The research life cycle and innovation through grey literature in nanotechnology in Korea

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Abstract

This paper studied the research life cycle of nanotechnology (NT) and its innovation through grey literature in the form of technical reports in Korea. The changes in the numbers of publications of grey literature and white literature in NT show the process of innovation, as technical reports and journal articles contain research results. Numbers of publications of Korean technical reports on National Discovery for Science Leaders (NDSL) and journal articles on Web of Science Science Citation Index Expended (WoS (SCIE)) are compared year by year. In general, the technical reports were produced at an earlier date than journal articles on the Web of Science. Grey literature contains creative ideas and research output, and reflects the early stage of nanotechnology and thus provides a means of tracing innovation in a specific field of science and technology in Korea.

1. Introduction

Grey literature such as technical reports, conference proceedings, etc. contains creative ideas, suggestions and research results. Researchers in science and technology fields use them for literature reviews and produce them to share their research output in the research life cycle. Scientists and researchers conduct R&D and write technical reports and then publish the research output in domestic and overseas journals. In this process, innovation in a certain field can be traced through an analysis of grey literature. The process of nanotechnology

development can be revealed through comparison of literature publications such as grey literature and white literature.

Nanotechnology emerged in the 1980's and has become one of the six technologies funded by the Korean government. Nanotechnology in Korea reflects the nation's innovation in science and technology. A similar situation can be seen in other developed countries. MIT selected 'nanopore sequencing' as one of 10 emerging technologies for 2012 and the World Economic Forum chose 'nanoscale design of materials' as one of the top 10 emerging technologies for the same year. Nanotechnology became one of leading technologies to change world.

This paper verified that the grey literature has contributed innovation of nanotechnology in Korea through case study. The goal of this study is to analyze the research life cycle of nanotechnology (NT) and trace innovation in Korea through grey literature in Korea. First, the Korea Institute of Science and Technology Information (KISTI) conducted in-depth interviews and close observations of 24 researchers working in NT to analyze the NT research life cycle. Second, to trace innovation through grey literature, the numbers of publications of Korean technical reports in NT appearing on National NDSL and journal articles on Web of Science Science Citation Index Expended (WoS (SCIE)) were countered and compared. The numbers of technical reports funded by Korean government on NDSL and journal articles written by Korean researchers on WoS (SCIE) from 1980 to 2011 were counted and compared. I assumed that the changes of numbers of publications of grey literature and white literature in nanotechnology show the process of innovation, because technical reports and journal articles contain research results. Research output is often evaluated by numbers of publications in renowned journals listed on Web of Science, Scopus, etc. The research output in the literature can be read, highly cited, and developed by other researchers.

2. The Research Life Cycle in Nanotechnology in Korea

2.1. Needs of analysis of the research life cycle in Korea

As a national information center for science and technology, KISTI should be aware of the information environment of domestic researchers and provide a stable system. To prepare for the changeable information environment, recognition of the R&D research life cycle is important. The R&D research life cycle in nanotechnology is to reveal the Korean situation.

According to Encyclopedia Britannica, 'nanotechnology' is the manipulation and manufacture of materials and devices on the scale of atoms or small groups of atoms. The 'nanoscale' is typically measured in nanometers, or billionths of a meter (*nanos*, the Greek word for "dwarf," being the source of the prefix), and materials built at this scale often exhibit distinctive physical and chemical properties due to quantum mechanical effects. Although usable devices this small may be decades away (microelectromechanical system), techniques for working at the nanoscale have become essential to electronic engineering, and nanoengineered materials have begun to appear in consumer products such as nano-silver toothbrush, nano laundry detergent, etc. The field of nanotechnology and nanoscience covers a broad area of expertise. Classical fields of physics, chemistry, material science, electrical/mechanical/chemical engineering, and medicine, are all involved in the new field of nanoscience. Furthermore research and development in this area is naturally multi-disciplinary. Nanotechnology includes nanoelectronics, nanomechanics, nanomaterials, nanomedicine, bionanotechnology, etc.

2.2 Conducting in-depth interviews and close observations

In-depth interviews and close observations were conducted in 2011 to shed light on the R&D research life cycle in nanotechnology. Twenty-four researchers working in the field of nanotechnology at the universities and research institutes were interviewed. The interviews were conducted from March to April 2011 for a month.

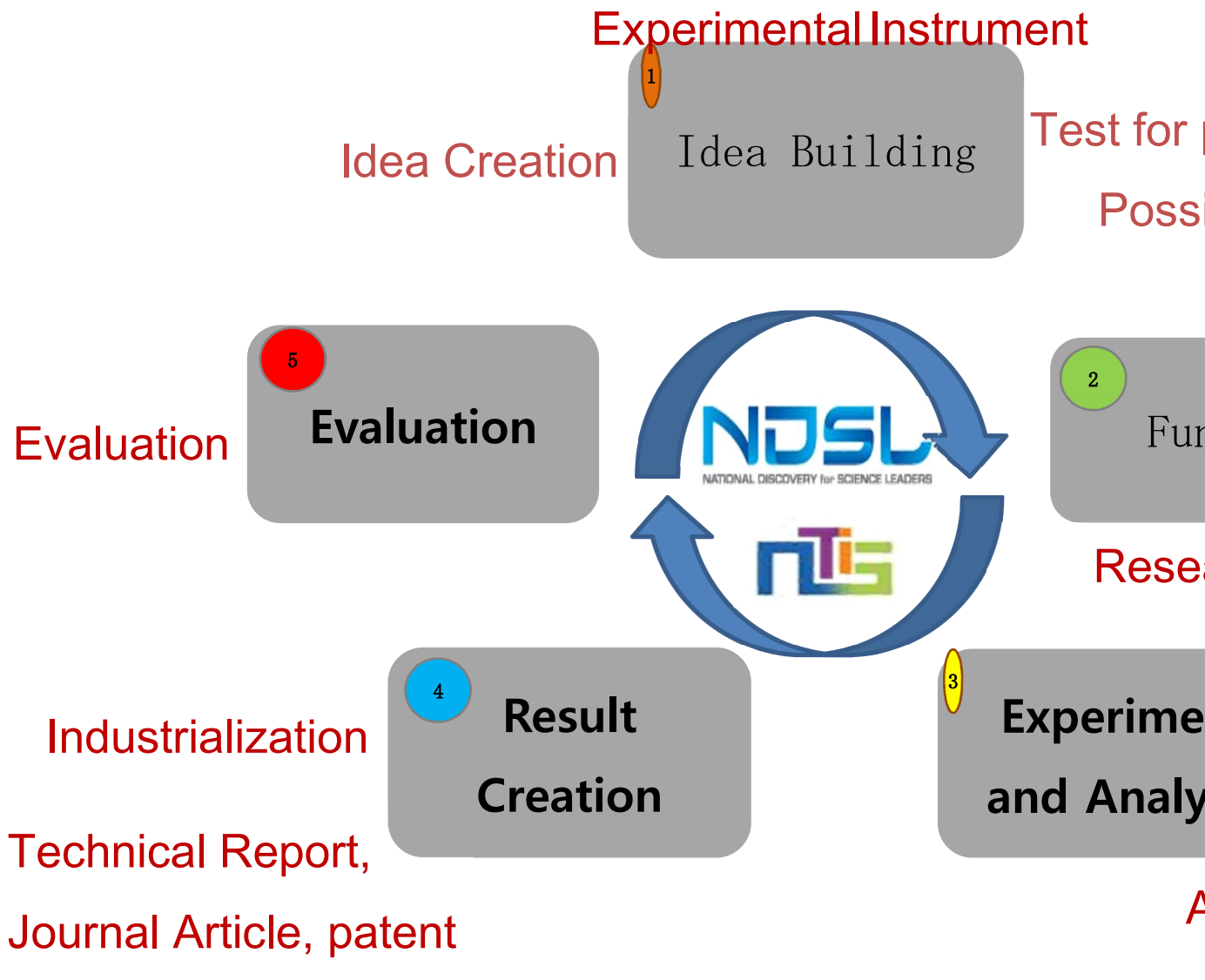
2.3. Analysis of research life cycle

According to the study, the research life cycle in nanotechnology can be divided into 5 stages (Fig. 1): idea building, funding, experiment and analysis, result creation, and evaluation. In idea building stage, researchers create idea, design experiment with instruments, and then test for practical possibility. In funding stage, researchers look for funding, write research plan and proposal, and seek out coworkers. In experiment and analysis stage, researchers conduct experiment and analyze research results. The results of creation appeared in technical reports, journal articles, and patents and became industrialized. The last stage of the research life cycle is the evaluation. In evaluation stage, research results are evaluated by funding agencies or other researchers. The stage doesn't end in the evaluation but it is influencing the new idea building stage for new projects. Therefore new research life cycle will begin. Research drives innovation in science and technology as well as human life. Research is undergoing revolution.

Needs are different in every stage of the research life cycle but needs for literature reviews through technical reports, patents, trends, and journal articles are evident in every stage of the research life cycle. The researchers use grey literature and white literature in every stage of

the research life cycle and also produce both forms of literature.

<Fig. 1> the Research Life Cycle in NT



3. Tracing innovation through grey literature

3.1 Scholarly Communication System based on NDSL and NTIS in Korea

The scholarly communication system in Korea is based on National Science and Technology Information System (NTIS) and National Discovery for Science Leaders (NDSL). The research results by scholars and researchers are collected in the forms of technical reports of national research and development projects through NTIS and journal articles are archived through the Article Contribution Management System (ACOMS). Researchers are should upload their technical reports and journal articles on the systems via the internet directly. The grey literature and white literature uploaded then provided to the public through the NDSL portal system. NDSL provides 133,006 titles of technical reports funded by the Korean government since the 1980'- and 1,366,319 Korean journal articles since 1940'-. NDSL also provides other domestic and overseas science and technology information such as patents, standards, fact data, etc. Researchers are both knowledge creators and consumers for NDSL, NTIS, and other domestic and overseas networks. They also communicate through internal and external communities and social networks in the research life cycle to share ideas and new discovery.

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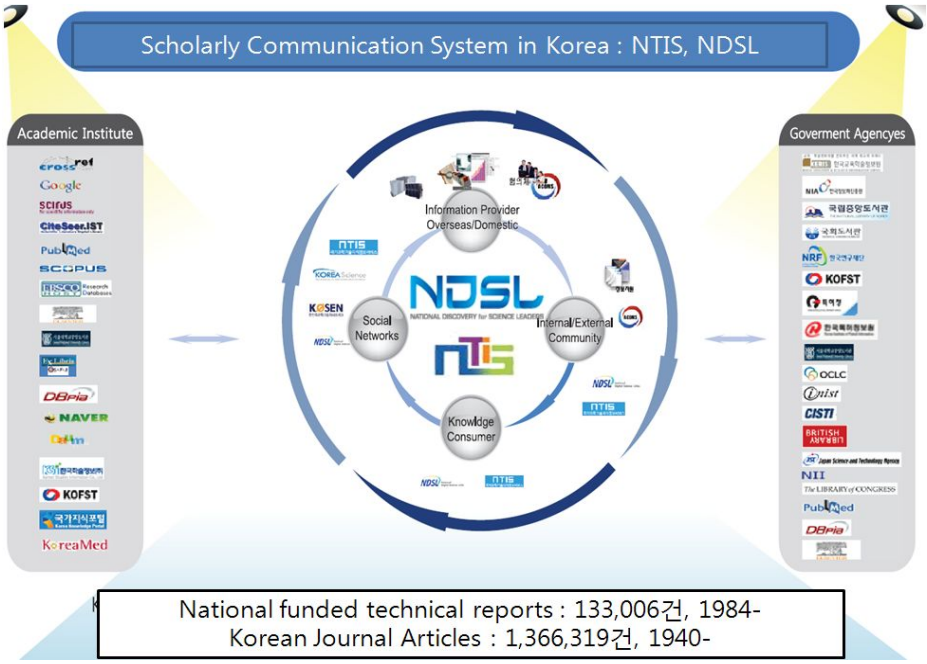
<Fig. 2> Scholarly Communication System in Korea through NTIS and NDSL (As of 2012)



3.2 Comparison of Technical Reports on NDSL and Journal Articles written by Koreans on WoS (SCIE)

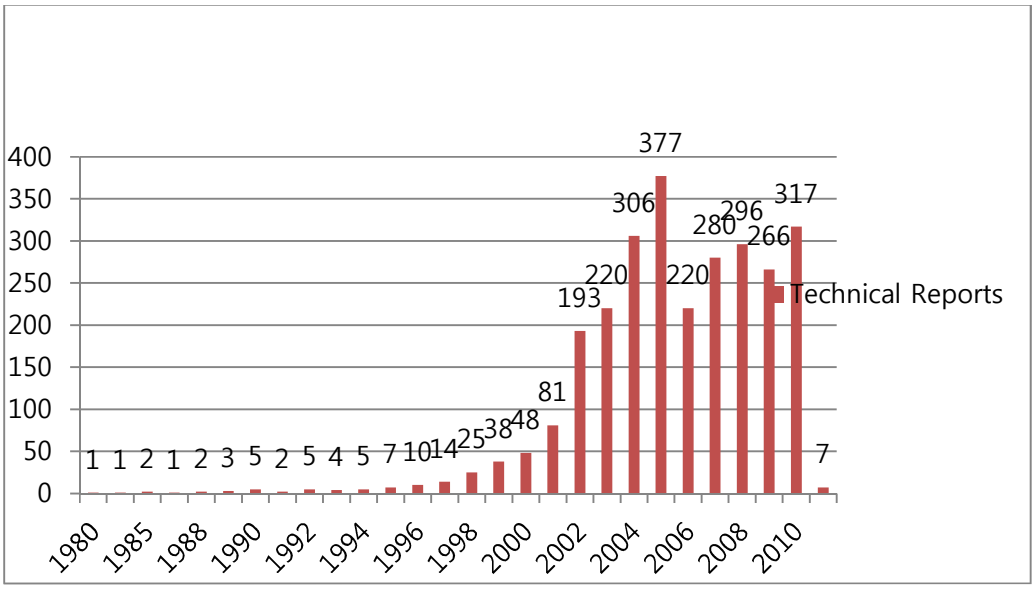
3.2.1 Data of Technical reports on NDSL and Journal Articles on WoS (SCIE)

- Data: technical reports funded by Korean government in nanotechnology on NDSL

Technical reports on nanotechnology funded by the Korean government have been published since 1980'-. Technical reports published by private enterprises were not included in this study. To extract records of technical reports on nanotechnology on NDSL, key word searching was used. The keywords were 'nano*' or '나노*'. The total numbers of technical reports was 2,736. The peak year of publication of technical reports was 2005. 377 titles were published in 2005. The number fell to 7 in 2011 (Fig. 3). The early stage of research development of NT appears in the grey

literature in the form of technical reports.

<Fig. 3> Korean Technical Reports in NT on NDSL (1980-2011)



As a multidisciplinary field, nanotechnology is related to numerous subjects such as applied physics, engineering and allied operations, chemical engineering and related technologies, metalworking processes and primary metal products, physics, ceramics and allied technologies, organic chemistry, precision instruments and other devices, etc. (Table 1).

<Table 1> Subjects of technical reports related to NT on NDSL

No	Subjects	Records
1	Applied physics	1,021
2	Engineering and allied operations	423
3	Chemical engineering and related technologies	299
4	Metalworking processes and primary metal products	272
5	Physics	255

6	Ceramic and allied technologies	251
7	Organic chemistry	234
8	Precision instruments and other devices	156
9	Technology applied sciences	111
10	Chemistry and allied sciences	103
11	Sanitary and municipal engineering Environmental protection engineering	85
12	Textiles	76
13	Other branches of engineering	60
14	Miscellaneous branches of medicine Surgery	47
15	Crystallography	44
16	Technology of other organic products	41
17	Physical chemistry	37
18	Elastomers and elastomer products	32
19	Food technology	30
20	Technology of industrial chemicals	29
21	Pharmacology and therapeutics	28
22	Systems	27
23	Heating, ventilating, air-conditioning engineering	22
24	Manufacturing	20
25	Civil engineering	19
26	Cleaning, color, coating, related technologies	19
27	Life sciences, biology	17
28	Inventions and patents	16
29	Light and infrared and ultraviolet phenomena	15
30	The others	

- Data: Journal Articles written by Korean in NT on WoS (SCIE)

In WoS (SCIE), journal articles that are written by Koreans, funded by Korean government

and sorted by the subject 'Nanoscience nanotechnology' are selected. The numbers of journal articles on Web of Science (SCIE) are used as evaluation criteria of R&D productivity at institutional, national, and global levels. There were no articles in the 1980's but journal articles written by Koreans have been increasing dramatically since 1990'-.

The subjects of journal articles on WoS (SCIE) related to nanoscience and nanotechnology include materials science multidisciplinary, physics applied, chemistry multidisciplinary, physics condensed matter, chemistry physical, engineering electrical electronic, metallurgy metallurgical engineering, optics, biotechnology applied microbiology, etc (Table 2).

<Table 2> 10 Subjects related to NT Journal Articles on Web of Science

No	Web of Science Categories	records	% of 5428
1	Nanoscience nanotechnology	5428	100
2	Materials science multidisciplinary	4660	85.851
3	Physics applied	3644	67.133
4	Chemistry multidisciplinary	2659	48.987
5	Physics condensed matter	2365	43.57
6	Chemistry physical	1682	30.987
7	Engineering electrical electronic	535	9.856
8	Metallurgy metallurgical engineering	354	6.522
9	Optics	161	2.966
10	Biotechnology applied microbiology	138	2.542

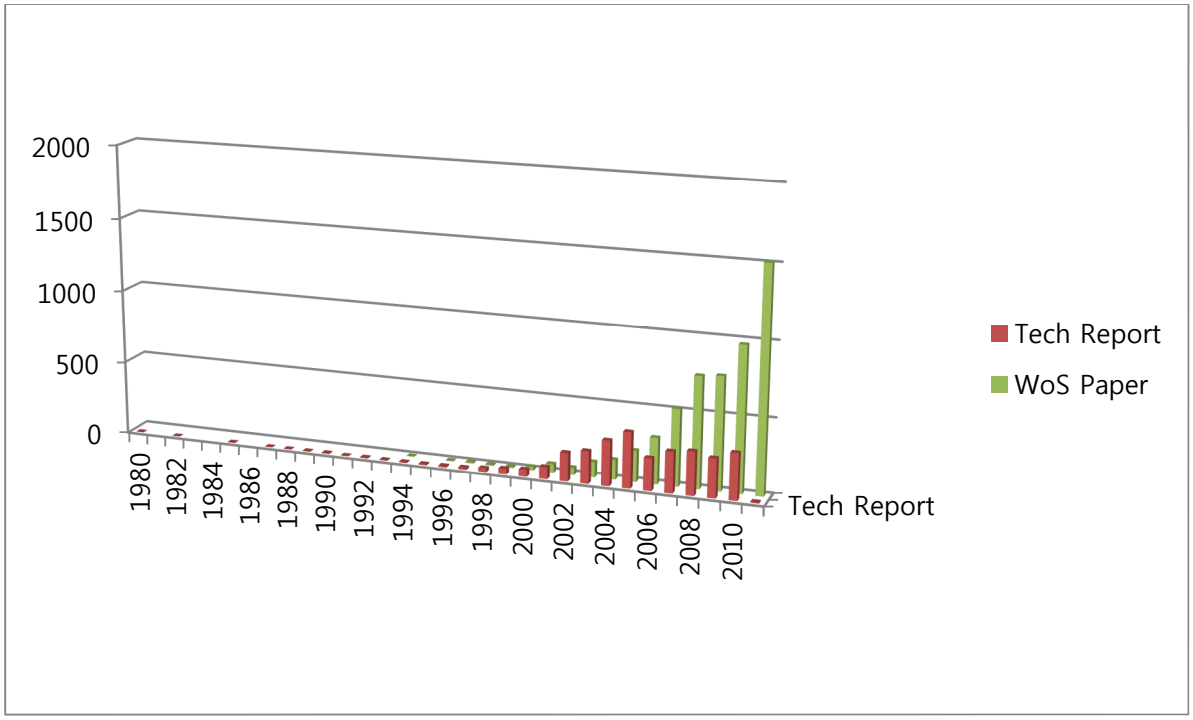
3.2.2 Comparison of Technical Reports on NDSL and Journal Articles on WoS (SCIE)

2006 was the turning point for dominant literature in nanotechnology. The trend moved from grey literature to global level white literature (Fig. 4). The numbers of WoS (SCIE)

publications has exceeded those of technical reports since 2006. WoS (SCIE) journal articles written by Korean in NT are still increasing. Nanotechnology became one of six technologies supported by the Korean government and the second most funded technology by the Korean government. In 2011, nanotechnology became the 10th most published subject in WoS journal articles written by Koreans.

However, technical reports fell dramatically in 2011. Technical reports or grey literature provided creative ideas and research results in the early stage of development of NT in Korea. When global level R&D was conducted, the research results appeared in WoS (SCIE). Grey literature was the driving force behind increasing of white literature in NT. These results indicate that innovation in NT has been taking place through grey literature. Grey literature contains the birth and early development of innovation in NT in Korea.

<Fig. 4> Comparison of Publication for White Literature and Grey literature (1980-2011)



Conclusion

The R&D research life cycle in nanotechnology in Korea can be divided into 5 stages. R&D researchers in nanotechnology use grey literature and white literature throughout the research life cycle. In general, researchers produced technical reports when they finished their R&D projects in the research creation stage. Grey literature contains important information, but it is difficult for other researchers to access it due to its method of distribution. The NDSL provides research output in technical reports, paper articles, etc through internet. published in Korea. Grey literature played an important role in the early stage of development of nanotechnology in Korea. Researchers later try to submit and publish their research output in well known journals such as those on the WoS, so that their results can be read and highly cited by other researchers.

Innovation in nanotechnology can be traced through grey literature, especially technical reports on NDSL. Technical reports in nanotechnology emerged the 1980s, peaked in 2005, and then reduced rapidly. 2006 is the turning point of the changing dominant literature in NT from grey literature and white literature. Grey literature contributed development of NT in Korea in early stage of research. Journal articles written by Korean in nanotechnology on the WoS (SCIE) appeared in the 1990's and has increased dramatically until now. NT became the 10^{th} most published subject in WOS (SCIE) papers written by Koreans in 2011. NT became one of six major technologies supported by the Korean government in 2011. NT was the second most funded technology by the Korean government in 2011. NT has influenced to other subjects, created knowledge, and changed human life. Innovation through grey literature is in progress in other area of science and technology.

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