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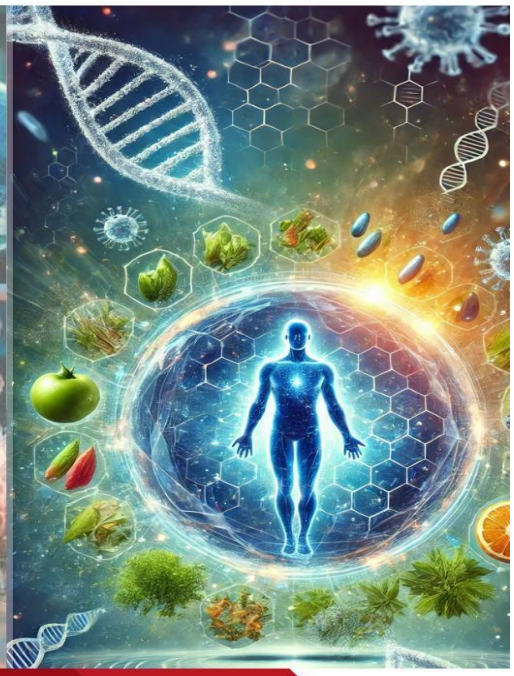

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Nanoscience and nanotechnology publication mapping in the Iranian ISI: a citation analysis method

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ABSTRACT

An in-depth citation analysis research was carried out to shed light on the multidisciplinary linkages of Iranian ISI publications on nanoscience and nanotechnology (N&N) and to map out its pattern of growth. Starting with 1 article in 1995 (with 26 citations), the trend of publications increases to 94 papers in 2007 (with 2425 citations). When it comes to the influence on N&N citations, journal articles are at the top with about 90%. References to books published after 2003 show how N&N has changed. As of the end of 2007, N&N's foundations were built upon fourteen distinct topic areas that included twenty-five specialties. With 48.5% of all citations, manufacturing and transport engineering is the leading topic area in N&N. Physical sciences come in at 15%, chemical sciences at 14.7%, and nano at 13.3%. On the other hand, the top three fields are materials engineering (16.48%), metallurgy (28.01%), and physics (17.33%). The results show a lot of variation, with quite substantial standard deviations on the whole. N&N in Iran encompasses a wide range of disciplines, however due to the ever-changing nature of nanotechnology, funding is becoming available. The entry of new nano sources into other domains is, after all, inevitable. Put simply, it seems like there is a two-way street when it comes to the connections between N&N and other fields. The confluence of fundamental sciences (chemistry and physics) and engineering (materials engineering and metallurgy) has the greatest influence on the fundamental elements of N&N in Iran, while the applied aspects are also greatly affected by this convergence.

Keywords: Bibliometrics; Citation analysis; Nanoscience; Nanotechnology; Institute of Scientific Information (ISI); Iran

INTRODUCTION

Nanoscience is Using the unique properties of materials with a size smaller than 100 nanometers (nm) is known as nanotechnology, while studying materials on a far smaller scale is known as nanoscience.

Nanoscience and nanotechnology (N&N) is widely considered to be a promising area for future technological development. Because of its interconnected nature and widespread use, N&N has prompted research and discussions that go over traditional academic boundaries. Simply said, this area of study thrives when instructors and students from all walks of life collaborate, share what they've learned, and learn from one another. According to scientometric studies, the "nano" sector has seen a meteoric rise in the number of publications and journals covering the topic, with the former seeing an even more dramatic increase than the latter. So, the purpose of this research is twofold: first, to identify the academic fields that are driving N&N forward, and second, to identify the fields that are disciplinaryly most closely linked to N&N. In sectors such as N&N, where Iran was an early adopter, this will provide information on the country's research performance. We bring up these two big research questions in the hopes that they would help us understand N&N better and foretell its future in Iran by shedding light on its features and requirements:

LITERATURE REVIEW

Over the past Braun et al. (1997), Meyer and Persson (1998), and Zhou and Leydesdoff (2006) are just a few of the recent efforts to bibliometrically analyze N&N. By reviewing the scholarly articles included in the ISI databases, Guan and Ma (2007) assessed the overall progress made in this emerging area. This study compares the N&N knowledge base in China to that of four other countries: France, Germany, Japan, and the US, and it offers an integrated bibliometric analysis of this basis. On the other hand, citation studies on N&N articles are still in their infancy. Meyer (2001) investigated the connections between N&N's scientific and technological communities using citation analysis. Among his key results is that, in contrast to other areas, N&N seems to have a comparatively high amount of citations linking nano-patents with nanoscience articles.

Meyer (2003) discussed new N&N developer communities and how to record their interactions in his dissertation. His research used a number of techniques to probe the nature of the exchange mechanisms at work in this area. Specifically, patent citation analysis was used. According to several patent citation analysis formats, "nanotechnology" is a collection of science-related domains that are driven by instruments and are

progressing towards technology. The fact that there are quite substantial path-dependencies between nations and industries was another discovery.

The rapid increase in nanoscale research by scientists and engineers across many fields, nations, and organizations is a relatively new phenomenon, as stated by Schummer (2004). To determine whether this apparent concurrence was accompanied by novel forms and degrees of multi- and multidisciplinary, institutional, and geographic research cohabitation, Schummer conducted a co-author study of over 600 articles published in "nano journals" in 2002 and 2003. Furthermore, according to his argument, there is now no evidence from nanoscale studies showing

the field's apparent multidisciplinary nature was really just a collection of unconnected, mostly monodisciplinary subfields that shared nothing more than the prefix "nano"; these subfields had little in common with one another beyond that.

Utilizing two primary indicators—publications and patent applications—Heinze (2004) examined the evolution of nanotechnology in Europe and compared it to that in the US. Next, we had a look at the disciplinary and patent specialty trends in the US and Europe after providing a quick review of the global growth of nanopublications and nanopatents and the proportion of each area. By combining databases of patents and publications, Heinze developed a way to quantify the impact of public research on the nanotechnology body of knowledge. Additionally, he discovered that there are approximately 90,000 publications in the Science Citation Index (SCI) from 1996 to 2001. Of these, a third can be attributed to the member states of the European Union, 26% to the US, 13% to Japan, 7% to the ten countries that were once associated with Europe, and 22% to other nations like Russia, China, Switzerland, and Israel. Research on nanoscale phenomena was mostly concentrated in Europe, which accounted for about 40% of all scientific nanopublications published globally. The majority of nanoscience-related SCI papers were in the fields of physics, chemistry, and materials science; in contrast, publications in the fields of biology and engineering were less common. In 2003, the field of materials science ranked thirteenth globally, followed by applied physics at ten percent, physical chemistry at ten percent, the theory of condensed matter at eight

percent, and general chemistry at six percent. Between 1999–2000 and 2003, Materials Science had a growth rate of 26%, whereas Chemistry had a growth rate of 61%. Polymer Science, Metallurgical Engineering, Chemical Engineering, and Applied Chemistry are the fastest-growing subfields, with rates of 35%, 29%, 29%, and 24%, respectively.

METHODS AND MATERIALS

The statistical population for this work is the 5767 citations of all 234 papers authored by Iranian authors indexed by the Institute for Scientific Information (ISI) and retrieved in 2008. These papers are available in the Web of Science's Science Citation Index. Except for 59 citations of which their bibliographic information could not be located, the remaining are citations classified into subjects using the online UNESCO thesaurus (http://databases.unesco.org/thesaurus/). The first step is to place the subjects into two main classes – "nano" and/or "non-nano". Three major subject domains in the UNESCO thesaurus are used, namely Science, Information and Communication, and Politics, Law and Economics.

Considering that there is no N&N thesaurus to date of this work, the presence of nano term in the title of a citation qualifies that the item is placed in the nano subject classification. The next step is the determination of related disciplines with N&N. Despite the fact that education and training of N&N are conducted at departments associated with basic sciences and engineering at the graduate level in Iran, the authors place N&N as a single discipline named Nanoscience and Technology to reflect generation of a new knowledge. All the retrieved items (citations) are presented into spreadsheet application software for statistical analysis.

FINDINGS

All 234 Iranian papers on N&N indexed in the ISI database, from 1995 (the first paper published) till 2008, are presented in Figure 1. This clear increasing trend, from 1 paper in 1995 to 94 papers in 2007, is indicative of the concentration of Iranian researchers to the emerging field of N&N in recent years. The acquired citations of these papers (5767) are depicted in Figure 2. The analyses are presented by types of publications, subject fields and related disciplines, in the following sub-sections.

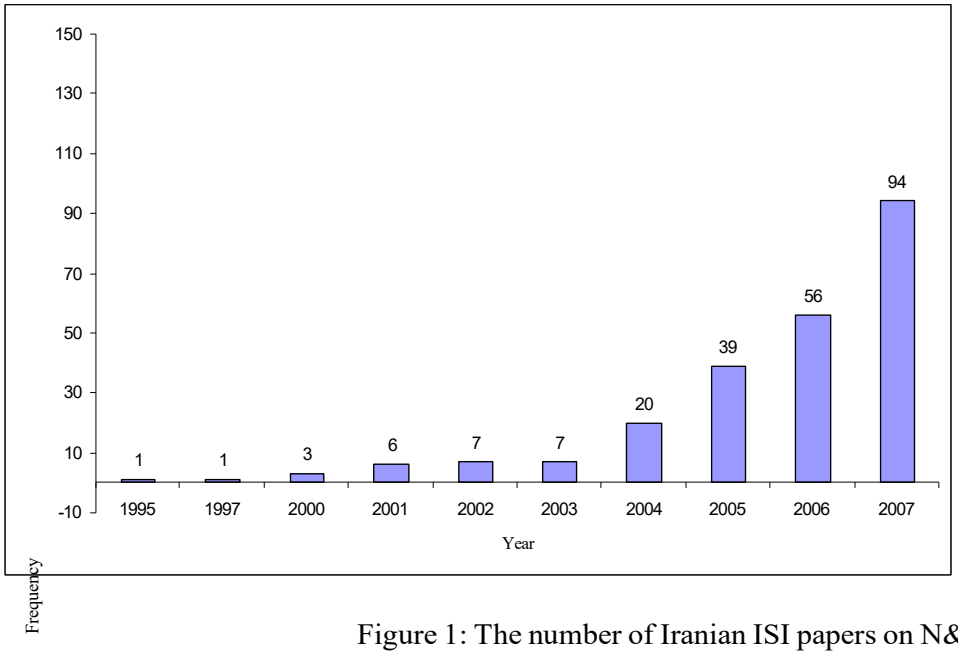

Figure 1: The number of Iranian ISI papers on N&N (n=234)

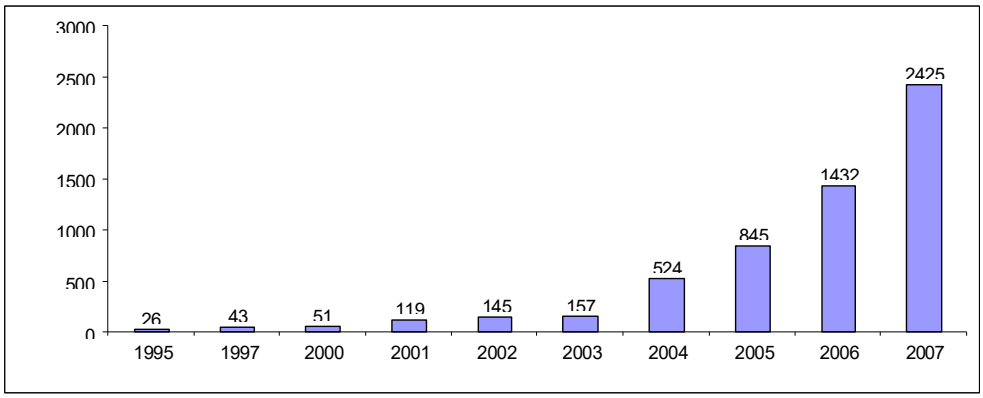

Figure 2: The number of citations of Iranian ISI papers on N&N (n=5767)

Types of publications

Figure 3 depicts the types of publications for all N&N citations output of Iranian researchers. The divergences in types of publications appear as journal paper (89.65%), conference papers (4.14%), book (3.53%), thesis and dissertation (0.75%), patent (0.38%), and miscellaneous (such as site and technical reports – 0.21%). A total of 1.35% publication could not be ascertained of its types. The difference between the minimum and maximum numbers of publication types is significant. With about 90%, journal papers have the most roles in the N&N citations. Books as one of the most secondary resources are cited after 2003. Interestingly, in the 2007 citation, books grow to 6.31%, following journal papers with a citation of about 87%. The overall statistical data is presented in Table 1.

Table 1: Types of Iranian ISI publications on N&N

Year / Type of documents	1995 n	%	1997 n	%	2000 n	%	2001 n	%	2002 n	%	2003 n	%	2004 n	%	2005 n	%	2006 n	%	2007 n	%	Total	Percentage	Average	Standard deviation
Paper	23	88.46	42	97.67	50	98.04	110	92.44	135	93.10	136	86.62	477	91.03	796	94.20	1280	89.39	2121	87.46	5170	89.65	517	661.70
Conference	2	7.70	0	0	0	0	5	4.20	5	3.45	16	10.19	27	5.15	28	3.31	63	4.40	93	3.84	239	4.14	23.9	30.40
Book	0	0	0	0	0	0	0	0	0	0	1	0.64	3	0.57	7	0.83	39	2.72	153	6.31	203	3.52	20.30	45.68
Thesis	1	3.84	1	2.32	1	1.96	2	1.68	2	1.38	1	0.64	7	1.34	5	0.59	11	0.77	12	0.49	43	0.75	4.30	4.00
Patent	0	0	0	0	0	0	0	0	1	0.69	0	0	5	0.95	5	0.59	5	0.35	6	0.25	22	0.38	2.20	2.52
Misc*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	11	0.45	12	0.21	1.20	3.28
Unclear	0	0	0	0	0	0	2	1.68	2	1.38	3	1.91	5	0.95	4	0.47	33	2.30	29	1.20	78	1.35	7.80	11.74
Total	26	100	43	100	51	100	119	100	145	100	157	100	524	100	845	100	1432	100	2425	100	5767	100	-	-

* Miscellaneous

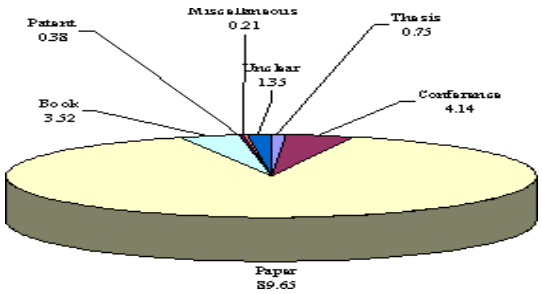

Figure 3: Distribution of types of publications for Iranian ISI papers on N&N

Table 2 shows the types of publications specified by subject fields. Except for two subject fields including agriculture and hydrology, the remaining cites journal papers more.

Table 2: Types of publications for Iranian ISI papers on N&N by subjects

Type of publication	Book	Paper	Thesis	Conference	Patent	Miscellaneous	Unclear	Total
Agriculture	1	0	0	0	0	0	0	1
Hydrology	1	0	0	0	0	0	0	1
Civil, Militry & Mining Eng.	0	3	0	0	0	0	0	3
Information Technology(Software)	0	5	0	1	0	0	0	6
Equipment & Facilities	1	12	0	0	0	0	0	13
Information Technology(Hardware)	3	34	0	4	0	0	0	41
Medical Sciences	2	62	0	0	0	0	0	64
Mathematics & Statistics	8	67	0	1	0	0	11	87
Materials & Products	15	73	0	1	1	2	3	95
Natural Sciences	1	115	1	0	0	0	0	117
Nano	13	750	1	4	1	0	1	770
Chemical Sciences	18	823	1	4	2	0	0	848
Physical Sciences	21	833	3	6	1	1	0	865
Manufacturing & Transport Eng.	119	2393	37	218	17	9	4	2797
With no Subject	0	0	0	0	0	0	59	59
Total	203	5170	43	239	22	12	78	5767

Table 3 shows the frequency of types of publications merely in the N&N subject field during the period under study. Citations to books in recent years (2006 – 2007) for N&N imply the advance and independence of this emerging field of science and technology. On the other hand, many nano conferences and

workshops in various countries made seminars as a significant type of publications in N&N. In contrast, citation to patents appears negligible despite the technological aspects of N&N. One can see, the more frequency of nano citations, the more are the types of documents during the time of study.

Frequency

Table 3: The number of types of publications for Iranian ISI papers on N&N during the time of study

Type of publication Year	Book	Paper	Thesis	Conference	Patent	Unclear	Total
1995	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
2001	0	3	0	0	0	0	3
2002	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0
2004	0	29	0	0	0	0	29
2005	0	84	0	0	0	0	84
2006	4	242	0	0	0	0	246
2007	9	392	1	4	1	1	408
Total	13	750	1	4	1	1	770

Subject fields

Table 4 and Table 4 and Figure 4 show the different domains of subjects covered by Iranian-authored N&Ns over the time period studied. As 2007 draws to a close, it becomes clear that fourteen distinct academic disciplines in Iran have laid the groundwork for N&N. Manufacturing and transport engineering and physical sciences appear to have made the most contribution to the interdisciplinary aspects of N&N as of the end of 2005, out of the four (4) top subject fields in N&N in Iran (chemical sciences, nano, physical sciences, and manufacturing and transport engineering). The growth of chemistry as a distinct academic discipline in Iran in 2006 and 2007 likely explains why it surpassed physical sciences in that year. From 1995 to 2007, manufacturing and transport engineering accounted for 48.5% of all citations, followed by physical sciences at 15%, chemical sciences at 14.7%, and nano at 13.3%.

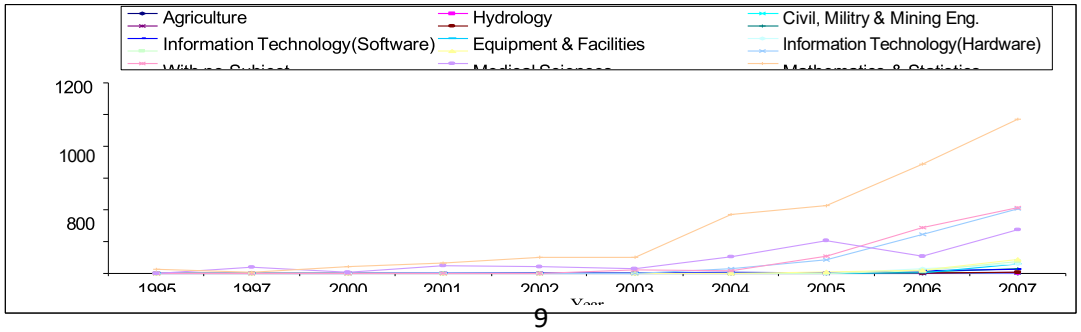

Figure 4: Distribution of subject fields of Iranian ISI papers on N&N during the time of study

Related disciplines

Table 5 displays all the disciplines participating in N&N ISI publications of Iran during the time of study. The discipline "nano" is deliberately removed from Table 5 to show the other disciplines involved in the mentioned N&N ISI publications. Among the 25 disciplines involved, metallurgy (with 28.01%) leads the contribution to Iranian ISI publications on N&N, followed by physics (17.33%) and materials engineering (16.48%). Although nano is a novel science with many fundamental and basic research questions, the high contributions of engineering subfields point to an increasing attention to more applied problems within the nano community. The comparison between citations to the nano (N&N) texts and other disciplines is presented in Figure 5. It seems that in recent years (2005-2007), the dynamic and self-motivated nature of nano has made it independent and led the provision of basic information in itself. In other words, nano as a field of study might gradually not require or depend on other scientific fields or outputs for advancement.

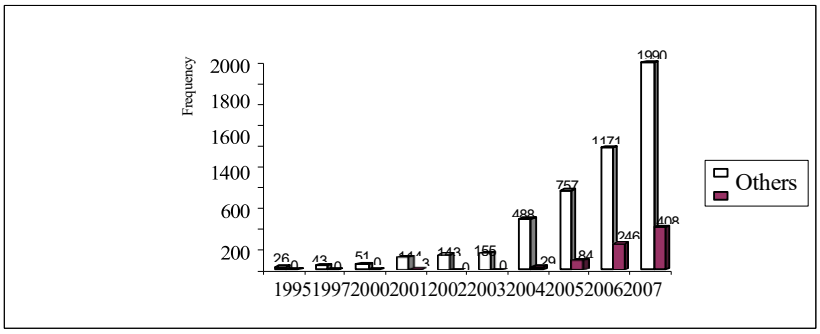

Figure 5: The comparison between citations to the nanoscience and nanotechnology (N&N) texts and other disciplines

DISCUSSION

The main goal of this research is the investigation of interactions of a novel discipline during its evolution time. The first Iranian ISI nano output was published in 1995 and after that an increasing trend occurs in the frequency of papers and their citations with 96 papers published and 2425 citations received in 2007. Due to the multidisciplinary nature of N&N, in response to the first research question concerning the subject fields that act as the dominant driving forces in advancing the development of

N&N in Iran, manufacturing and transport engineering, physical sciences and chemical sciences appear to be the main ones among the 14 subject fields identified. As anticipated, the lack of citations to nano subject field before 2001 is related the novelty and/or insufficiency of nano sources. As the frequency and types of sources grow in the nano fields (after 2004), one can see its independency and uniformity and in turn citations to nano itself. On the other hand, in recent years with growing attitude on the knowledge of N&N for other subject fields, the interactions and cooperation among related subject fields increase (e.g. materials and products, equipment and facilities and natural sciences after 2005 as well as medical sciences, mathematics and statistics after 2006 involved in N&N as an emerging subject field).

In response to the second question on the areas most closely related to N&N that act as the driving force from other disciplines, findings of this study showed that about 86% of citations are pertained to the other disciplines sources. Basically, 25 disciplines take part in the construction of nano foundations. The first Iranian ISI paper on nano cited only two disciplines namely metallurgy and materials engineering. This situation is gradually changed with the increasing of divergence of disciplines encountered in N&N in the subsequent years. Consequently, while N&N in Iran is a multidisciplinary field, the dynamic nature of nano causes it to afford the sources for itself, gradually. Besides, it is

nano sources enter in the non-nano fields in the years that follow. In other words, the relationships among N&N and other disciplines appear mutually. Finally, it seems that in outlining the perspectives of N&N in Iran, the convergence between basic sciences (physics and chemistry) and engineering (materials engineering and metallurgy) have the highest impacts on their fundamental and applied aspects, respectively.

CONCLUSION

This study is based on a citation analysis of Iranian ISI papers on nanoscience and nanotechnology (N&N). The number of publications ranges from 1 paper in 1995 (with 26 citations) to 94 papers in 2007 (with 2425 citations). Journal papers have the most impacts on the N&N citations. Citation to books after 2003 is an indicative of N&N evolution during the time. In the period of study, 14 different subject fields containing 25 disciplines contribute in the foundations of N&N. The four (4) top subject fields in N&N are manufacturing and transport engineering (with 48.5% of all citations), physical sciences (15%), chemical sciences (14.7%), and nano (13.3%). On the other hand, metallurgy (28.01%), physics (17.33%) and materials engineering (16.48%) appear as the top three disciplines participating in N&N publications. While N&N in Iran is a multidisciplinary field, the dynamic nature of nano causes it to afford the sources for itself gradually; and it is inevitable that the relationships among N&N and other disciplines appear to be mutually. In general, the standard deviations of the data in this work are fairly large, indicating considerable variability among them.

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