

Mapping the Iranian ISI papers on Nanoscience and Nanotechnology: a citation analysis approach

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ABSTRACT

To clarify the interdisciplinary relationships of Iranian ISI papers on nanoscience and nanotechnology (N&N) and scheme its development pattern, a detailed citation analysis study was conducted. An increasing trend of publications from 1 paper in 1995 (with 26 citations) to 94 papers in 2007 (with 2425 citations) is obtained. With about 90%, journal papers have the most impacts on the N&N citations. Citation to books after 2003 is an indicative of N&N evolution. To the end of 2007, 14 different subject fields containing 25 disciplines contribute in the foundations of N&N. The 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%). Alternatively, metallurgy (with 28.01%), physic (17.33%) and materials engineering (16.48%) appear as the top three disciplines. In general, the standard deviations of the data are fairly large, indicating considerable variability among them. While N&N in Iran is a multidisciplinary field, the dynamic nature of nano causes to afford sources itself gradually. Besides, it is inevitable that novel nano sources enter in other fields in the future. In other words, the relationships among N&N and other disciplines appear mutually. Finally, in the outlining perspectives of N&N in Iran, the convergence of basic sciences (physics and chemistry) and engineering (materials engineering and metallurgy) have the highest impacts on their fundamental and applied aspects, respectively.

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

INTRODUCTION

Nanoscience is the field of study of nanoscale materials and nanotechnology is the exploitation of strange properties of materials smaller than 100 nanometers (nm) to create useful objects.

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Nanoscience and nanotechnology (N&N) have been identified by many as a key future technology area. The widespread nature of N&N and its close interaction with other sciences as well as technologies have stimulated interdisciplinary researches and communications. In other words, this scientific discipline only thrives in a collaborative environment where faculty and students from different disciplines discuss ideas, collaborate and share their expertise.

Scientometrics studies have shown an explosion in the “nano” area with the immense increase in the number of publications and the number of related journals, commensurate with this increasing number of publications. The present work hence attempts to (a) identify the subject fields that are the dominant driving forces in advancing the development of N&N, and (b) determine the areas most closely related to N&N as the driving force from other disciplines. This will provide a clear picture of Iran’s research performance as an early entered nation into critical technologies such as N&N. Hoping that this study provides additional perspective on the nature and requirements of N&N as the basis for anticipating its future developments in Iran, two substantial research questions are posed:

- a) What are the subject fields that act as the dominant driving forces in advancing the development of N&N?
- b) What are the areas most closely related to N&N that act as the driving force from other disciplines?

LITERATURE REVIEW

Over the past few years, several attempts have been made to study N&N in a bibliometric manner (Braun et al. 1997; Meyer and Persson 1998; and Zhou and Leydesdoff 2006]. Guan and Ma (2007) analysed the overall development in this novel field by studying the scientific publications indexed by ISI databases. It provides an integrated bibliometric study of the knowledge base of N&N in the Chinese research community, including comparisons with four other nations: namely France, Germany, Japan, and the United States. However, little citation analyses have been reported on N&N publications up to now. Meyer (2001), using citation analysis, explored the interrelationships between science and technology in N&N. His main findings are that there were only a small number of citations connecting nano-patents with nanoscience papers, while N&N appeared to be relatively well connected in comparison with other fields.

Meyer (2003) in his dissertation addressed emerging developer communities in N&N as well as methods to capture exchange processes between them. To explore exchange processes in this field, his study applied various methods. In particular, it used patent citation analysis. Various formats of patent citation analysis described "nanotechnology" as a set of instrument-driven scientific fields on their way towards science-related technologies. Another finding was that both countries and industries exhibit relatively strong path-dependencies.

Schummer (2004) described the recent development that scientists and engineers of many disciplines, countries, and institutions increasingly engage in nanoscale research at breathtaking speed. By co-author analysis of over 600 papers published in "nano journals" in 2002 and 2003, Schummer investigated if this apparent concurrence was accompanied by new forms and degrees of multi- and interdisciplinary as well as of institutional and geographic research cohabitation. Moreover, he argued that current nanoscale research reveals no particular

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patterns and degrees of interdisciplinary and that its apparent multidisciplinary consisted of different largely mono-disciplinary fields which were rather unrelated to each other and which hardly shared more than the prefix "nano".

Heinze (2004) analyzed the development of nanotechnology in Europe and made comparisons with the United States by studying two basic indicators: publications and patent applications. After a brief overview of the worldwide expansion of nanopublications and nanopatents as well as the share of different regions, disciplinary and patent specialization patterns of both Europe and the United States were examined. Heinze provided a methodology for measuring the contribution of the public research sector to the knowledge base in nanotechnology by linking patent and publication databases. Also, he found that between 1996 and 2001, there are about 90,000 worldwide publications in the Science Citation Index (SCI), a third of which can be attributed to the European Union Member States, 26% to the United States, 13% to Japan, 7% to the ten formerly associated European countries and 22% to other countries including Russia, China, Switzerland and Israel. With about 40% of all scientific nanopublications worldwide, Europe was a major player in the international research community on nanoscale phenomena. Within nanoscience, physics, chemistry and materials science made up the bulk of SCI publication, whereas publications in biology and the engineering sciences were less frequent. It was found that the following areas are the world wide top 5 SCI subdisciplines in 2003: Materials Science (13%), Applied Physics (10%), Physical Chemistry (10%), Physics of Condensed Matter (8%) and General Chemistry (6%). The growth rates in Materials Science and Chemistry were 26% and 61% respectively between 1999-2000 and 2003. Expanding subfields are Polymer Science (growth rate of 35%), Metallurgical Engineering (29%), Chemical Engineering (29%) and Applied Chemistry (24%).

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.

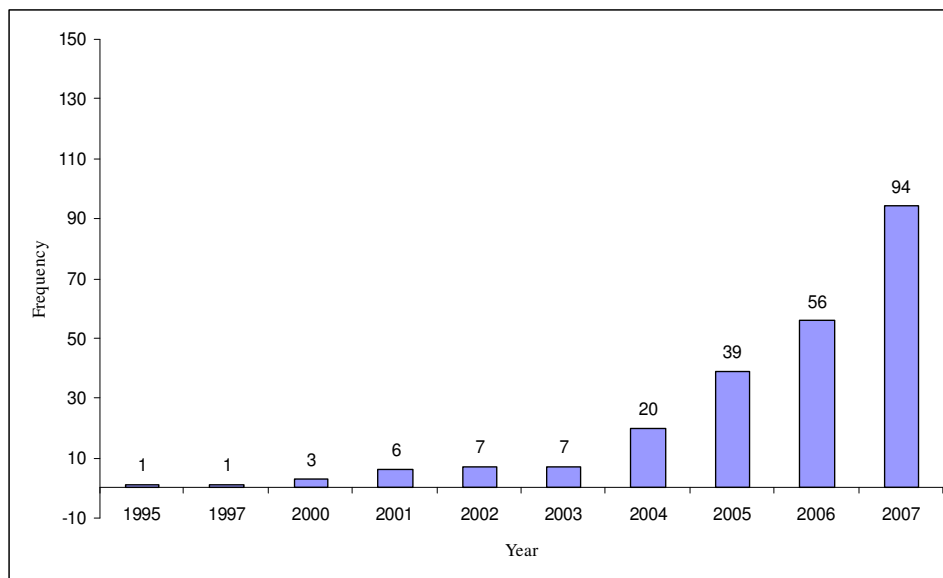


Figure 1: The number of Iranian ISI papers on N&N (n=234)

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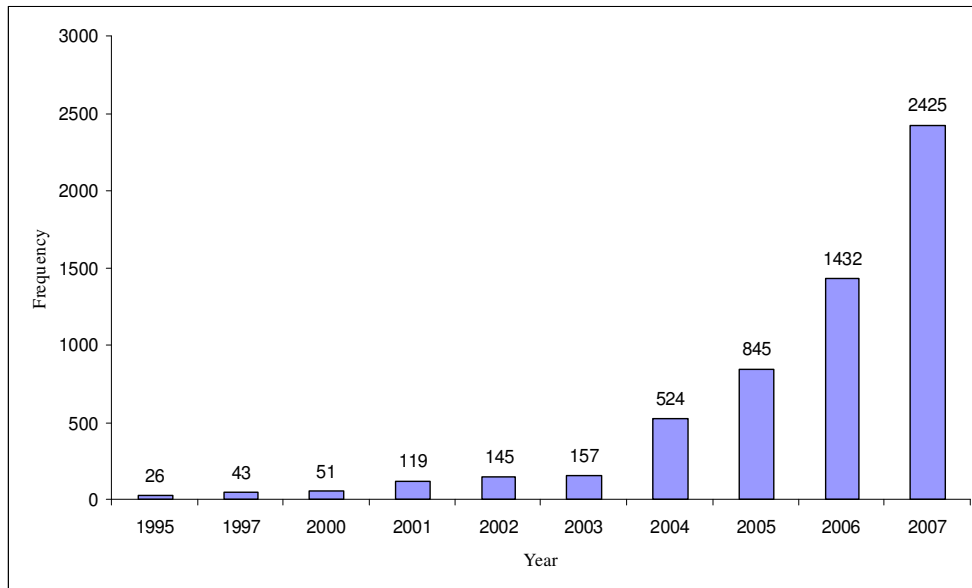


Figure 2: The number of citations of Iranian ISI papers on N&N (n=5767)

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		1997		2000		2001		2002		2003		2004		2005		2006		2007		Total	Percentage	Average	Standard deviation
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%						
Paper	23	88.46	42	97.67	50	98.04	110	92.44	135	93.10	136	86.62	177	91.03	196	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

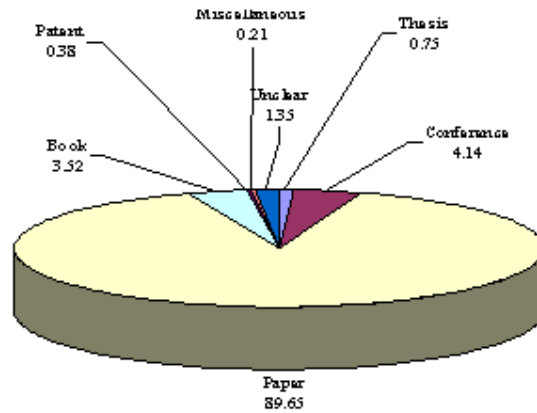


Figure 3: Distribution of types of publications for Iranian ISI papers on N&N

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 Subject field	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, Military & 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

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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.

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

Type of publication	Book	Paper	Thesis	Conference	Patent	Unclear	Total
Year							
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 Figure 4 demonstrate various subject fields in the N&N authored by Iranians during the period under study. In the end of 2007, it appears fourteen different subject fields contribute in the foundations of N&N in Iran. Among the four (4) top subject fields in N&N in Iran (manufacturing and transport engineering, physical sciences, chemical sciences, and nano), it appears that manufacturing and transport engineering as well as physical sciences have the most contribution in the interdisciplinary aspects of N&N, to end of 2005. However in 2006 and 2007, chemical sciences took over physical sciences probably due to the development of chemistry as a field of research in Iran compared to the other subject fields. For the overall ordering during the period of 1995-2007, about 48.5% of all citations are attributed to manufacturing and transport engineering, 15% to physical sciences, 14.7% to chemical sciences and 13.3% to nano.

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

Year Subject field	1995		1997		2000		2001		2002		2003		2004		2005		2006		2007		Total	Percentage relative frequency	Average	Standard deviation
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%						
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	0	0	1	0.02	0.1	0.31
Hydrology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	0	0	1	0.02	0.1	0.31
Civil, Military & Mining Eng.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	3	0.12	3	0.05	0.3	0.90
Information Technology (Software)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	6	0.25	6	0.10	0.6	1.78
Equipment & Facilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.12	4	0.28	8	0.33	13	0.23	1.3	2.54
Information Technology (Hardware)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0.77	30	1.24	41	0.71	4.1	9.21
With no Subject	0	0	0	0	0	0	2	1.68	2	1.38	2	1.27	7	1.34	4	0.47	15	1.05	27	1.11	59	1.02	5.9	8.24
Medical Sciences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.28	60	2.47	64	1.11	6.4	17.91
Mathematics & Statistics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	1.95	59	2.43	87	1.51	8.7	18.73
Materials & Products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.12	18	1.26	76	3.13	95	1.65	9.5	22.80
Natural Sciences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1.30	19	1.33	87	3.59	117	2.03	11.7	25.84
Nano	0	0	0	0	0	0	3	2.52	0	0	0	0	29	5.53	84	9.94	246	17.17	408	16.82	770	13.35	77.0	132.51
Chemical Sciences	0	0	0	0	0	0	0	0	0	0	22	14.01	15	2.86	109	12.90	289	20.17	413	17.03	848	14.70	84.8	139.55
Physical Sciences	0	0	38	88.37	8	15.69	50	42.02	41	28.28	31	19.75	104	19.85	208	24.62	109	7.61	276	11.38	865	15.00	86.5	86.00
Manufacturing & Transport Eng.	26	100	5	11.63	43	84.31	64	53.78	102	70.34	102	64.97	369	70.42	427	50.533	687	47.94	972	40.08	2797	48.50	279.7	313.11
Total	26	100	43	100	51	100	119	100	145	100	157	100	524	100	845	100	1433	100	2425	100	5767	100.00		

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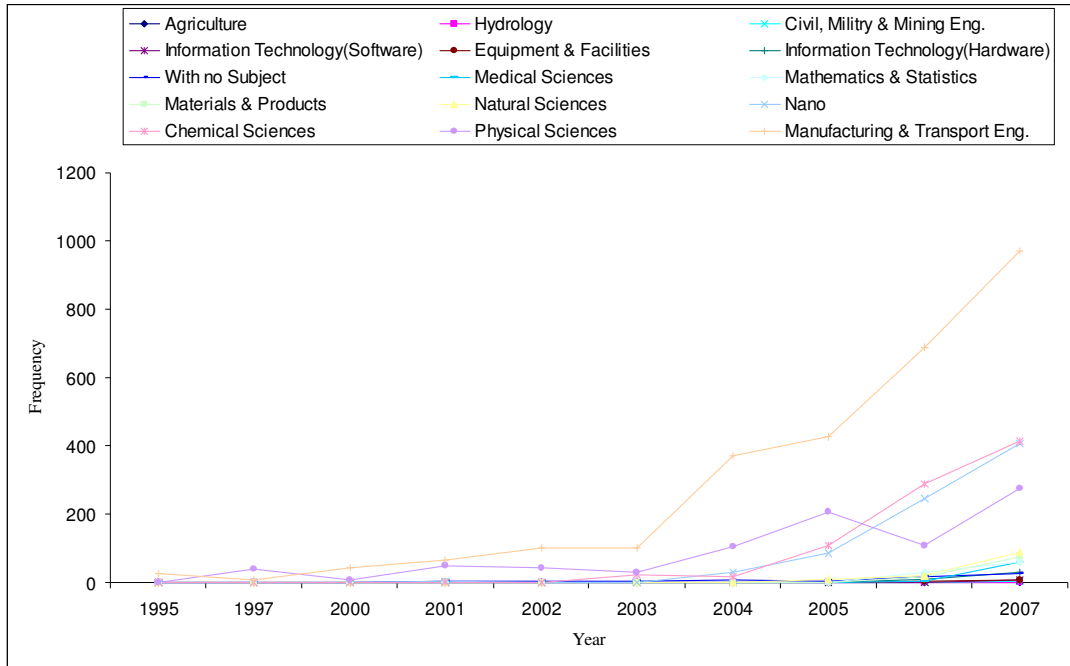


Figure 4: Distribution of subject fields of Iranian ISI papers on N&N during the time of study

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.

Table 5: All disciplines participating in N&N of Iran in the time of study

Year Discipline	1995		1997		2000		2001		2002		2003		2004		2005		2006		2007		Total	Percentage relative frequency	Average	Standard deviation
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%				
Analytical Chemistry	0	0	0	0	0	0	0	0	0	0	2	1.27	0	0	1	0.12	84	5.87	58	2.39	145	2.51	14.50	28.84
Physical Chemistry	0	0	0	0	0	0	0	0	0	0	20	12.74	0	0	23	2.72	31	2.16	140	5.77	214	3.71	21.40	41.12
Organic Chemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0.59	34	2.37	108	4.45	147	2.55	14.70	32.68
Inorganic Chemistry	0	0	0	0	0	0	0	0	0	0	0	0	1	0.19	76	8.99	121	8.45	63	2.60	261	4.53	26.10	41.91
Applied Chemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0.16	4	0.07	0.40	1.20
Mathematics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	1.89	59	2.43	86	1.49	8.60	18.62
Statistics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	1	0.04	2	0.03	0.20	0.40
Biochemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0.63	26	1.07	35	0.61	3.50	7.96
Biophysics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1.30	1	0.07	60	2.47	72	1.25	7.20	17.89
Biology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0.63	1	0.04	10	0.17	1.00	2.68
Physics	0	0	38	88.37	8	15.69	50	42.02	41	28.28	31	19.75	104	19.85	209	24.73	98	6.84	277	11.42	856	14.84	85.60	86.14
Electrooptic Engineering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	1.54	16	0.66	38	0.66	3.80	7.71
Computer Engineering (Hardware)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.21	20	0.82	23	0.40	2.30	5.96
Computer Engineering (Software)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0.25	6	0.10	0.60	1.8
Metallurgy	7	26.92	0	0	0	0	28	23.53	63	43.45	33	21.02	250	47.71	284	33.61	286	19.97	432	17.81	1383	23.98	138.30	150.39
Material Sciences	19	73.08	5	11.63	30	58.82	25	21.01	37	25.52	62	39.49	49	9.35	84	9.94	158	11.03	345	14.23	814	14.11	81.40	97.11
Polymer Engineering	0	0	0	0	0	0	0	0	0	0	0	0	14	2.67	4	0.47	20	1.40	40	1.65	78	1.35	7.80	12.66
Electrical & electronic Engineering	0	0	0	0	13	25.49	7	5.88	2	1.38	7	4.46	62	11.83	48	5.68	228	15.92	232	9.57	599	10.39	59.90	87.37
Chemical Engineering	0	0	0	0	0	0	0	0	0	0	0	0	8	1.53	1	0.12	22	1.54	24	0.99	55	0.95	5.50	9.06
Mechanic Engineering	0	0	0	0	0	0	4	3.36	0	0	0	0	0	0	11	1.30	10	0.70	15	0.62	40	0.69	4.00	5.49
Civil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	3	0.12	4	0.07	0.40	0.91
Medical Biochemistry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.14	2	0.08	4	0.07	0.40	0.80
Pharmacy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.14	58	2.39	60	1.04	6.00	17.34
Entomology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	0	0	1	0.02	0.10	0.30
Agriculture Engineering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.07	0	0	1	0.02	0.10	0.30
N&N	0	0	0	0	0	0	3	2.52	0	0	0	0	29	5.53	84	9.94	246	17.18	408	16.82	770	13.35	77.00	132.51
Unclear	0	0	0	0	0	0	2	1.68	2	1.38	2	1.27	7	1.34	4	0.47	15	1.05	27	1.11	59	1.02	5.90	8.26
Total	26	100	43	100	51	100	119	100	145	100	157	100	524	100	845	100	1432	100	2425	100	5767	100.00		

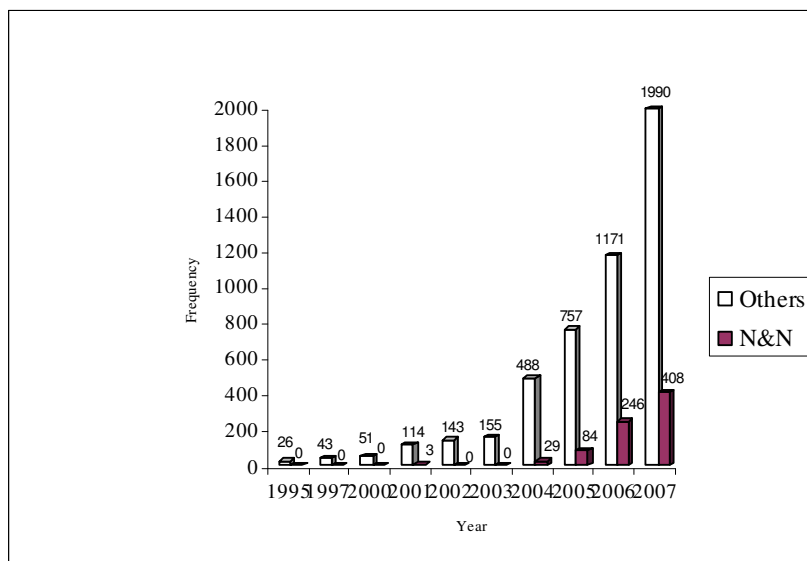


Figure 5: The comparison between citations to the nanoscience and nanotechnology (N&N) texts and other disciplines

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 inevitable that novel

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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