (NLM) Classification in the USA. Also, the importance of medicine is well documented in the maps drawn by Leydesdroff and Rafol (2009) and Small (1999) so that the medical field is one of the main fields mapped by them.

To understand the situation of research in medical fields in Iran, as well as the awareness of know-how and development in this field, along with the inter-links of its sub-fields and determining the most effective subject categories, we seek to carry out the co-citation mapping of medical publications from Iran indexed in SCIE during 2003 to 2007. The study also seeks to present a clear image of the condition of scientific products in medicine with the quantity of their citations and effects so that the approach may be fruitful in planning and decision-making in medicine. In line with this, we will assess the significance of the difference among the effective categories in medicine with other medical subject categories in the number of the scientific products, the number of citations, and the mean citation per article.

## LITERATURE REVIEW

There have been numerous studies conducted in drawing scientific maps by using co-citation analysis. Small (1993) generated the co-citation maps of science based on articles indexed in ISI databases during 1983-1989, and investigated alterations in the relations among various fields in that period. White and McCain (1998) used the author co-citation analysis (ACA), to construct the scientific maps in information science during 1972-1995. Later, Small (1999) drew the map of ISI articles in 1995 by using co-citation clusters. Network is reported on a dataset of about 36000 documents. The overall map of the main hierarchy consists of 35 level-four clusters. The map shows four main topic regions (physical science, biology, medicine and social sciences). The cluster of medicine has a close link with the biology cluster; there are sub-clusters within medicine including cardio-vascular diseases, and central nervous systems (CNS) diseases.

Boyack et al. (2005) drew the map of all sciences published in 2000 based on articles indexed in the ISI databases. Moya-Anegon et al. (2005) mapped the structure of Spanish publications in 2002 based on subject category co-citation. Vargas-Quesada et al. (2006) paid attention to the drawing of the maps of great scientific domains. From the Web of Science (WoS), they retrieved all the scientific publications of USA which had been indexed in the year 2002. They studied the articles through using the category co-citation analysis. In another study, Klavans and Boyak (2007) compared two maps drawn based on the ISI and Scopus databases. Osareh and McCain (2008) mapped the structure of chemistry in Iran by using author co-citation analysis during 1990-2006. In a new approach, Porter and Rafols (2009) used the knowledge mappings in order to show the degree of inter-disciplinarity over six research domains during 1975-2005. They chose these domains based on the ISI subject categories and scrutinized the targeted alterations within the fields. For their purposes, they used the number of cited disciplines and references per article, co-authors per article and drawing the co-citation maps in the targeted research domains. In another study, Leydesdorff and Rafols (2009) extracted the Journal Citation Report (JCR) 2006 data and drew the world map based on the ISI subject categories. The subject categories were divided into 14 factors or major fields, while their largest category turned out to be the category of biomedical sciences. In his latest study, Small (2010) used co-citation maps as an approach to analyze inter-disciplinary relationships.

## RESEARCH OBJECTIVES AND HYPOTHESES

The present study seeks to:

a) Determine the number of articles, the number of citations received, as well as the mean citation per document in different medical subject categories based on the publications of Iranians indexed in the Science Citation Index (SCI).
b) Investigate the situation of various subject categories in the scientific maps of medicine in Iran during 2003-2007.
c) Determine the most influential subject categories in the scientific maps of medicine in Iran during 2003-2007.

In line with this, three hypotheses are tested as follows:

Hypothesis 1: There exists a significant difference between the number of scientific publication in the influential medical subject categories with the other medical subject

categories.

Hypothesis 2: There is a significant difference between the number of citations of the influential medical subject categories with the other medical subject categories.

Hypothesis 3: There exists a significant difference between the mean citations per document in the influential medical subject categories with the other medical subject categories.

## MATERIALS AND METHODS

In the article by Borner et al. (2003), and in the user manual of Network workbench (2009), the steps for drawing scientific maps are studied. These steps include data extraction, selection of analysis unit, selection of measures, layout (calculation of similarities, and ordination) and finally displaying. In the present study, the above steps are considered as follows.

a) ***Data collection:*** In the present study, the study population includes all medical literature published by Iranians during 2003-2007 in journals indexed by the SCIE. We have chosen the years 2003-2007 as there had been a sudden jump in 2003 in the number of the scientific products of Iran (Esfanjani et al. 2010). Therefore, the year 2003 was chosen as the starting point in our study. The year 2007 was selected too as in the scientific co-citation studies one has to investigate in the previous 4-5 years (Small 1993; White and McCain 1998; Porter and Rafolz 2009). The reason is that in selecting the threshold for co-citation studies, one has to follow a trend so that the indexed articles have received the highest number of citations. In the present study, the adequate time span for receiving citations had to be followed as the number of citations received and the mean citations for each document were both investigated in the study hypothesis. Data were extracted from the WoS database and the SCIE. With the search "CU=Iran", and limiting the article publication time to 2003-2007, all articles published during that period and indexed in the above database were retrieved. The targeted articles were limited to medical subjected categories and their related domains, and this was conducted using the analysis facilities available at the above database. The total number of articles retrieved is 10247 in 60 medical subject categories. The retrieved publications in medical domain were stored in "full record" in ISI format so they could be used in the successive phases of mapping the scientific map of Iran. The references of these publications were analyzed for co-citation study. Bearing in mind that the threshold in constructing scientific maps depends on the research condition and population, the present study sought the articles for co-citation analysis, which have had at least two citations.

b) ***The selection of data analysis unit:*** Considering the fact that in co-citation, one may use different fields such as the authors, articles, journals, and finally the subject categories as the data analysis unit, we chose medical subject categories in ISI based on the approach suggested by Moya-Anegon et al. (2005) for this study.

c) ***The selection of assessment unit and calculating the similarities:*** Since the scientific maps are usually constructed based on calculating the similarities between the data analysis units, in the present study, we used the frequency of subject category co-citation in constructing the scientific map. This has been possible by using Network

Workbench tool (NWB).

d) ***Construction and display of the map****:* In ordinating and displaying the targeted scientific map, NWB tool is also used. This open source tool is used for network analysis, modeling, and visualization in social sciences, biomedicine, and physics domains with an accessibility possibility to more than 80 algorithms, and makes possible the observation for 30 sample data sets for studying the network. Scientometrics calculation facilities provide grounds for document co-citation, extracting bibliographic coupling, word co-occurrence, and co-author networks. Moreover, it is possible to enter the data in different formats, such as the ISI format (*.isi), pajek.NET(*.net), Scopus, Bibtext, and EndNote Export Format; the tool also utilizes different mapping algorithms such the Guess algorithm (Borner et al. 2010; Network Work Bench 2009). The NWB Tool allows the data to be processed, different kinds of networks to be built, a graph analysis over the built networks to be performed, and finally the scientific maps to be visualized. Moreover, the tool is able to carry out a temporal analysis (Cobo et al. 2011). Users of the NWB Tool can:
    - Access major networks datasets online or load their own networks.
    - Perform network analysis with the most effective algorithms available.
    - Generate, run and validate network models.
    - Use different visualizations to interactively explore and understand specific networks.
    - Share datasets and algorithms across scientific boundaries" (Network Work Bench 2009).

In this study, the retrieved publications were saved in five files in the ISI format. Since the NWB tool provides co-citation just up to the document level, the researchers were bound to impose certain alterations to the records retrieved form the ISI in the Word format. Thus, the subject categories of each document in references of articles were retrieved via the JCR, and were replaced in the targeted reference. It seems quite natural that the references not supported by the "Web of Science" were deleted from the present study. Then, the cleaned data were loaded in the NWB; and network of co-citation were extracted and displayed via this tool.

## FINDINGS

The scientific products of Iran during 2003-2007 were altogether 10247 documents in 60 medical subject categories. This shows a rising trend that reached to 3967 topics in 2007, compared to 904 topics in 2003.

Table 1 shows the number of articles published in medical subject categories and the citations received. The field *Pharmacology & pharmacy* produced 1257 documents and had been the most productive category followed by *Biochemistry & molecular biology*, and *Immunology* occupying the second and third ranks, respectively. Table 1 also shows the rate of the citations received by different medical subject categories during the years under scrutiny. *Pharmacology & pharmacy* with 6267 citations, *Biochemistry & molecular biology* with 4913 citations, and *Biochemical research methods* with 3064 citations occupy the first three ranks. The least cited categories include *Health policy and services* with 4 citations, *Medical ethics* with 14, and *Medicine, legal* with 20 citations.

Table 1: Distribution of Articles by Iranians in Medical Subject Categories with the Citations Received during 2003-2007

| Medical category | Scientific products | Total cited | Mean Citation per article |
|---|---|---|---|
| Pharmacology & Pharmacy | 1257 | 6267 | 4.99 |
| Biochemistry &Molecular Biology | 756 | 4913 | 6.5 |
| Immunology | 738 | 2602 | 3.53 |
| Neurosciences | 648 | 2274 | 3.51 |
| Clinical Neurology | 628 | 1269 | 2.02 |
| Surgery | 623 | 1995 | 3.2 |
| Medicine, General & Internal | 568 | 1500 | 2.64 |
| Transplantation | 491 | 746 | 1.52 |
| Public, Environmental & Occupational Health | 486 | 1531 | 3.15 |
| Biotechnology & Applied Microbiology | 447 | 2238 | 5.01 |
| Oncology | 425 | 1488 | 3.5 |
| Urology & Nephrology | 412 | 866 | 2.1 |
| Endocrinology & Metabolism | 398 | 1649 | 4.14 |
| Pediatrics | 392 | 763 | 1.96 |
| Chemistry, Medicinal | 384 | 2730 | 7.11 |
| Gastroenterology & Hepatology | 380 | 1418 | 3.73 |
| Hematology | 368 | 980 | 2.66 |
| Toxicology | 357 | 1324 | 3.71 |
| Obstetrics & Gynecology | 333 | 932 | 2.8 |
| Medicine, Research & Experimental | 323 | 1197 | 3.71 |
| Biochemical Research Methods | 293 | 3064 | 10.46 |
| Radiology, Nuclear Medicine & Medical Imaging | 268 | 642 | 2.4 |
| Nutrition & Dietetics | 262 | 1460 | 5.57 |
| Dermatology | 239 | 964 | 4.03 |
| Cardiac & Cardiovascular Systems | 220 | 487 | 2.21 |
| Peripheral Vascular Disease | 213 | 242 | 1.14 |
| Psychiatry | 211 | 977 | 4.63 |
| Ophthalmology | 187 | 876 | 4.68 |
| Microbiology | 181 | 947 | 5.23 |
| Dentistry, Oral Surgery & Medicine | 173 | 893 | 5.16 |
| Infectious Diseases | 167 | 999 | 5.98 |
| Tropical Medicine | 161 | 379 | 2.35 |
| Pathology | 148 | 803 | 5.46 |
| Parasitology | 147 | 416 | 2.92 |
| Medical Laboratory Technology | 142 | 482 | 3.39 |
| Physiology | 131 | 389 | 2.97 |
| Engineering, Biomedical | 121 | 801 | 6.62 |
| Allergy | 117 | 205 | 1.75 |
| Virology | 93 | 447 | 4.81 |
| Respiratory System | 81 | 218 | 2.69 |
| Rheumatology | 78 | 76 | 0.97 |
| Integrative & Complementary Medicine | 57 | 387 | 6.79 |
| Orthopedics | 54 | 299 | 5.54 |
| Otorhinolaryngology | 53 | 102 | 1.92 |
| Anesthesiology | 50 | 134 | 2.68 |
| Critical Care Medicine | 44 | 237 | 5.39 |
| Health Care Sciences & Services | 38 | 204 | 5.37 |

| Medical category | Scientific products | Total cited | Mean Citation per article |
|---|---|---|---|
| Rehabilitation | 36 | 175 | 4.86 |
| Anatomy & Morphology | 33 | 88 | 2.67 |
| Medical Informatics | 29 | 131 | 4.52 |
| Nursing | 29 | 155 | 5.34 |
| Emergency Medicine | 24 | 117 | 4.88 |
| Geriatrics & Gerontology | 18 | 47 | 2.61 |
| Andrology | 17 | 116 | 6.82 |
| Clinical Psychology | 14 | 90 | 6.43 |
| Substance Abuse | 11 | 74 | 6.73 |
| Health policy & services | 7 | 4 | 0.57 |
| Medicine, Legal | 7 | 20 | 2.86 |
| Neuroimaging | 6 | 22 | 3.67 |
| Medical ethics | 5 | 14 | 2.8 |

The results reveal that *Biochemical research methods* with a mean of 10.46 citations per article ranks the first, followed by *Chemistry, medicinal* and *Andrology* ranking the second and third, respectively. The category *Health policy and service*s, with 0.57 citations per article, ranks as the least cited category, followed by *Rheumatology* and *Peripheral vascular diseases.*

In order to construct the co-citation map in the years under our investigation, we selected all articles that received at least two citations, and used NWB tool for the mapping process. In the maps constructed, light- and bold- colored lines are indicative of the links between different categories for their weight. Stronger links are shown with darker-colored and thicker lines, while the weaker links are with lighter-colored and narrower ones. Moreover, there are 4 groups of nodes in the maps. Some show just one medical subject category, while the others are indicative of two or more; still others, display a combination of medical and non-medical subject categories, while a few are indicative of one or some non-medical subject categories.

Due to the fact that some maps are constructed disregarding co-citation threshold, and in order to show the stronger links, it was decided to select the links with weights more than 20, and the targeted maps were constructed based on this decision.

Figure 1 shows that in 2003, the link between *Medicine, general & internal* category and *Pharmacology & pharmacy* is very strong. The same strength also exists between *Pharmacology & pharmacy* and *Neurosciences*. This figure also shows that *General & internal medicine* is very effective in the medical scientific map in 2003. It has formed a small network inside the main network and has many links to other medical subject categories. *Biochemistry & molecular biology; pharmacology &;* and *Neurosciences* are also important in this network.

As can be seen in Figure 2, there exists a very strong link between medical subject categories of *Pharmacology & pharmacy*; and *Neurosciences*; *Biochemistry & molecular biology*; and *Medicine*, g*eneral & internal medicine*. A strong link is also visible between the subject categories of *Medicine, gerneral & internal;* and *Public, environmental & occupational health*. In this map, three small networks can be seen whose center are *Medicine, general & internal; pharmacology & pharmacy*; and *Biochemistry & molecular biology.* The *Multidisciplinary sciences* subject category is also important in this map.

Figure 2 also shows that there are more nodes and links in the category co-citation map of medicine in 2004 than 2003. A small network has formed in the right of main network, consisted of *Analytical chemistry* and a compound node of *Biochemical research methods* and *Analytical chemistry*. The *Medicine, general & internal; Pharmacology & pharmacy; Biochemistry & molecular biology;* and *Neurosciences* are the most effective nodes in this map.

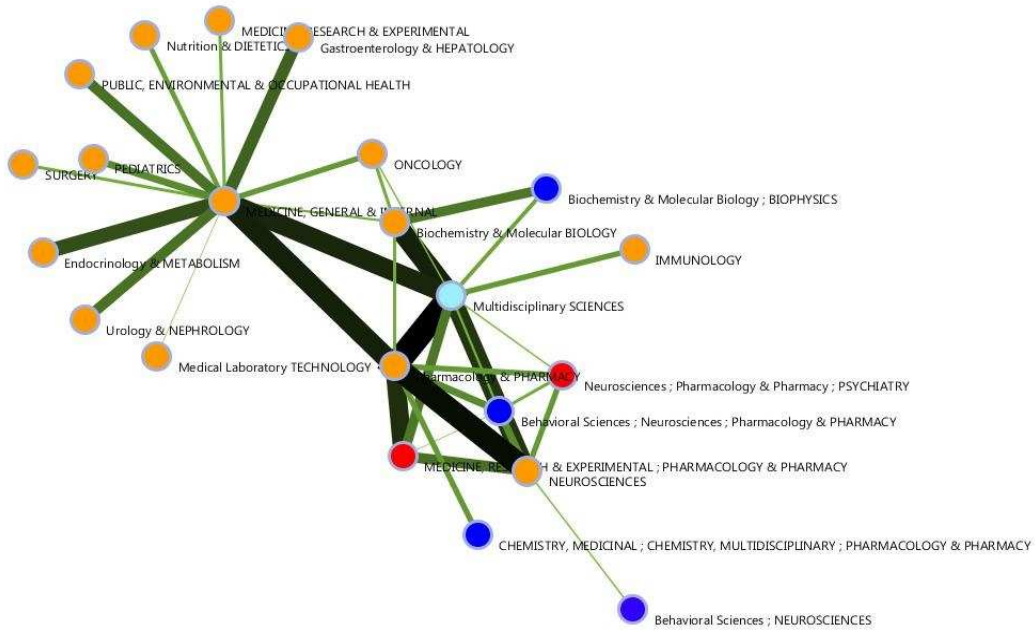


Figure 1: The Medical Scientific Map of Iran in 2003

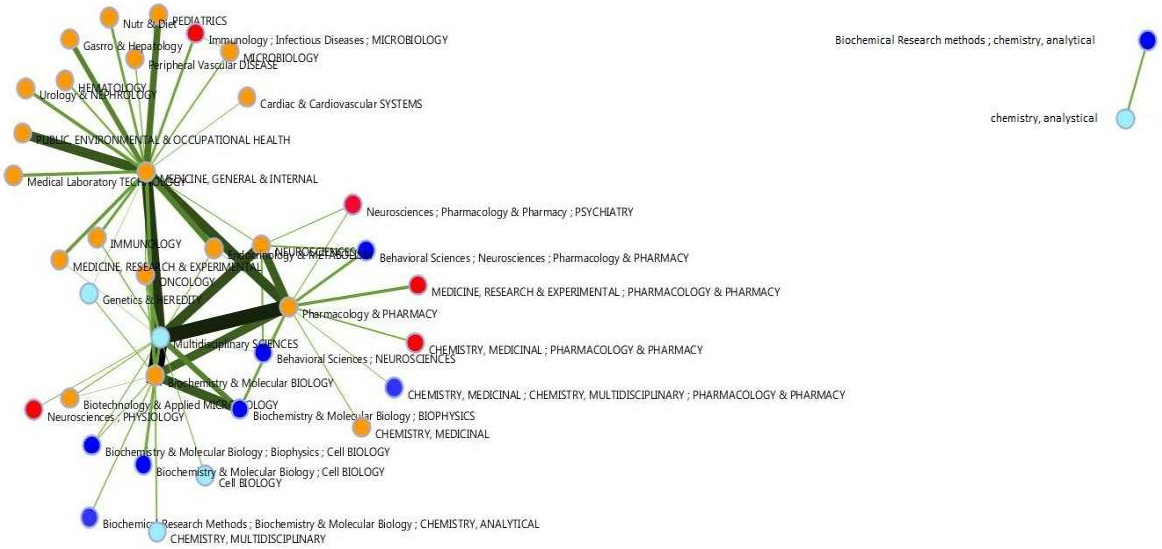


Figure 2: The Medical Scientific Map of Iran in 2004

Figure 3 indicates that the subject categories *Medicine, General & internal*; *Pharmacology & pharmacy*; *Biochemistry & molecular biology*; and *Neurosciences*, all are centers of smaller networks which are related to more nodes.

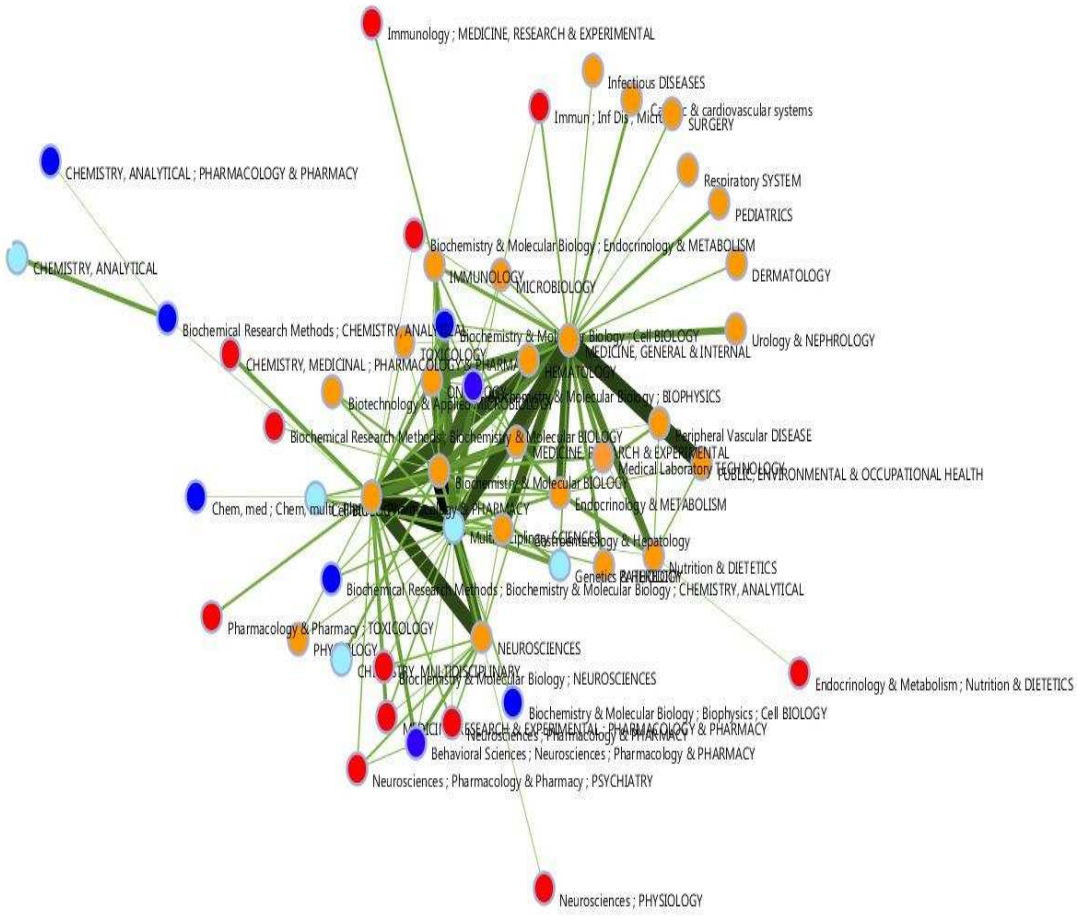


Figure 3: The Medical Scientific Map of Iran in 2005

There are more nodes and stronger co-citation relations between different nodes. The small network of *Chemistry, analytical* and *Biochemical research methods; Chemistry, analytical* in the 2004 map is joined to the main map through *Pharmacology & pharmacy.* The links between the following subject categories are quite outstanding:
- *Medicine, general & internal*, and *Public, environmental and occupational health;*
- *Medicine, general & internal*, and *Pharmacology & pharmacy*;
- *Pharmacology & pharmacy* and *Neurosciences;*
- *Pharmacology & pharmacy*, and *Biochemistry & molecular biology.*

There are small networks in Figure 4 mapped inside the main map. Some of these networks with centers including the categories of *Medicine, general & internal*; *Pharmacology & pharmacy*; *Biochemistry & molecular biology*; *Medicine, research & experimental*; and *Neurosciences,* which each have a remarkable links with other subject categories. There are more non-subject and compound categories in this 2006 map and the co-citation relations between different nodes are complicated than the previous years.

Figure 5 illustrates the medical scientific map of Iran in 2007. The nodes, whose names are identified, show a medical subject category. The number of these nodes and co-citation links between them is more than the previous years. It is 38 in 2007, while is 15 in 2003.

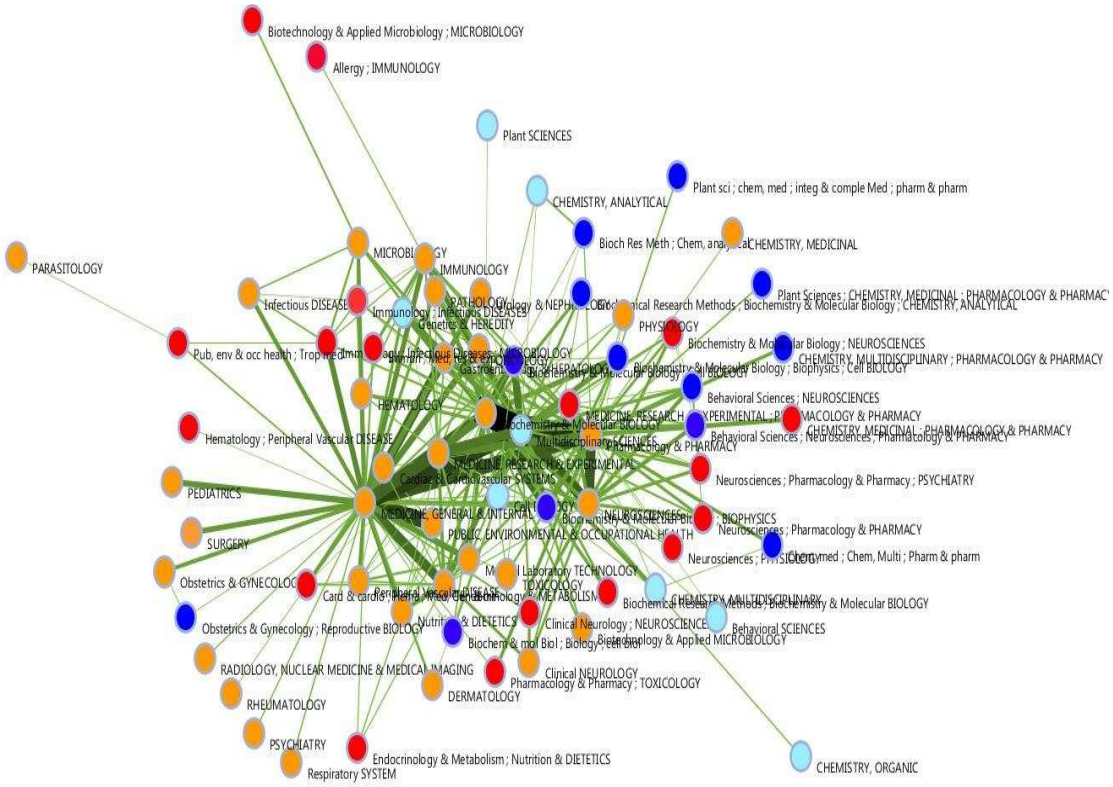


Figure 4: The Medical Scientific Map of Iran in 2006

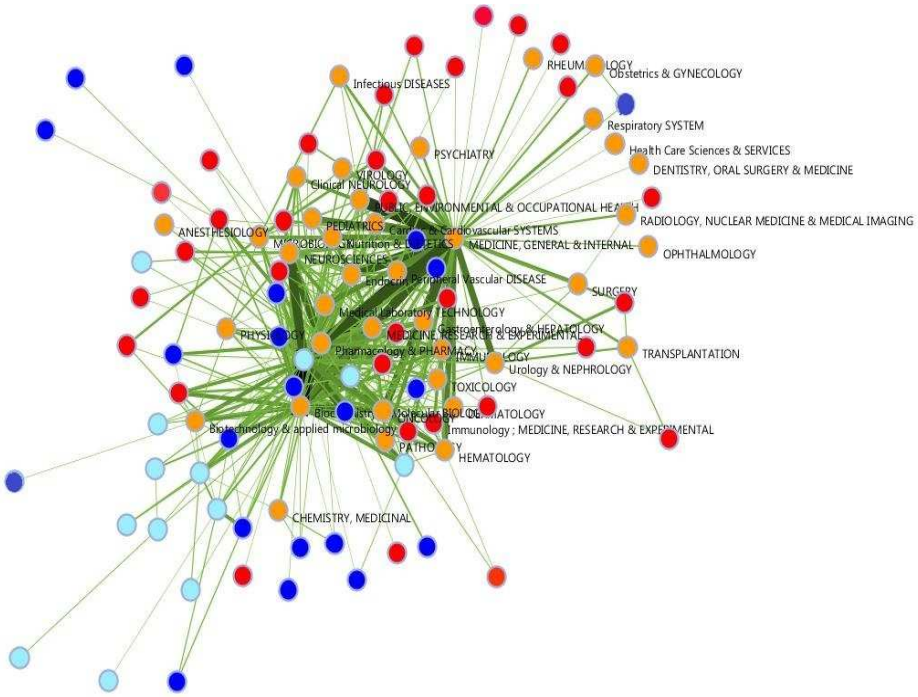


Figure 5: The Medical Scientific Map of Iran in 2007

Figures 6, 7, and 8 also indicate other kinds of nodes in the medical scientific map of Iran in 2007. Figure 6 shows some nodes that consisted of two or more medical subject categories. The number of these nodes has increased compared with the previous years, from 2 in 2003 to 33 in 2007.

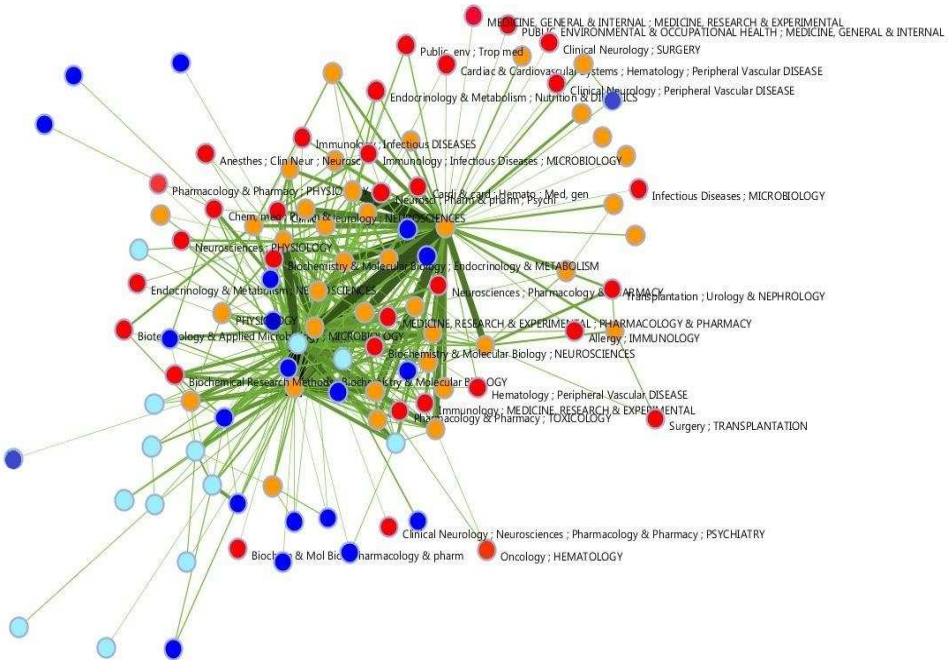


Figure 6: Nodes Consisting of Two or More Medical Subject Categories in the Medical Scientific Map of Iran in 2007.

Figure 7 indicates that in the medical scientific map of Iran in 2007, there are some nodes showing non-medical subject categories. The number of these nodes is 13, while that in 2003 is 2 (Figure 1). This increase is also seen in the number of compound nodes that is shown in Figure 8. Most of these nodes are in the lower-left of the map and are close to *Biochemistry & molecular biology.* In this map, there are 11 nodes showing non-medical subject categories, while in 2003 there is only one node of this kind. The category of *Multidisciplinary sciences* is evident between these nodes in all years.

Figure 8 shows some nodes that consist of medical & non-medical subject categories. Most of these nodes are in the left of the map and are related to *Biochemistry & molecular biology* and *Pharmacology & pharmacy*. The number of these nodes is 21 in this map (Figure 8), while is 2 in the 2003 map (Figure 1).

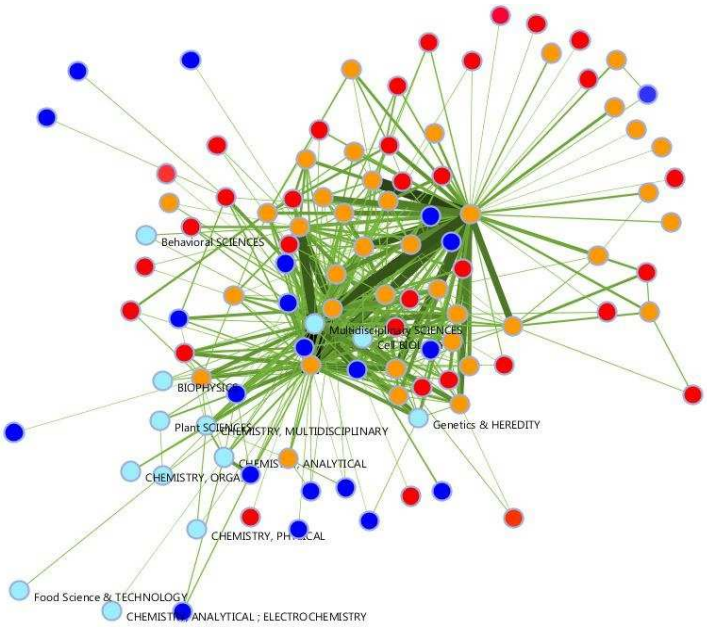


Figure 7: Nodes Consisting of Non-medical Subject Categories in the Medical Scientific Map of Iran in 2007

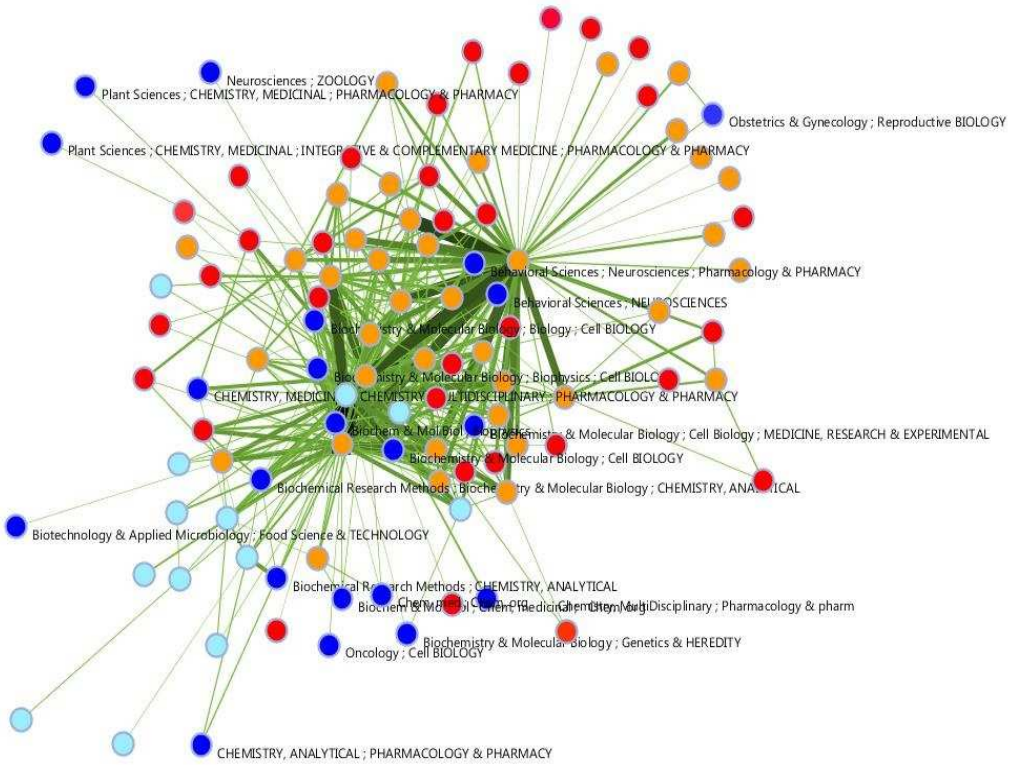


Figure 8: Nodes Consisting of Medical and Non-medical Subject Categories in the Medical Scientific Map of Iran in 2007

Based on the medical scientific maps in Figures 5 to 8, the number of nodes and links increase from the year 2003 to 2007. This is detailed in Table 2. It also shows that the weight of links in the maps has increased during the period under study. The weight of co-citation links is 161 in 2007, while it is only 50, at most, in 2003.

Table 2: The Characteristics of the Medical Scientific Maps Drawn for 2003-2007

| Year | Number of nodes | Number of links | Maximum weight of links |
|---|---|---|---|
| 2003 | 22 | 36 | 50 |
| 2004 | 38 | 58 | 77 |
| 2005 | 51 | 127 | 104 |
| 2006 | 72 | 250 | 161 |
| 2007 | 105 | 438 | 204 |

In the maps so far constructed, certain medical subject categories have had more impact than others. These subject categories have had the most links with other categories and they themselves can be considered as a small map, which surrounds the other subject categories. The most effective medical subject categories are as follows:

a) Medicine, general & internal
b) Pharmacology & pharmacy
c) Biochemistry & molecular biology
d) Neurosciences
e) Medicine, research & experimental
f) Endocrinology & metabolism
g) Oncology
h) Immunology
i) Public, environmental & occupational health
j) Medical laboratory technology

Finally, by using T-Test for two independent groups, it became clear that there existed a significant difference between the two effective categories, and other categories regarding the number of total papers produced (P = 0.004). The amount of scientific papers is significantly more in the categories with more impacts in the scientific maps.

Moreover, a significant difference was observed between the two categories, which were most effective, and other categories concerning the rate of the citations (P =0.015). The number of citations is significantly more in the categories with more impact in the scientific maps. However, no significant difference was found between the two categories which had been the most effective, and other categories concerning mean citations per article.

## DISCUSSION

The findings of this study indicate that there has been a rising trend in the medical scientific papers published by Iranians during the years under study (2003-2007). Regarding the reiterations made by the Iran Ministry of Health and Medical Education (2010) and bearing in mind the concepts put forth in the Comprehensive Scientific Health Map of Iran in accomplishing the first rank in the number of scientific papers published in

the region and among all Islamic countries, the increase seems to be natural and it is expected that the trend will be upward in the future.

Considering the quantity of the scientific papers published in different medical subject categories, it is necessary to pay more attention to areas with the fewest scientific output. More planning is also required to promote the subject categories with better rankings.

The average citation per article, next to the total citation numbers, shows the quality of each article published in each of the subject domains, and the attention of the researchers in such domains to the articles bears high importance. It is necessary to pay more attention to the quality of the articles published, so that these papers might enhance the number of citations at both the national and international levels. This is more needed in the subject categories with the fewer citations per article. Therefore, the sole quantity increase in scientific papers may not be regarded as a strategic target as the quality of the published articles.

As indicated in the article earlier, in order to construct the co-citation map of Iran during the years under study (2003-2007), all articles with at least two citations were selected, and the map was constructed. Thus, the importance of citations is very clear. In general, it may be said that an article with no citation will automatically be deleted from the scientific circle and from the scientific citation maps after a period of time.

The number of nodes and links, during the years under study has increased. This has caused a density in the map constructed in each year relative to its previous year. Also, it can be visible that the weight of links has increased successively. This can be distinguished from the thickness or narrowness of their lines. The maximum weight of the links has grown from 50 in 2003 to 204 in 2007, which shows a stronger co-citation link between different subject categories, revealing the domains that were given more attention by the medical experts and scientists.

The interesting point in the maps is the presence of the non-medical subject categories in the medical scientific map of Iran. This is due to the relationship between the different scientific domains, and the inter-disciplinarity of sciences, so that, the literature of other domains is used when writing a scientific article. The increase in the number of non-medical and compound subject categories in the maps of different years is indicative of the attention given by medical specialists to non-medical subjects, and the collaboration of different experts from different domains in conducting scientific research which is following a growing trend. The study of interdisciplinarity is one of the applications of scientific maps as Small (2010) has noted in his article.

The subject categories including *Medicine, General & internal;* and *Pharmacology & pharmacy* have more links with other categories. This might be due to their more interdisciplinarity nature than the other subject categories, followed by the subject categories *Biochemistry & molecular biology* as well as *Neurosciences*.

Based on the information from the maps, there are 10 most effective subject categories in medicine. The number of the links, which bind these to the other categories, is more. Moreover, some non-medical categories or a combination of categories have a high impact in the maps constructed. Some of such categories are related to the categories of *Neurosciences*; *Pharmacology & pharmacy*; while others are related to chemistry, which include *Chemistry, multidisciplinary*; and *Chemistry, analytical.* The subject category of *Cell*

*biology* is also quite visible in the maps. However, the most important non-medical subject category visible in the maps is *Multidisciplinary sciences* whose colorful presence and strong relations with the other doamins are more visible. It can be said that almost all subject categories have a strong link with the *Multidisciplinary sciences*, as there are high-impact journals such as *Science* and *Nature* in this category that publish articles in all scientific domains and, it is natural that this is shown strongly in all maps constructed.

The hypothesis testing in this paper shows a significant difference between two most effective subject categories, and other categories concerning the number of scientific papers published and the rate of citations. In other words, the number of scientific products and citations in the most effective categories is significantly higher. Therefore, as more information is produced and more citations are received, there will be more colorful and stronger domain visible in the citation maps. But there has not been a significant difference between the mean citations received per article in the two most effective medical subject categories with other categories. In other words, in the effective medical subject categories, the mean citations received, is not significantly different with the other categories, though there have been more scientific products with more citations. This means that the quality of the published articles in these domains is not much different from the others. Therefore, we suggest that more attention has to be devoted to the quality of the articles produced.

Based on the results obtained from this study, it is suggested that a committee be formed at the Iran Ministry of Health and Medical Education, which should be in charge of providing and constructing the medical scientific maps in different periods, so that, this can be utilized by medical experts, specialists, students, and policy makers. Such maps may be also constructed at the Iran Ministry of Research, Science & Technology, which can include all science subject disciplines in Iran in a greater scale. It is also suggested that the scientific maps be constructed using different techniques and approaches in order to provide a clearer outlook of scientific products, authors, and scholarly journals for potential users. The scientific maps of different countries, especially those of Islamic countries be compared, and this can provide us with the information on research productivity and scientific impact of Iran and the Islamic countries.

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