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The Growth and Interdisciplinary Patterns of Nanoscale Research in Iran

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Abstract

Based on citation analysis, this work describes the growth and interdisciplinary patterns of nanoscale research in Iran. It covers all the Iranian ISI papers on nanoscience and nanotechnology indexed in the ISI databases in 2008 and surveys the corresponding data from the beginning to 2007. Moreover, in an international context, a brief comparison is made between our data and those of other countries. A substantial annual growth rate is obtained for the number of publications and their corresponding citations. By the end of 2008, eighteen different subject fields including thirty-eight disciplines comprised the foundations of nanoscale research. The topmost subject field is chemical sciences and the topmost discipline appears to be physics. Hence, nanoscale research in Iran is a multidisciplinary and interdisciplinary endeavor (through a convergence among basic sciences and engineering) that pervades among other subject fields and/or disciplines starting with materials and physics and later extending to chemistry and other areas. In an interdependent context, this is possibly due to the dynamic nature and potentials of nanoscience and nanotechnology. In general, nanoscale research in Iran resembles the overall worldwide nanopublication patterns excepting the rather greater concentration on the scientific over the technology orientations.

Keywords: Nanoscale Research, Citation Analysis, ISI, Iran, Interdisciplinary, Multidisciplinary.

Introduction

Nanoscale research is related to materials, devices and structures smaller than 100 nanometers (nm). Research in nanoscale phenomena has increased over the last decade across the world. Both the fundamental understanding of structures and processes at the atomic and molecular scale (nanoscience) and the utilization and control on nanoscale phenomena for specific purposes (nanotechnology), have flourished considerably in recent years.

In this newly emerging field of science and technology, there are many unanswered questions concerning scientometrics. One of the most important questions is the degree of integration or scattering of nanoscale field which can be answered by the examination of bibliometric networks. Accordingly, the present work mainly deals with this question based on the analysis of citations for the international nanopublications in Iran. In general, publications are taken as a proxy for basic research and scientific orientation, and patent applications as a proxy for applied research and technology orientation. However, the proper definition of the fields of science and technology for their analyses is challenging.

Review of Literature

Recent scientometric studies have shown that nanoscale research is a fast growing field and many articles are annually published in this field which cover different multidisciplinary and interdisciplinary issues (Braun 1997, Hullmann 2003). It is worth noting that in 2007, scientometrics devoted a special issue to nanoscale research.

Meyer (2001) explored the interrelationships between science and technology in nanoscience and nanotechnology. He found that there were only a small number of citations connecting nano-patents with nanoscience papers, while nanoscience and nanotechnology appeared to be relatively well connected in comparison with other fields.

Schummer (2004) applied the co-author analysis to over 600 papers published in "nano journals" in 2002 and 2003. He found that current nanoscale research reveals no particular patterns or degrees of interdisciplinary and that it is apparently multidisciplinary consisting 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. After a brief overview of the worldwide expansion of nanopublications and nanopatents and the share of different regions, the disciplinary and patent specialization patterns of Europe and the United States were examined. 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 publications, whereas publications in biology and the engineering sciences were less frequent. Among the worldwide top 5 SCI subdisciplines in 2003, he found materials science (13%), applied physics (10%), physical chemistry (10%), physics of condensed Matter (8%) and general chemistry (6%). The growth rates in materials science were 26% between 1999-2000 and 2003, and 61% in chemistry. Expanding subfields were polymer science (35%), metallurgical engineering (29% growth), chemical engineering (29%) and applied chemistry (24%).

Bassecoulard (2007) presented a citation-based mapping exercise in the nanoscience field as well as a first sketch of citation transactions (a measure of cognitive dependences).

The structural analysis of the list of references in papers suggested that the moderate multi-disciplinary, observed at the aggregate level, partly stemed from an actual interdisciplinary at the paper level.

Schummer (2007) reported the disciplinary involved in the institutionalization of nanotechnology researches at universities in the period 1992-2006. At the beginning, merely electrical engineering and physics departments were involved, but gradually the involvement of biomedicine, mechanical engineering, chemistry, and materials science were observed, respectively. In 2006, the order of disciplines appeared as: chemistry, physics, electrical engineering, materials science, mechanical engineering and biomedicine.

Very recently, Baradar (2009) reported the mapping of nanoscience and nanotechnology in Iran by citation analysis of ISI papers during 1995-2007. A clear growth in the number of publications was observed from 1 in 1995 to 94 in 2007. While journal papers had the most impact on the nanoscale research citations, reference to books began after 2003. By the end of 2007, 14 different subject fields containing 25 disciplines contributed to nanoscience and nanotechnology of Iran. The 4 top subject fields in nanoscience and nanotechnology were manufacturing and transport engineering, physical sciences, chemical sciences and nano, respectively. Similarly, metallurgy, physics and materials engineering appeared as the top three disciplines in the Iranian nanoscale research.

Procedure

The statistical population for this study is the 3375 citations of 136 papers published by Iranian authors in nanoscience and nanotechnology indexed by Institute for Scientific Information (ISI) in the year 2008. The citations are classified into subjects using online UNESCO thesaurus, second edition 2003. All the subjects are placed in the two main classes "nano" and "non-nano".

It is worth mentioning that the presence of the prefix "nano" in the title of a citation qualifies that the item is placed in the nano subject classification. The three subject domains of UNESCO thesaurus which were met are science, information and communication, and politics, law and economics. In the next step, the related disciplines contributing to nano are determined. To show the generation of a new knowledge, we deliberately placed nanoscience and nanotechnology in a unitary discipline. This is despite the fact that in Iran education and training of nano are conducted at two different university departments associated with basic sciences and engineering at the graduate level. For statistical analysis, all the retrieved citations were presented into the spreadsheet application software.

Findings

Nanopublication Growth and Types

Figure 1 shows the number of Iranian publications and their corresponding citations on nanoscience and nanotechnology in the ISI databases per year for the period 1995-2008. The results cover a 14 year time window. Despite the slow growth pattern at earlier years, the annual growth rate of 44% in 2008 is compatible with the explosive worldwide nanopublications (Schummer, 2007). Commonly, the growth is more pronounced after 2003.

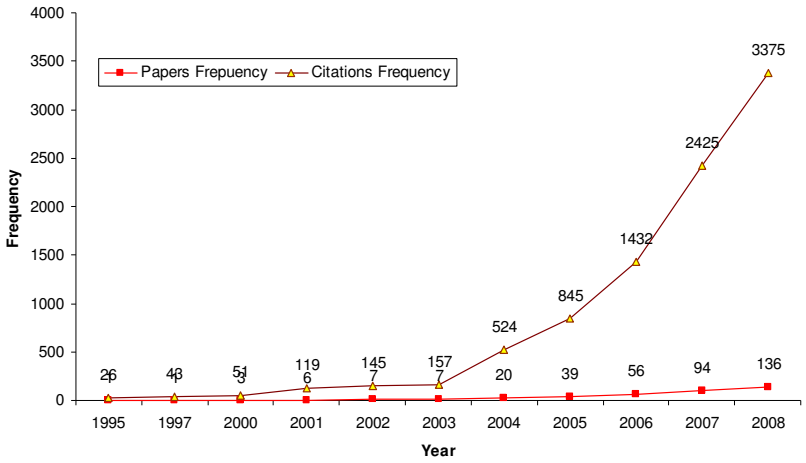

Figure 1. The number of nanopublications and corresponding citations per year.

Various types of publications for citations of Iranian ISI papers on nanoscience and nanotechnology appear as journal paper, thesis and dissertation, book, conference, patent, unclear and miscellaneous (site, technical reports…) (Figure 2).

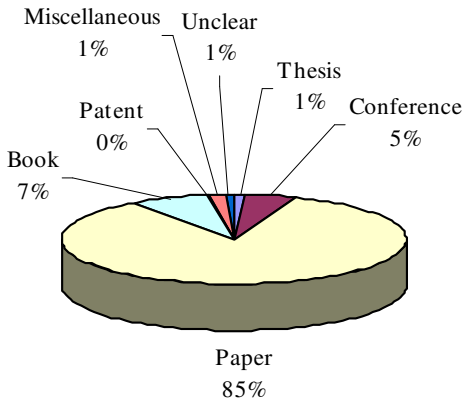

Figure 2. Types of publications for Iranian nanopublications citations in 2008.

Of these citations, 85% are journal papers while books, as a secondary resource, follow with a share of only 7%. Another notable fact in this Figure is the negligible share of

citations to patents as an indicator of technological innovations. In other words, nanosclae researches in Iran have emphasized the nanoscience aspects rather than nanotechnology hitherto.

Subject fields and related disciplines

Previous study by Baradar (2009) has classified Iranian nanopublications into subjects and disciplines from the beginning to 2007. The increasing trend of subject fields and disciplines in the development of nanoscale research in Iran is also continued in 2008. To the end of 2008, eighteen different subject fields had a share in the foundations of nanoscale research in Iran (Figure 3). Compared with the report in 2007, four subject fields including industry, earth sciences, information sciences and organization & management are added to the fields of nanoscale research in Iran while the subject field of hydrology is deleted. The 4 top subject fields are chemical sciences, manufacturing and transport engineering and physical sciences, respectively. Interestingly, this order is different from that reported for the period 1995-2007. The preference of chemical sciences over manufacturing & transport engineering in the interdisciplinary aspects of nanoscale research in Iran is also different from many other countries indicating the advancement of chemical researches in Iran compared to the other fields.

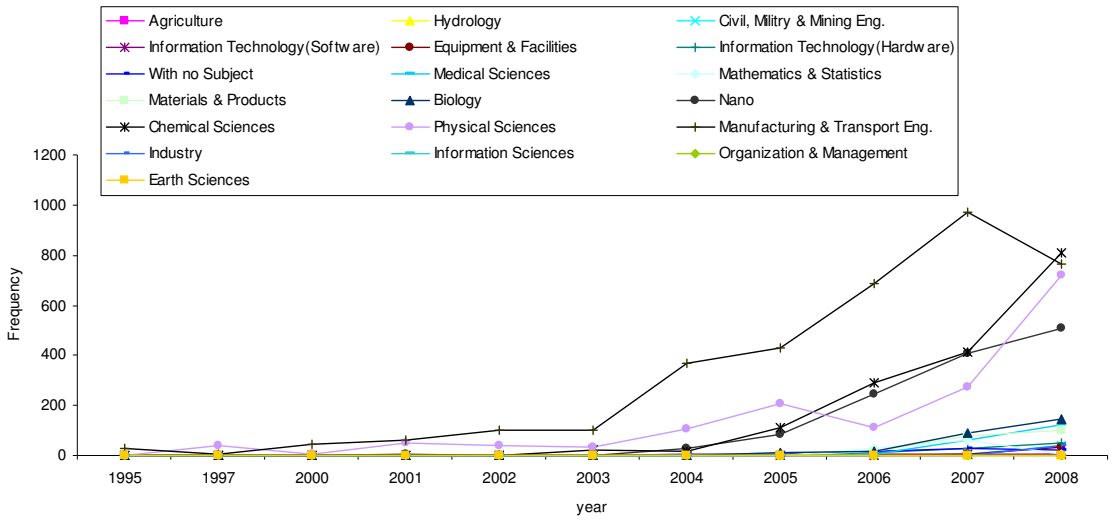

Figure 3. Diversity in the subject fields of Iranian nanopublications per year.

Of the disciplines involved in the nanoscale research of Iran up to 2008, (excluding the discipline "nano" itself for showing the effect of other disciplines), 38 are listed as follows (Table 1).

Table 1

Disciplines involved in Iranian nanopublications in 2008

Discipline	Frequency	Percentage relative frequency
Physics	699	20.71
Nano	509	15.08
Metallurgy	382	11.32
Analytical Chemistry	299	8.86
Material Sciences	233	6.90
Polymer	144	4.27
Inorganic Chemistry	136	4.03
Physical Chemistry	120	3.56
Organic Chemistry	91	2.70
Chemical Engineering	91	2.70
Biology	80	2.37
Electronic Engineering	62	1.84
Pharmacy	59	1.75
Food Engineering	57	1.69
Mechanical Engineering	43	1.27
Biophysics	41	1.21
Medicinal Engineering	40	1.19
Medicine	38	1.13
Environmental Science	36	1.07
Biotechnology	30	0.89
Electrooptic Engineering	30	0.89
Biochemistry	26	0.77
Unclear	25	0.74
Applied Chemistry	20	0.59
Textiles and Fibers	18	0.53
Dyes and Pigments	16	0.47
Medical Biochemistry	14	0.41
Industrial Management	8	0.24
Immunology	7	0.21
Mathematics	6	0.18
Computer Engineering	5	0.15
Agriculture	3	0.09
Dentistry	2	0.06
Information Technology	2	0.06
Health	1	0.03
Geology	1	0.03
Civil	1	0.03
Total	3375	100.00

All disciplines are displayed in descending order, so the top 10 ones make up 80% of the ISI publications output, the 28 remaining items just 20%. Again, compared with the report in 2007, thirteen disciplines containing food engineering, medicine, medicinal engineering, environmental science, biotechnology, textiles and fibers, dyes and pigments, industrial management, immunology, dentistry, information technology, health and geology are added to the domain of nanoscale research, while three disciplines, statistics, entomology and computer engineering (hardware) are deleted. The list reveals the special attention of medical researchers to nano lately. Likewise, metallurgy with 19.30%, physics with 17.00%, materials engineering with 11.45% and electronic engineering with 7.23% appear as the top 4 disciplines.

To delineate the development of nano as a novel field of science and technology, a comparison is made between citations to the nano sources and to the other disciplines as represented in Figure 4.

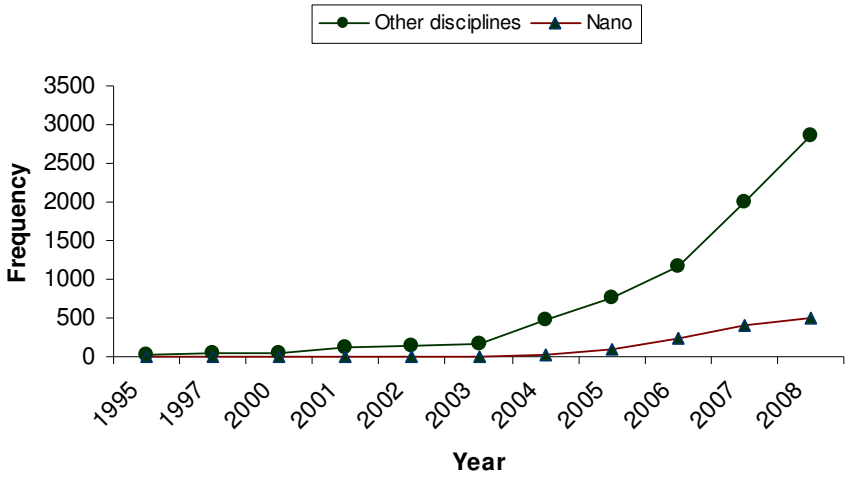

Figure 4. The comparison between citations to the nano and to the other disciplines per year.

The contribution of nano references to the nanopublications has grown with a sizeable rate after 2004 across all scientific disciplines. Definitely, this increase enhances the advancement of nano to become a comprehensive knowledge field due to the dynamic and self-motivated nature of nanoscience and nanotechnology.

In summary, one may stress that the nanoscience is an emerging scientific community with intense exchanges going beyond the boundries of disciplinary backgrounds and is not merely a community of thought built around a particular scale of observation of nature. Nanoscale research in Iran integrates across various areas and disciplines due to its multidisciplinary and interdisciplinary character. On the other hand, the dynamic nature and prospect of nano help increase the building up of nano sources themselves as well as share substantially in the advancement of the non-nano fields in the future. In general, it seems that the convergence between basic sciences (physics and chemistry) and engineering

(materials engineering and metallurgy) has the lion's share in the development of the nanoscale research in Iran.

Iranian nanoscale research in an international context

During 1994 there were published less than 2000 papers worldwide (Pouris 2007). Six years later, in 2000, there were 11855 papers and during 2004 there were published 30375 papers (in the ISI databases).

The share of Iran in this field ranges from 0.03% to 0.15% in the period 2000-2004, which appears to be small but shows a promising trend. However, far from the quantity of Iranian nanoscale researches, their growth pattern and research objectives appears to be comparable to those reported for many other countries. For instance, the top subject area in many countries such as South Africa, India, South Korea, and Australia happens to be materials science. Moreover, the top 3 subject fields in many countries are materials science, physics and chemistry. The top 5 disciplines involved in European nanoscience and nanotechnology are materials science, applied physics, physical chemistry, physics condensed matter and general chemistry with the less involvement of biology and engineering sciences. In a worldwide context, the disciplines mostly involved in nanoscale researches are chemistry, physics, biology, medicine and engineering with a clear increase in the involvement of chemistry in the recent years (Wong, 2007). Interestingly, major portions of these findings are in good agreement with our data for nanoscale research in Iran.

Conclusion

A citation analysis of Iranian ISI papers on nanoscience and nanotechnology in 2008 was performed and compared to the period 1995-2007. The number of publications shows an increase from 1 paper in 1995 (with 26 citations) to 136 papers in 2008 (with 3375 citations). Journal papers are the most frequent ones in the nanoscale research citations (85%). 18 different subject fields comprising 38 disciplines have their share in the foundations of Iranian nanoscale research with the top 4 subject fields of manufacturing and transport engineering (with about 48.5% of all citations), physical sciences (15%), chemical sciences (14.7%), and nano (13.3%). Similarly, there are the top 4 disciplines of metallurgy with 28.01%, physics with 17.33% and materials engineering with 16.48%. Fairly good consistency is observed among our findings in Iran and the four countries compared.

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