Analysis of the citation impact of national journals toward SCIE journals on JCR ranking

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ABSTRACT

The prior studies in the citation analyses of Korean natural science and engineering journals found that they have cited SCIE (Science Citation Index Extended) journals significantly. This research investigated the citation impact of the Korean natural science and engineering journals (from 2009 to 2014) toward SCIE journals in terms of JCR (Journal Citation Reports) ranking changes. First, this research analyzed the cited numbers and citation age by subject and journal through the citation analysis of the cited SCIE journals. Second, this research created the co-citation networks of journals and subjects by using co-citation analysis of SCIE journals. Based on the same method, we also assessed the network centrality measures and compared the citation numbers in each journal. Third, this research analyzed the changes in journal ranking in SCIE journal citation index by reflecting the citations of Korean natural science and engineering journals into JCR. Our results indicate that engineering has higher cited numbers, smaller peak-time, and cited half-time values than natural science. These results mean the journal articles in engineering are more quickly consumed and decreased than natural science journals, respectively. Second, this research visualized the co-citation network of SCIE journals and subject areas based on the Korean journals, and it also measured the network centrality in journals and subjects. Third, this research found that the existing journal Impact Factor (IF) (2 years) has been changed significantly if we apply the Korean journal citations into JCR in 2014, and there are significant changes in JCR journal rankings in engineering and natural science. This research shows the impact of Korean journals on SCIE journals, and the results of this study can be used for the future evaluation of journals. The practical implications were presented for Asian countries as well as Korea to develop their own JCR rankings and for their academic libraries to provide better scholarly services.

Keywords: Korea scholarly journals; Citation analysis; Journal co-citation analysis; Social network analysis; Science Citation Index; Journal Citation Reports

https://doi.org/10.22452/mjlis.vol23no2.1

INTRODUCTION

Web of Science (WoS) provides information services about citation indexes for the major journals. The WoS citation index databases are categorized into Science Citation Index Expanded (SCIE), Social Science Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI) depending on disciplines, and in each category provides the Journal Citation Reports (JCR), including diverse citation indexes based on inter-journal citation index. The concept of SCIE was initially proposed by Eugene Garfield in 1955, and the Impact Factor (IF) of JCR has been used to assess the qualities of journals (Garfield 2006). The SCIE has included the major journals in science-engineering areas, and the journals in SCIE are considered critical journals in each discipline by research institutions and researchers. Researchers usually refer to SCIE journal articles for writing their own research papers, and they also have tried to publish their articles in the SCIE journals. As of recently, Google Scholar includes the WoS citation information and extends its usage for developing journal and author rankings.

According to International Monetary Fund (IMF), in 2014 the Republic of Korea ranked 13th in the world economy. According to Organization for Economic Co-operation and Development (OECD) in 2017, the Republic of Korea ranked 1st in terms of the ratio of Research & Development (R&D) investment out of GDP among OECD countries. This large investment in R&D led to the increase of the production of research articles and their citations by Korean journals, and therefore, the Republic of Korea is now perceived as the emerging research-production center of the world (Leydesdorff and Zhou 2005). According to a SCIE article survey in science-engineering (So 2015), the Republic of Korea ranked 12th in terms of the number of publications in SCIE, and ranked 13th in number of citations. Kim, So and Choi (2014) analyzed the percentage of article publications in diverse disciplines, and found that natural science and engineering disciplines produced more than 70 percent of the entire articles published in the Korean journals including: Biomedical Sciences (18%), Chemistry (17%), Material Sciences (13%), Computer Sciences (12%), and Clinical Medicine (11%) (Kim, So and Choi 2014). According to JCR in 2014, the Republic of Korea has a total of 102 SCIE journals, and according to the Korea Institute of Science and Technology Information (KISTI) survey on List of Korean Natural Science and Engineering Journal, in August 2015, the Republic of Korea has a total of 1,160 primary journals (Kang and Kim 2015). Based on prior studies on the citation trend in the Korean journals, Korean natural science and engineering journals have cited international (other countries) journals heavily, and especially, the portion of SCIE journals is very high.

This research analyzed the citation impact of national journals toward SCIE journals on JCR by sampling natural science and engineering journals published in Korea. For the analysis, this research employed the Korea Science Citation Database (KSCD) by KISTI as the data source. KSCD has the Korean natural science and engineering primary journals in all research areas, and especially, it has the important Korean journals in the areas of natural science and engineering. This research focuses on the natural science and engineering journals for its reliable SCIE citation impact analysis. In this research, the field of natural science includes: Biological Sciences, Earth & Environmental Sciences, Chemistry, Physics, Mathematics, and Computer & Information Sciences. Also, the field of engineering includes Electrical & Electronic Engineering, Mechanical Engineering, Chemical Engineering, Materials Engineering, Civil Engineering, and Environmental Engineering. This research employed the Korean Science and Engineering Citation Index (KSCI) service based on the KSCD. It utilized three different methods to analyze the citation impact of national journals toward SCIE journals. Firstly, it examined cited numbers and citation age in subject areas and journals through cited SCIE journal citation analysis. Secondly, it created co-citation network of

journals and subject areas by using SCIE journal co-citation analysis. The research also assessed the network centrality measures of each journal by using Gephi, a social network analysis tool, and compared the number of citations of each journal (Bastian, Heymann and Jacomy 2009). Additionally, this research visualized the map of science citations based on the co-citation frequency matrix (the journal-to-journal co-citation frequency matrix) by using a network visualization tool, VOSviewer (Van Eck and Waltman 2010). Third, the study analyzed the changes of journal rankings by recalculating the IF (2 years) of the major SCIE journals in natural science and engineering by reflecting the citation records of Korean journals for SCIE journals into the existing JCR. The structure of this paper includes report on prior studies of related research area, discusses the research method, and presents the results.

LITERATURE REVIEW

After the 1960s, diverse citation analysis methods such as bibliographic coupling analysis and co-citation analysis have been developed. In bibliographic coupling analysis, two or more articles are considered to have similar subjects if they have the same articles cited, and for the unit of analysis, article and author combinations were developed and used for bibliographic coupling analysis (Kessler 1963; Zhao and Strotmann 2008). In co-citation analysis, any frequently co-cited articles are considered to be very relevant, and depending on the unit of analysis, article-author co-citation analysis, article co-citation analysis, and subject co-citation analysis have been developed and used so far (Marshakova 1973, Small 1973; White and Griffith 1981; McCain 1991). Apart from citation relationship, co-word analysis method has been developed and utilized for co-author relationship and keyword relationship analyses (Liu, Hu, and Wang 2012). Small and Garfield (1985) developed the global map of science based on the co-citation analysis in SCIE and SSCI database, and scholars have worked on the knowledge organization analysis in disciplines based on the map of science (Boyack, Klavans and Börner 2005).

Additionally, the network centrality analysis based on the social network analysis has been applied for citation analysis. The core concepts of network centrality include degree centrality, betweenness centrality, and closeness centrality (Freeman 1978). The centrality of the connection level is calculated by the sum of the direct connections from a node. The centrality of the connection level is measured by any nodes which are closely connected (i.e., less than two levels), so it provides a somewhat limited centrality. Therefore, it is an appropriate measurement for the local centrality. The closeness centrality is defined as the sum of the shortest paths between one node and the other nodes, and it can find the most central node in a network which is the shortest path among all the nodes. Therefore, it is a useful measurement for examining the global centrality. The betweenness centrality is measured by the position level of one node among other nodes, and any nodes which have high betweenness centrality can mediate with other group of nodes. Leydesdorff and Zhou (2005) found that the betweenness centrality can be used to measure academic relationships (Dolfsma and Leydesdorff 2008). There are a number of Social Network Analysis tools such as Pajek and UCINET, and recently Gephi and VOSviewer, which are heavily utilized for the social network analysis due to their visualization methods.

A number of Asian countries have developed their own citation indexes for the purpose of their journal citation analysis and evaluation, and those Asian country-based citation indexes include Malaysian Citation Index (MyCite) (Zainab et al. 2012), Thai-Journal Citation Index (TCI) (Sombatsompop et al. 2012), Chinese Science Citation Database (CSCD) (Jin and Wang

1999), and Korea Science Citation Database (KSCD) (Choi et al. 2013). The China National Knowledge Infrastructure (CNKI), especially, also developed the Annual Report for International Citation of Chinese Academic Journals (CAJ-INCR) to measure the citation impact of international journals toward Chinese domestic journals (Wu et al. 2015). Since the early 2000, KISTI in the Republic of Korea has developed KSCD, which provides Korea Science Citation Index (KSCI) based on citation data from Korean natural science and engineering primary journals. KSCD includes the important journals in natural science and engineering, and it also includes a good number of medicine and pharmaceutical journals. Therefore, KSCD is the most appropriate platform to garner citation analysis in natural science and engineering fields.

A prior study on journal citation analysis based on KSCI, the reference analysis from Korean journals, shows that Korean journal articles cite mostly other journals, followed by conference papers, book sections, and other reference types. This research also indicates that the number of international journal articles are higher than the number of domestic Korean journal articles (Choi et al. 2013). The most critical component from these analyses shows that SCIE and Scopus journal articles are among the most heavily cited international journal articles. In addition, the citation age analysis of international journals shows that the highest citation point by Korean natural science and engineering journals for the international journals is 3.5 years on average, and the citation half-time is 9 years on average (Choi et al. 2013).

Compared to the studies focusing on Korean journals and their impacts on JCR, other scholars also investigated how national journals influence the existing JCR Impact Factor (IF) and its ranking. Miguel-Dasit et al. (2005) reported how Spanish health science journals that were not registered in JCR, had affected the IFs of the radiological journals registered in JCR; they found that the IFs of the radiological journals in JCR had increased, especially in European journals rather than U.S. journals. Aleixandre-Benavent et al. (2007) also found that the Spanish health science journals that were not registered in JCR influenced the IFs of JCR journals by increasing the IFs of mostly U.S. and British journals. Comparatively, Wu et al. (2015) assessed the international influence of more than 6,000 Chinese journals, the results indicated some of the Chinese journals have strong international influences in terms of IF and citation counts.

Since Korean natural science and engineering journal articles cite SCIE journal articles heavily (Lee et al. 2012) re-calculated the journal IF index by combining the citation index of Korean computer engineering journals and JCR in 2010 and compared it to the prior index; they confirmed significant changes in journal ranking. However, its overall analysis of natural science and engineering disciplines was limited because the scope of analysis was restricted to those specific areas, and the KSCD collection was very narrow (Lee et al. 2012). Jo and Lee (2012) analyzed the citation trend of Korean pharmaceutical journals, and they found no significant relationships between the citation rankings of SCIE and JCR. Therefore, they suggested that the Korean citation index needs to be considered along with JCR for the appropriate evaluation of journals in research and application. Their study was limited, however, because it only focused on the Korean domestic pharmaceutical research areas rather than the entire science-engineering research areas (Jo and Lee 2012). As a result, this research has utilized the KSCD which was extended in the scope of journals and improved by the identification of journals, and it overcame the limitations of existing citation analysis studies and performed a comprehensive citation analysis in natural science and engineering research.

METHOD

This research investigated the citation impact of Korean natural science and engineering journals toward SCIE journals in terms of JCR ranking changes. This research examined (a) the cited numbers and citation age by conducting citation analysis of the cited SCIE journals; (b) the co-citation networks of journals and subjects using co-citation analysis of SCIE journals; and (c) the changes in journal ranking in SCIE journal citation index by applying the citations of Korean journals into JCR. This research employed the KSCD of KISTI for analyzing the citation impact of national journals toward SCIE journals. In 2016, KSCD as KSCI service database had 550 thousand journal articles and 1.2 million references from 2002 to 2015. The experiment was conducted based on the SCIE journal articles cited by the Korean journal articles of natural science and engineering from 2009 to 2014 that were stored in KSCD.

Table 1 and 2 present the status of KSCD and the scope of the experiment for this research. This research utilized a total of 3,731,983 references in 192,168 journal articles in the 463 Korean natural science and engineering journals. Among the approximately 3.7 million references, there are 1,418,000 SCIE journal articles (i.e., about 38%) included in 7,605 SCIE journals. This research used the Fields of Science Technology (FOS) of OECD and Science Category (SC) of WoS. We selected WoS for our analysis methods since it is the major scholarly information service that provides citation indexes. Additionally, WoS has ranked as highly credible with a large scope of citation indexed journals (Meho and Yang 2007). The OECD FOS categorizes the entire disciplines into 6 main categories and 42 sub-categories, and the WoS SC categorizes the science-engineering disciplines into 176 categories. We used both OECD FOS and WoS SC subject area mapping provided by the Web of Knowledge.

For the experiment method, first, we conducted the citation analysis and measured the citation age of cited SCIE journal articles by Korean journal articles. The citation age means the years spent for the citation after its original publication, and it is measured by the difference between the year cited and the year published. Based on the citation year, immediacy citation rate, peak-time of citation, and citation half-time can all be calculated. The Immediacy Citation rate is the number of citations in the year an article was published. Peak-Time was the year when the article was more heavily cited. The Cited Half-time is used to measure the life span of an article, and it is measured by the point where the aggregated number of citations reaches 50 percent among the total number of citations (Lee and Yoon 1996). Second, this research employed the co-citation analysis method of SCIE journals, so it developed the co-citation analysis network among journals and subject areas and eventually measured the centrality score and number of citations for each journal. For this analysis, we developed the program which creates a co-citation matrix, and we also employed Gephi and VOSviewer for visualizing the network centrality index and network itself. Third, we analyzed the effect of the IF (2 years) of the SCIE journals based on the citation records of Korean natural science and engineering journals on the ranking of SCIE journals compared to the existing IF index ranking. For this analysis, we utilized the citation records in 2014 from the KSCD in natural science and engineering (see Table 1 and 2 for experimental data) and the 2014 JCR for SCIE published in 2015. This research employed the 2014 JCR report since it matches the citation records in 2014 from the KSCD in terms of time frame. We utilized the Pearson correlation coefficient for analyzing the relationship between the existing index and newly created index. Impact Factor (IF) is calculated by the average number of citations which refer to the articles published in a journal for two years. Specially, the IF is defined as:

A = Total number of citations from (X-1) year and (X-2) year by the designated journals for a Journal, J, in X year
B = Total number of citable items (i.e., published articles) from (X-1) year and (X-2) year in a Journal, J

IF of a Journal, J, in X year = A / B

Table 1: Status of KSCD (2009-2014) and Experiment Data Scope
(Natural Science and Engineering, 2009-2014)

KSCD Status (2009~2014)				
Years Published	**No. of Journals**	**No. of Articles**	**No. of References**	**No. of SCIE Journal Article Citations**
2009	677	47,947	990,467	432,253
2010	723	50,020	1,043,542	439,002
2011	738	51,661	1,112,063	479,356
2012	659	47,089	1,025,996	433,584
2013	650	48,209	1,075,475	323,046
2014	700	51,779	1,196,751	525,795
Total	850	296,705	6,444,294	2,633,036
Experiment Scope : KSCD Natural Science and Engineering (2009~2014)				
Years Published	**No. of Journals (Natural Science)**	**No. of Articles**	**No. of References**	**No. of SCIE Journal Article Citations**
2009	185	13,951	288,183	128,664
2010	192	14,187	295,563	120,231
2011	191	14,699	317,592	131,190
2012	192	14,088	319,185	131,517
2013	188	14,672	343,944	102,493
2014	191	15,324	372,186	152,038
Sub-Total	215	86,921	1,936,653	766,133
Years Published	**No. of Journals (Engineering)**	**No. of Articles**	**No.of References**	**No.of SCIE Journal Article Citations**
2009	**194**	**16,076**	**252,123**	**97,056**
2010	200	17,054	275,143	102,485
2011	198	17,277	287,977	110,718
2012	216	17,510	301,918	109,205
2013	211	17,908	317,209	84,294
2014	226	19,406	360,683	148,109
Sub Total	248	105,231	1,795,053	651,867
Grand Total	**463**	**192,152**	**3,731,706**	**1,418,000**

Table 2: Subject Areas of KSCD Natural Science and Engineering Journals (Data Scope: 2009-2014)

Main Category	Sub Category	No. of Journals	No. of Articles	No. of References	No. of SCIE Journal Article Citations
Natural Science	Mathematics	22	8,653	150,322	47,941
	Computer & Info. Sciences	40	14,436	248,144	45,420
	Physical Sciences & Astronomy	18	8,721	159,562	96,051
	Chemical Sciences	22	13,277	349,688	166,959
	Earth & Related Environ. Science	45	13,538	297,990	89,050
	Biological Sciences	55	16,794	509,384	287,760
	Other Natural Sciences	13	11,502	221,563	32,952
	Sub Total	215	86,921	1,936,653	766,133
Engineering and Technology	Civil Engineering	44	13,646	241,042	61,700
	Electrical & Electronic Eng.	49	28,350	365,421	104,154
	Mechanical Engineering	33	14,550	201,823	70,875
	Chemical Engineering	5	2,181	45,682	17,838
	Materials Engineering	31	14,406	291,659	137,212
	Medical Engineering	6	1,892	45,305	28,774
	Environmental Engineering	29	9,442	145,775	41,107
	Environmental Biotechnology	6	3,517	105,159	57,523
	Industrial Biotechnology	1	68	729	202
	Nano-Technology	2	126	4,333	3,265
	Other Eng. & Technologies	42	17,053	348,125	129,217
	Sub Total	248	105,231	1,795,053	651,867
	Grand Total	**463**	**192,152**	**3,731,706**	**1,418,000**

RESULTS

Citation Analysis of SCIE Journals in KSCD

We conducted the citation analysis of the cited SCIE journals in Korean natural science and engineering journals based on the data scope and research methods in section 3. First, we analyzed the citation status by published years and subject areas, and then we analyzed the citation speed by subject areas.

Figure 1 shows the total percentage of citations in each year for SCIE journal articles by the 463 Korean journals based on KSCD from 2009 to 2014. The green, blue, and red marks show the percentages of citations by Korean natural science, engineering, and both natural science and engineering journals, respectively. This graph shows that articles published from 1994 to 2014 were heavily cited by the Korean natural science and engineering journals.

Additionally, we reviewed the number of citations in the cited SCIE journals by 463 Korean natural science and engineering journals based on KSCD from 2009 to 2014, and our results indicated that among 7,603 SCIE journals, 311 journals have more than 1,000 citations and have more than 50 percent of the total citations. The top 20 most cited journals in natural

science and engineering are presented in Appendix A, and the top 20 journals based on co-citation network centrality are presented in Appendix B.

Figure 1: Percentages of Citations Each Year for SCIE Journal Articles by the 463 Korean Journals based on KSCD from 2009 to 2014

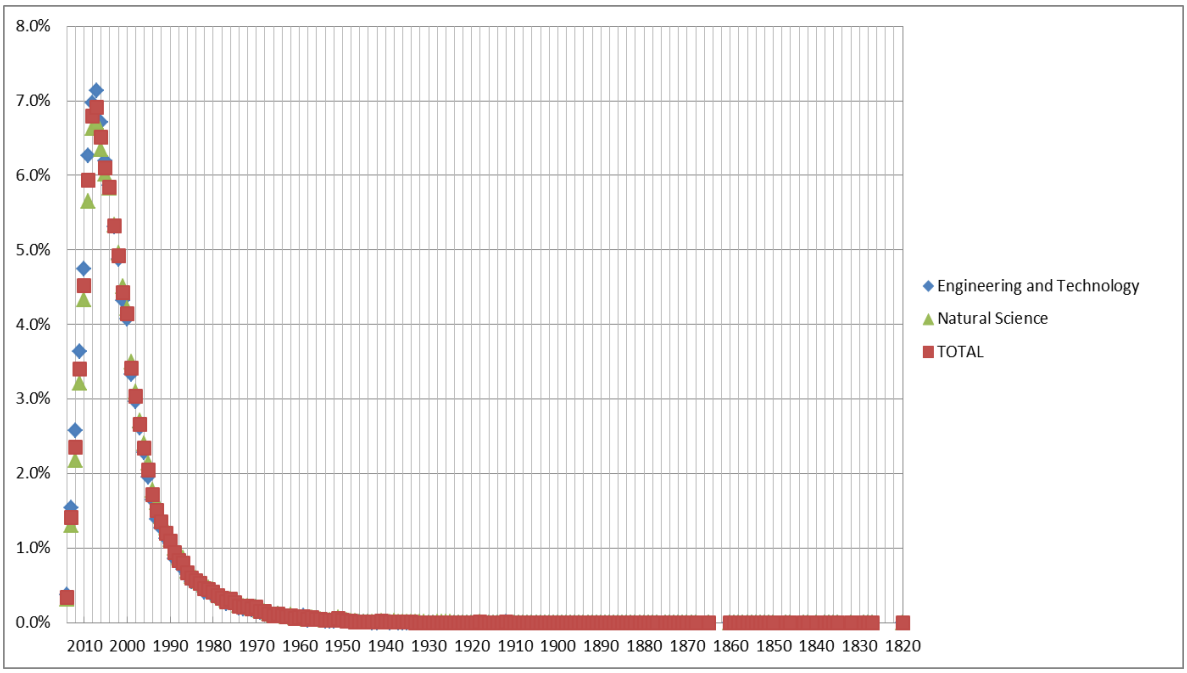


Table 3 presents the entire citation status categorized by OECD subject areas. The results show that the Korean natural science and engineering journals cite the SCIE natural science and engineering journals most often; however, they also cite other journals such as medicine, agriculture, and ocean studies. This is because the natural science and engineering journal articles usually refer to diverse areas of research. By investigating the natural science and engineering areas, natural science disciplines cite more journals and articles than engineering disciplines, however, engineering disciplines have more citation rates by journal (i.e., the number of citations by the number of journals) than natural science disciplines. Based on the mid-subject areas, Biological Sciences has the highest share rate (13.3%) followed by Chemical Sciences (9.5%) in natural science, and Materials Engineering has the highest share rate followed by Electronic Engineering in engineering.

The Korean natural science and engineering journals cite more than 80 percent of SCIE natural science and engineering journals. We calculated the citation age by consolidating journals into subject areas and produced Table 4, including immediacy citation rate, peak-time, and citation half-time. Since this research focuses on the citation point by Korean journals from 2009 to 2014, we calibrated the starting point of citation age for each year as 0. The results show that engineering has high immediacy citation rate, citation peak-time, and citation half-time. This means that engineering journal articles are more quickly consumed and in decline than natural science journal articles.

Table 3: Citation Status of SCIE Journals by 463 Natural Science and Engineering Journals based on KSCD from 2009 to 2014 (OECD Subject Category Citation Statistics) Main Category

	Mid Category	No. of Journals	% of Journals	No. of Citations	% of Citations
Natural Science	Mathematics	557	7.324%	59,687	4.209%
	Computer & Info. Sciences	264	3.471%	35,405	2.497%
	Physical Sciences and Astronomy	276	3.629%	109,719	7.738%
	Chemical Sciences	356	4.681%	134,960	9.518%
	Earth & Related Environ. Sciences	476	6.259%	91,534	6.455%
	Biological Sciences	1,067	14.030%	188,671	13.305%
	Other Natural Sciences	42	0.552%	29,879	2.107%
	Sub Total	3,038	39.947%	649,855	45.829%
Engineering and Technology	Civil Engineering	123	1.617%	50,893	3.589%
	Electrical & Electronic Eng.	274	3.603%	98,341	6.935%
	Mechanical Engineering	218	2.867%	71,814	5.064%
	Chemical Engineering	82	1.078%	37,013	2.610%
	Materials Engineering	264	3.471%	107,715	7.596%
	Medical Engineering	71	0.934%	7,311	0.516%
	Environmental Engineering	117	1.538%	25,718	1.814%
	Environmental Biotechnology	100	1.315%	33,245	2.344%
	Industrial Biotechnology	5	0.066%	4,843	0.342%
	Nano-Technology	2	0.026%	27	0.002%
	Other Eng. & Technologies	269	3.537%	80,686	5.690%
	Sub Total	1,525	20.053%	517,606	36.503%
Medical and Health Sciences	Basic Medical Research	513	6.746%	62657	4.419%
	Clinical Medicine	1,454	19.119%	95,086	6.706%
	Health Sciences	518	6.811%	28,636	2.019%
	Sub Total	2,485	32.676%	186,379	13.144%
Agricultural Sciences	Agriculture, Forestry, Fisheries	222	2.919%	31,196	2.200%
	Animal and Dairy Science	42	0.552%	7,087	0.500%
	Veterinary Science	107	1.407%	5,473	0.386%
	Other Agricultural Science	19	0.250%	6,375	0.450%
	Sub Total	390	5.128%	50,131	3.535%
Social Sciences	Psychology	64	0.842%	2,836	0.200%
	Economics and Business	39	0.513%	9,848	0.694%
	Educational Sciences	29	0.381%	1,084	0.076%
	Sociology	-	-	-	-
	Law	-	-	-	-
	Political Science	-	-	-	-
	Social and Economic Geography	-	-	-	-
	Media and Communication	-	-	-	-
	Other Social Sciences	-	-	-	-
	Sub Total	132	1.736%	13,768	0.971%
Humanities	History and Archaeology	35	0.460%	261	0.018%
	Languages and Literature	-	-	-	-
	Philosophy, Ethics and Religion	-	-	-	-
	Art	-	-	-	-
	Other Humanities	-	-	-	-
	Sub Total	35	0.460%	261	0.018%
	Total	**7,605**	**100.000%**	**1,418,000**	**100.000%**

Table 4: Immediacy Citation Rate, Citation Peak-Time, Citation Half-time in Natural Science and Engineering SCIE Journals (OECD Subject Category Citation Status) Main Category

	Mid Category		Immediacy Citation Rate	Citation Peak-Time	Citation Half-time
Natural Science	Mathematics		1.0%	3	11.4
	Computer and Information Sciences		1.8%	4	7.1
	Physical Sciences and Astronomy		1.5%	2	7.3
	Chemical Sciences		1.4%	3	6.7
	Earth and Related Environ. Sciences		1.5%	5	8.4
	Biological Sciences		1.3%	4	8.6
	Other Natural Sciences		0.8%	8	10.3
		Sub Total	1.4%	3	8.1
Engineering and Technology	Civil Engineering		1.9%	4	6.2
	Electrical & Electronic Engineering		1.9%	3	6.0
	Mechanical Engineering		1.7%	2	7.8
	Chemical Engineering		2.4%	2	6.0
	Materials Engineering		1.6%	2	6.0
	Medical Engineering		1.6%	2	6.2
	Environmental Engineering		2.2%	2	6.9
	Environmental Biotechnology		1.5%	3	7.1
	Industrial Biotechnology		1.5%	6	6.2
	Nano-Technology		0.0%	2	4.2
	Other Engineering & Technologies		2.0%	3	6.7
		Sub Total	1.9%	2	6.5
Total	**Citation Peak-Time Total**		**1.6%**	**3**	**7.3**

This research also calculated the immediacy citation rate, citation peak-time, and citation half-time for the top 40 SCIE journals in natural science and engineering. In natural science, *Applied Physics Letters* (14,543 citations) was highly cited by Korean journals followed by *Science* (14,405 citations); the immediacy citation rates for these journals were 0.6 percent and 0.4 percent, the citation peak-times were 5 and 9, and citation half-time was 7.2 and 10.4, respectively. In engineering, *Applied and Environmental Microbiology* (7,529 citations) was highly cited by Korean journals followed by *Food Chemistry* (5,942 citations). The immediacy citation rates for these journals were 0.5 percent and 3.3 percent, the citation peak-times were 9 and 3, and the citation half-time was 10.7 and 4.4, respectively.

Co-Citation Network Analysis of SCIE Journals based on KSCD

We conducted co-citation network analysis and social network analysis for the cited 7,605 SCIE journals that appeared in the references of Korean natural science and engineering journals from 2009 to 2014 based on KSCD. As the first step, we created a journal co-citation network matrix based on the frequency of co-citations in 7,605 SCIE journals. To avoid any bias regarding disciplines, we used the citation numbers in each journal divided by its total number of references (i.e., SCIE journal citations) (Small and Sweeney 1985). Based on the journal co-citation network matrix, we (a) created the journal co-citation network by using Gephi and measured the basic information of the network and major centrality values; (b) created the subject co-citation matrix based on the citation frequencies of subject areas using the above method; and (c) employed VOSviewer to visualize the co-citation network of journals and subject areas, and created the co-citation maps of journals and subject areas.

The analysis of results of the co-citation network for journals and subject areas are presented in this section. We analyzed the co-citation matrix of the 7,605 SCIE journals which were cited more than once in KSCD by using Gephi. There are 7,591 nodes, excluding the journals which have only self-citations, and there are 1,130,542 total edges of those nodes with an average difference of 297.9. In addition, the network density is 0.039, which measures the level of connections among nodes in a network. We calculated the centrality index for each journal based on the co-citation network of journals, and we identified top 20 SCIE journals in natural science and engineering based on the weighted degree. Table 5 shows the averages of centrality indexes of SCIE journals in subject areas in natural science and engineering.

Table 5: Analysis Results of Co-Citation Network Centrality of Natural Science and Engineering SCIE Journals (OECD Subject Category Centrality Indexes)

Main Category	Mid Category	Degree Sum	Degree Average	Weighted Degree Average	Closeness centrality Average	Betweenness centrality Average
Natural Science	Mathematics	73,816	132.5	80.7	0.42995	0.00012
	Computer & Info. Sciences	38,513	147.0	88.3	0.44313	0.00011
	Physical Sciences & Astronomy	74,691	270.6	311.3	0.46576	0.00018
	Chemical Sciences	163,106	458.2	319.5	0.48463	0.00019
	Earth & Related Environ. Science	112,412	238.2	155.3	0.46164	0.00026
	Biological Sciences	441,604	415.0	157.4	0.47765	0.00015
	Other Natural Sciences	23,934	569.9	636.9	0.47439	0.00369
	Sub Total	928,076	306.4	176.7	0.46309	0.00021
Engineering and Technology	Civil Engineering	28,961	235.5	283.0	0.45575	0.00014
	Electrical & Electronic Eng.	53,670	195.9	232.6	0.45359	0.00012
	Mechanical Engineering	61,903	285.3	234.0	0.46692	0.00013
	Chemical Engineering	35,348	431.1	364.4	0.48180	0.00019
	Materials Engineering	83,895	319.0	330.8	0.46724	0.00012
	Medical Engineering	26,129	368.0	86.3	0.48098	0.00017
	Environmental Engineering	23,098	197.4	154.1	0.45192	0.00007
	Environmental Biotechnology	62,776	627.8	294.2	0.49665	0.00028
	Industrial Biotechnology	4,115	823.0	774.8	0.50915	0.00101
	Nano-Technology	256	128.0	12.2	0.46845	0.00001
	Other Eng. and Technologies	100,602	374.0	235.2	0.47104	0.00018
	Sub Total	480,753	315.7	254.1	0.46680	0.00015
	Total	**1,408,829**	**297.9**	**149.8**	**0.46385**	**0.00016**

In the natural science, Biological Sciences has the highest sum of degrees, and Other Natural Sciences has the highest average of weighted degree (i.e., degree centrality). Chemical Sciences has the highest average of closeness centrality, and Other Natural Sciences has the highest average of betweenness centrality. In engineering, Other Engineering and Technologies has the highest sum of degrees, and Industrial Biotechnology has the highest averages of weighted degree (i.e., degree centrality), closeness centrality, and betweenness centrality. The engineering journals have higher centrality indexes, except with betweenness centrality, as compared to natural science SCIE journals.

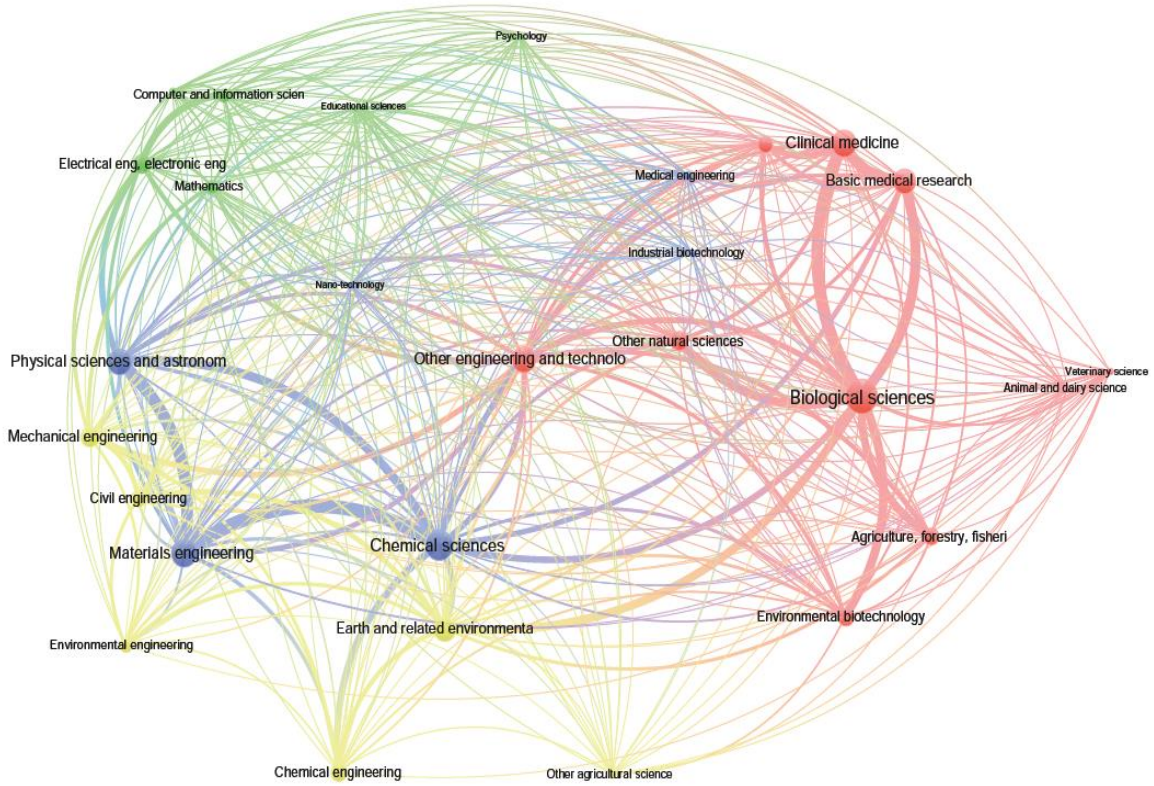
In the subject area co-citation network, there are 29 subject areas for the 7,591 nodes of SCIE journals, and 399 edges for those subject areas. The total number of the degree of nodes (i.e., the number of nodes connected to other nodes) is 798 and the average degree

is 27.5. Additionally, the network density (ranging from 0 to 1), which represents the connectivity of nodes in a network, is 0.983. Biological sciences (82,430.1) has the highest network weighted degree in natural science, followed by Chemical Sciences (66,141.5) and Physical Sciences and Astronomy (45,623.7). In engineering, material engineering (54,417.1) has the highest network weighted degree followed by Mechanical Engineering (30,113.01).

Figure 2 shows the co-citation network among subject areas, and it suggests that Chemical Sciences, Materials Engineering, Biological Sciences, Clinical Medicine, Chemical Sciences, Physical Sciences and Astronomy, Biological Sciences, and Basic Medical Research have the strong co-citation relationships among subject areas.

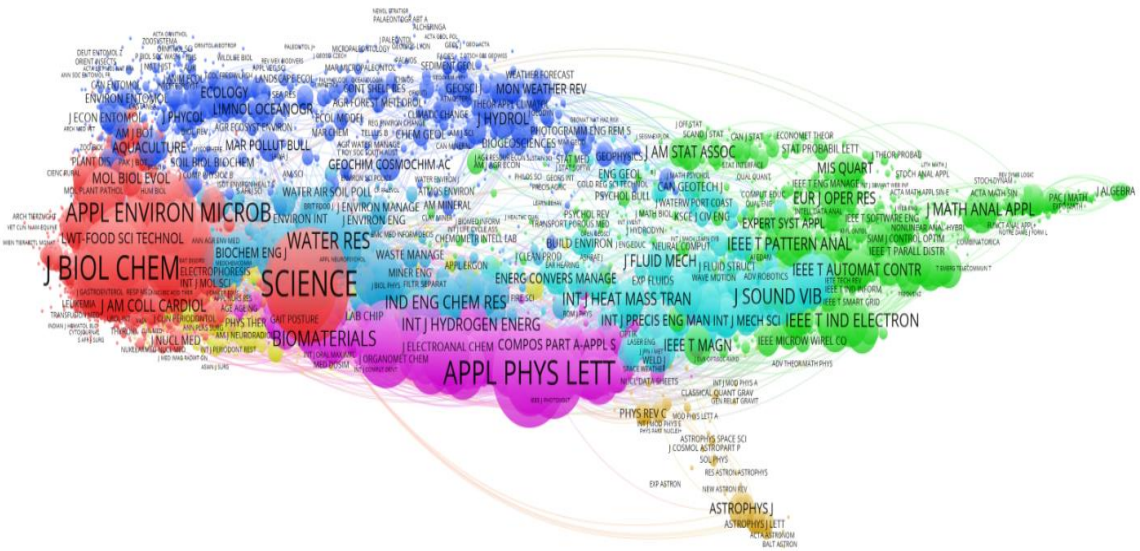
Figure 3 provides a visualization of the co-citation network of SCIE journals by creating a network map using VOSviewer. This figure shows the co-citation intensity of major journals through this network map. The network clustering (color) and the sizes of journals are determined by Linlog/modularity analysis method of VOSviewer.

Figure 2: Co-Citation Map of OECD Subject Categories (29 sub categories) Network Visualization*



*Network Visualization Using VOSviewer (SCIE journals, OECD FOS subject area mapping, co-citation matrix was normalized by VOSviewer's association method)

Figure 3: Co-citation Map of SCIE Journals Network Visualization*



*Network map was created by using VOSviewer, Co-citation matrix was normalized by VOSviewer's Linlog/modularity method

Ranking Change Experiment of SCIE Journals based on KSCD

We investigated the effect of the SCIE journals' IF (2 years) adjusted by the Korean natural science and engineering journals on the ranking of SCIE journals compared to the existing IF ranking. We used the 2014 JCR for SCIE that was published in 2015. The ranges of experiment data include the 2014 citation records of SCIE journals in the KSCD natural science and engineering areas (presented in Table 1 and 2), and based on this data range, we only used 2012-2013 citation records for recalculating the IF (2 years).

Since JCR already included the citation records of 93 Korean SCIE journals in natural science and engineering, we excluded them in this data analysis. Therefore, the final experiment target includes the 36,994 citation records of Korean natural science and engineering journals for 5,454 SCIE journals mapped in 8,618 SCIE journals in 2014 JCR. There was a total of 3,164 SCIE journals that were excluded from this data analysis because we only focused on the Korean journals in natural science and engineering of KSCD.

For the experiment procedure, first, we added the citation records of KSCD journals into the citation frequencies of 2014 JCR journals from 2009 to 2013 for each year. Second, we calculated the IF (2 years) based on the aggregated citation frequencies for each JCR journal. Third, we compared the IF (2 years) of 2014 JCR and the aggregated IF (2 years) for each JCR journal. Fourth, we analyzed the updated data for each journal by OCED and WOS subject category. We also analyzed the relationship between the existing index and the aggregated index for 'Electrical & Electronic Engineering', which was used in the specific experiment of the prior JCR ranking change experiment based on KSCD (Lee et al. 2012).

We then calculated the difference of ranking change for each journal based on the IF (2 years) of 2014 JCR and the percent rank value of the newly aggregated IF (2 years). Table 6 presents the top 20 SCIE journals that have the largest differences. Those top 20 journals are all from the SCIE journals published in the Republic of Korea (c.f., 45 Korean journals out of 50 SCIE

journals, and 56 Korean journals out of 100 SCIE journals). This result indicates that citation records from Korean natural science and engineering journals significantly influence the rank change of the Korean SCIE journals rather than other SCIE journals from other nations. This result suggests that as more Korean natural science and engineering journals move into SCIE journals, the influence of Korean journals would increase their citation impacts of the existing and newly added Korean SCIE journals.

Table 6: The List of Top 20 Journals for Ranking Change Experiment

Rank	WOS Subject Category	WOS Journal Title	(A) JCR 2014 IF (2year)	(B) Percent Rank of (A)	(C) Aggregated IF (2year)	(D) Percent Rank of (C)	Rank Change (D-B)
1	Optics	Journal of the Optical Society of Korea	1.179	30.3%	1.833	50.0%	19.7%
2	Construction & Building Tech.	Steel & Composite Structures	0.964	23.5%	1.604	43.2%	19.7%
3	Mechanical Engineering	Intl' Journal of Precision Eng. & Manufacturing	1.205	31.1%	1.81	49.3%	18.2%
4	Material Science, Multidisciplinary	Electronic Materials Letters	1.98	53.9%	2.81	71.9%	18.0%
5	Civil Engineering	Structural Engineering & Mechanics	0.927	21.7%	1.464	38.9%	17.2%
6	Civil Engineering	Earthquakes and Structures	0.693	13.6%	1.219	30.8%	17.2%
7	Civil Engineering	Geomechanics and Engineering	0.604	10.4%	1.057	26.0%	15.6%
8	Construction & Building Tech.	Computers and Concrete	0.869	19.6%	1.34	34.9%	15.3%
9	Meteorology & Atmospheric Sci.	Asia-Pacific Journal of Atmospheric Sciences	1.347	35.6%	1.851	50.5%	14.9%
10	Mechanical Engineering	International Journal of Automotive Technology	0.969	23.7%	1.45	38.5%	14.8%
11	Electrical & Electronic Eng.	Journal of Power Electronics	0.777	16.3%	1.214	30.6%	14.3%
12	Metallurgy & Metallurgical Eng	Korean Journal of Metals and Materials	1.405	37.4%	1.883	51.2%	13.8%
13	Chemistry, Multidisciplinary	Carbon Letters	1.625	44.4%	2.138	57.5%	13.1%
14	Mechanical Engineering	Journal of Mechanical Science & Technology	0.838	18.7%	1.232	31.4%	12.7%
15	Civil Engineering	Smart Structures and Systems	1.368	36.3%	1.789	48.8%	12.5%
16	Metallurgy & Metallurgical Eng	Metals and Materials International	1.579	43.1%	2.061	55.5%	12.4%
17	Polymer Science	Polymer-Korea	0.528	8.1%	0.901	20.2%	12.1%
18	Automation & Control Systems	Intl' Journal of Control Automation & Systems	0.954	22.9%	1.321	34.3%	11.4%
19	Biochemical Research Method	Biochip Journal	1.09	27.5%	1.43	37.6%	10.1%
20	Telecommunications	ETRI Journal	0.771	16.1%	1.058	26.0%	9.9%

Table 7 presents the comparison between the 2014 IF (2 years) of the journals and the percentage rank of aggregated index by subject areas. The significant ranking increase was observed in engineering followed by natural science, agricultural, water, and ocean sciences, and medical and pharmaceutical sciences by reviewing the main categories that have more than 100 journals. By reviewing the mid-category, in natural science, 'Computer and Information Sciences' has the highest-ranking change rate (42.6%), and in engineering, there are a number of mid-categories which have more than 50 percent of ranking change, including: 'Nano-Technology' (100%), 'Civil Engineering' (60.7%), 'Electrical Engineering, Electronic Engineering' (59.9%), 'Environmental Engineering' (53.1%), 'Chemical Engineering' (52.9%), 'Mechanical Engineering' (50.8%). In conclusion, this results of this research indicate that citation records by Korean natural science and engineering journals can change the ranking of SCIE journals in the entire engineering disciplines, rather than in the natural science disciplines.

Table 7: Ranking Change Result by Subject Areas (IF based on KSCD VS. Existing 2014 JCR IF)

Main Category	Mid-Category	No. of journals	IF 2 year N>O	IF 2 year N<=O	IF 2 year N>O rate
National Science	Computer and Information Sciences	202	86	116	42.6%
	Earth & Related Environ. Sciences	338	72	266	21.3%
	Mathematics	346	67	279	19.4%
	Physical Sciences and Astronomy	218	39	179	17.9%
	Chemical Sciences	285	49	236	17.2%
	Biological Sciences	780	129	651	16.5%
	Other Natural Sciences	24	2	22	8.3%
	Sub Total	2,193	444	1,749	20.2%
Engineering and Technology	Nano-Technology	1	1	-	100.0%
	Civil Engineering	107	65	42	60.7%
	Electrical & Electronic Engineering	242	145	97	59.9%
	Environmental Engineering	98	52	46	53.1%
	Chemical Engineering	70	37	33	52.9%
	Mechanical Engineering	189	96	93	50.8%
	Other Engineering & Technologies	217	88	129	40.6%
	Materials Engineering	222	79	143	35.6%
	Environmental Biotechnology	82	29	53	35.4%
	Medical Engineering	58	14	44	24.1%
	Industrial Biotechnology	5	1	4	20.0%
	Sub Total	1,291	607	684	47.0%
Medical and Health Sciences	Basic Medical Research	402	33	369	8.2%
	Health Sciences	321	25	296	7.8%
	Clinical Medicine	912	46	866	5.0%
	Sub Total	1,635	104	1,531	6.4%
Agricultural Sciences	Other Agricultural Science	7	2	5	28.6%
	Animal and Dairy Science	32	7	25	21.9%
	Agriculture, Forestry, Fisheries	145	23	122	15.9%
	Veterinary Science	51	5	46	9.8%
	Sub Total	235	37	198	15.7%
Social Sciences	Economics and Business	33	11	22	33.3%
	Educational Sciences	20	1	19	5.0%
	Psychology	41	1	40	2.4%
	Sub Total	94	13	81	13.8%
Humanities	History and Archaeology	6	1	5	16.7%
	Grand Total	**5,454**	**1,206**	**4248**	**22.1%**

Finally, we analyzed the correlation in the specific area of 'Electrical & Electronic Engineering', in which the prior study on JCR ranking change experiment was conducted by reflecting KSCD (Lee at al. 2012). The Pearson correlation coefficients show the significant correlations in the overall ranges except for two of these ranges that were less than 0.6; the correlation coefficient for the range of 91 to 100 was lower than 0.5, which shows a low relationship (Table 8). Therefore, this research confirmed that the citations by the Korean natural science and engineering journals in KSCD can significantly influence the ranking changes in the various subject areas of JCR.

Table 8: Pearson Correlation Coefficients of Journal Ranking Changes based on IF (2 years) (Electrical & Electronic Engineering)

Ranking Range (KSCD+JCR 2014)	Results of Correlation Analysis (comparison: JCR 2014)
1-10	1.0000
11-20	0.9758
21-30	0.9030
31-40	0.9879
41-50	0.9766
51-60	0.9861
61-70	0.9649
71-80	0.5430
81-90	0.9152
91-100	0.3435
101-110	0.8630
111-120	0.9028
121-130	0.9656
131-140	0.9850

DISCUSSION

This research analyzed the citation impact of Korean natural science and engineering journals, which have the highest citations toward SCIE journals. The scope of the experiment includes the SCIE citation data by the Korean journals in natural science and engineering from 2009 to 2014, and this research conducted citation analysis and co-citation network analysis. We also conducted the ranking change experiment in major citation indexes by applying citation data from Korean journals into 2014 JCR.

First, this research measured the citation age such as citation status, citation peak-time, and citation half-time by journal and subject area. The results indicate that 311 journals have more than 1,000 citations, accounting for more than 50 percent of total citations among a total of 7,603 SCIE journals. In addition, natural science have the highest number of citations (3,038 journals, 45.8% of share rate) followed by engineering (1,525 journals, 35.5% of share rate). The natural science has a higher number of journals cited and number of citations than engineering, however, engineering has more citation rates by number of journals. According

to the mid-subject category in natural science, Biological Sciences (13.3%) and Chemical Sciences (9.5%) have high share rates by number of citations compared to the entire citations. In engineering, Materials Engineering (7.5%) and Electrical & Electronic Engineering (6.5%) have a high citation share rate. Based on the results of citation age analysis, engineering journals have high immediacy citation rate (natural science: 1.4% vs engineering: 1.9%), citation peak-time (natural science: 3 years vs engineering: 2 years), and citation half-time (natural science: 8.1 years vs engineering: 6.5 years) compared to the natural science journals. In both engineering and natural science, the immediacy citation rate was 1.6 percent; the citation peak-time was 3 years, and the citation half-time was 7.3 years, which is relatively lower than Choi and colleagues' recent study (i.e., 9 years) with international engineering journals (Choi et al. 2013). Since the engineering journals have more application research, their SCIE journal articles were consumed and in decline quickly compared to natural science, which pursue more fundamental science research.

Second, this research visualized the co-citation network of SCIE journals and subject areas based on the citations by Korean natural science and engineering journals and measured the network centrality indexes by subject area and journal. In natural science, 'Other Natural Sciences' has the highest averages of weighted degree (i.e., local degree centrality) and betweenness centrality, and 'Chemical Sciences' has the highest average of closeness centrality. In engineering, 'Other Engineering and Technologies' has the high sum of degree, and 'Industrial Biotechnology' has the highest averages of weighted degree (i.e., local degree centrality), closeness centrality, and betweenness centrality. The engineering journals have higher centrality indexes except betweenness centrality as compared to natural science journals.

Third, we calculated the difference of ranking change for each journal based on the percent rank of aggregated IF (2 years) by reflecting 5-year journal IF of 2014 JCR and the citation records of Korean natural science and engineering journals in KSCD. We found that the Korean SCIE journals are included within the top 20 rank (45 Korean SCIE journals in the top 50, and 56 Korean SCIE journals in the top 100), which shows that the Korean journals significantly influence the ranking change of Korean SCIE journals rather than other SCIE journals from other nations. This result confirmed what Miguel-Dasit et al. (2005) found about Spanish journals' positive impact on the existing JCR ranking especially focusing on European journals. Additionally, by comparing the 2014 JCR IF (2 years) of journals and the percentage index rank of the aggregated index by subject areas, we found that the major subject areas for the ranking changes (i.e., increase of ranking) of journals include: engineering followed by natural science, agricultural, water, and ocean sciences, and medical and pharmaceutical sciences by the main categories. According to the mid-category, in natural science, 'Computer and Information Sciences' has the highest-ranking change ratio (42.6%). In engineering, the mid-categories that have more than 50 percent of ranking change ratio includes: 'Nano-Technology' (100%), 'Civil Engineering' (60.7%), 'Electrical Engineering, Electronic Engineering' (59.9%), 'Environmental Engineering' (53.1%), 'Chemical Engineering' (52.9%), and 'Mechanical Engineering' (50.8%). We also analyzed the correlation in the specific area of 'Engineering, Electrical & Electronic', in which the prior study on JCR ranking change experiment was conducted by reflecting KSCD. The Pearson correlation coefficients show the significant correlations in the overall ranges, except two ranges which have less than 0.6; the correlation coefficient for the range of 91 to 100 is lower than 0.5, which shows a very low correlation. This finding supports what Lee et al. (2012) found from their JCR ranking change experiment. Therefore, this research confirmed that the citations by the Korean natural science and engineering journals in KSCD can significantly influence the ranking changes in the various subject areas of JCR.

This research has diverse practical implications. First, the results of this research can be used for Korean academic libraries to subscribe appropriate academic journals for their researchers as a guideline. Korean academic libraries mostly utilize JCR as a guideline for their journal subscriptions; however, this research can provide a new guideline for Korean academic libraries to evaluate a number of SCI journals for subscription. Second, the results of this research can be also used for scholarly search services in Korea (e.g., Korean National Digital Science Library and scholarly search in Naver.com) to recommend highly cited SCIE academic journals in Korea. Especially, those scholarly search services in Korea can prioritize their search results based on the updated journal rankings from this study. Third, the research method and procedure in this research can be applied for other Asian countries to develop their own JCR rankings based on their researchers' usages and needs of academic journals. This will eventually help domestic academic libraries in Asian countries to better identify suitable academic journals and provide better scholarly services in their countries.

CONCLUSION

This research showed that the Korean natural science and engineering journals have significant citation impacts on SCIE journals in terms of JCR ranking changes. First, we found that the articles in engineering are rapidly used up than the articles in natural science by reviewing the cited numbers and citation age through the citation analysis of the cited SCIE journals. Second, this research showed that the Korean journal citations significantly affect the existing journal IF (2 years) and the JCR journal rankings in engineering and natural science journals. Third, this research suggested that the impact of Korean journals on SCIE journals can be utilized for the evaluation of existing journals in a national perspective. Finally, this research recommended that Asian countries can consider to develop their own revised JCR rankings to better evaluate the existing JCR rankings by reflecting the citations of their countries' academic journals into JCR.

In terms of future research, first, it is necessary to analyze the citation impact of the entire research areas of science and technology by including health sciences in Korea. Also, future research can extend the current research to the citation impact of Korean social science journals toward SSCI journals. Second, future research can examine the citation impact of domestic journals toward academic conference proceedings, especially in computer sciences, which have high citation rates toward academic conference proceedings. Third, future research can be extended to investigate the authors and research institutions of journal articles in terms of their citation status and author co-citation network. Additionally, in the technical perspective, future research can consider developing a scholarly information database for identifying authors, articles, and their references more rapidly and precisely. The scholarly information database can be utilized to monitor the citation status of domestic journals toward SCIE and SSCI journals and provide better scholarly services for domestic researchers in Asian countries.

ACKNOWLEDGEMENT

This research received no specific grant from any funding agency in the public, commercial, or not-for profit sectors.

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APPENDIX

Appendix A: List of Top 20 Journals in Natural Science and Engineering (based on the number of citation)

Main Category	Mid-Category	Journal Title	Abbreviated Journal Title	No. of Citation	Immediacy Citation Rate	Citation Peak-Time	Citation Half-time
Natural Science	Physical sciences and astronomy	APPLIED PHYSICS LETTERS	APPL PHYS LETT	14,543	0.6%	5	7.2
	Other natural sciences	SCIENCE	SCIENCE	14,405	0.4%	9	10.4
	Earth & related environmental sciences	ECOLOGICAL ECONOMICS	ECOL ECON	11,931	0.8%	11	9.3
	Biological sciences	JOURNAL OF BIOLOGICAL CHEMISTRY	J BIOL CHEM	11,801	0.6%	8	10.9
	Other natural sciences	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	P NATL ACAD SCI USA	11,065	0.7%	5	10.0
	Physical sciences and astronomy	JOURNAL OF APPLIED PHYSICS	J APPL PHYS	9,285	0.6%	6	10.7
	Chemical sciences	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	J AM CHEM SOC	8,894	0.4%	5	8.9
	Physical sciences and astronomy	PHYSICAL REVIEW B	PHYS REV B	8,428	0.6%	5	10.2
	Physical sciences and astronomy	PHYSICAL REVIEW LETTERS	PHYS REV LETT	7,945	0.6%	6	10.2
	Chemical sciences	JOURNAL OF APPLIED POLYMER SCIENCE	J APPL POLYM SCI	6,246	1.0%	3	8.1
	Earth and related environmental sciences	ENVIRONMENTAL SCIENCE & TECHNOLOGY	ENVIRON SCI TECHNOL	6,034	0.6%	5	8.3
	Chemical sciences	JOURNAL OF POWER SOURCES	J POWER SOURCES	5,946	1.8%	3	5.0
	Earth and related environmental sciences	WATER RESEARCH	WATER RES	5,406	1.1%	9	8.6
	Chemical sciences	POLYMER	POLYMER	5,111	0.5%	9	8.0
	Chemical sciences	MACROMOLECULES	MACROMOLECULES	4,929	0.2%	7	9.9
	Chemical sciences	ADVANCED MATERIALS	ADV MATER	4,554	1.4%	4	5.8
	Biological sciences	PLANT PHYSIOLOGY	PLANT PHYSIOL	4,178	0.6%	5	9.6

	Chemical sciences	JOURNAL OF PHYSICAL CHEMISTRY B	J PHYS CHEM B	3,879	0.2%	8	7.4
	Biological sciences	BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS	BIOCHEM BIOPH RES CO	3,597	1.9%	4	7.1
	Physical sciences and astronomy	JOURNAL OF THE KOREAN PHYSICAL SOCIETY	J KOREAN PHYS SOC	3,538	4.0%	2	1.8
Engineering and Technology	Environmental biotechnology	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	APPL ENVIRON MICROB	7,529	0.5%	9	10.7
	Other engineering and technologies	FOOD CHEMISTRY	FOOD CHEM	5,942	3.3%	3	4.4
	Materials engineering	THIN SOLID FILMS	THIN SOLID FILMS	5,854	1.0%	4	6.7
	Civil engineering	JOURNAL OF HAZARDOUS MATERIALS	J HAZARD MATER	5,274	2.3%	4	3.8
	Mechanical engineering	JOURNAL OF SOUND AND VIBRATION	J SOUND VIB	5,200	0.8%	5	9.1
	Materials engineering	MATERIALS SCIENCE AND ENGINEERING A-STRUCTURAL MATERIALS PROPERTIES MICROSTRUCTURE AND PROCESSING	MAT SCI ENG A-STRUCT	4,768	1.1%	5	6.3
	Chemical engineering	JOURNAL OF MEMBRANE SCIENCE	J MEMBRANE SCI	4,500	1.6%	6	6.5
	Industrial biotechnology	BIOMATERIALS	BIOMATERIALS	4,290	1.2%	6	6.6
	Electrical eng, electronic eng	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	IEEE T IND ELECTRON	4,131	2.2%	3	4.5
	Materials engineering	LANGMUIR	LANGMUIR	4,074	0.7%	7	7.0
	Materials engineering	JOURNAL OF THE AMERICAN CERAMIC SOCIETY	J AM CERAM SOC	3,926	0.5%	4	11.5
	Civil engineering	ENGINEERING STRUCTURES	ENG STRUCT	3,923	1.1%	4	5.8
	Other engineering and technologies	JOURNAL OF MATERIALS PROCESSING TECHNOLOGY	J MATER PROCESS TECH	3,870	0.8%	6	6.7
	Electrical eng, electronic eng	IEEE TRANSACTIONS ON POWER ELECTRONICS	IEEE T POWER ELECTR	3,663	2.6%	2	5.2
	Other engineering and technologies	JOURNAL OF FOOD SCIENCE	J FOOD SCI	3,506	0.2%	17	18.6
	Materials engineering	APPLIED SURFACE SCIENCE	APPL SURF SCI	3,413	2.4%	3	4.5
	Materials engineering	JOURNAL OF ALLOYS AND COMPOUNDS	J ALLOY COMPD	3,395	3.6%	3	3.6
	Materials engineering	CARBON	CARBON	3,387	1.8%	7	6.9
	Materials engineering	NANO LETTERS	NANO LETT	3,349	1.1%	6	4.6
	Materials engineering	CHEMISTRY OF MATERIALS	CHEM MATER	3,335	0.2%	6	7.6

Appendix B: List of Top 20 Journals in Natural Science and Engineering (based on Co-citation Network Centrality, Degree Sum)

Main Category	Mid-Category	Journal Title	Abbreviated Journal Title	degree	weighted degree	Closeness centrality	Betweenness centrality
Natural Science	Other natural sciences	SCIENCE	SCIENCE	5091	12713.3	0.8	0.07557
	Earth and related environmental sciences	ECOLOGICAL ECONOMICS	ECOL ECON	4899	10576.1	0.7	0.06591
	Other natural sciences	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA	P NATL ACAD SCI USA	4668	10020.3	0.7	0.06114
	Biological sciences	JOURNAL OF BIOLOGICAL CHEMISTRY	J BIOL CHEM	3471	10324.5	0.6	0.01087
	Biological sciences	BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS	BIOCHEM BIOPH RES CO	2985	3344.2	0.6	0.00579
	Chemical sciences	ANALYTICAL BIOCHEMISTRY	ANAL BIOCHEM	2601	2165.2	0.6	0.00354
	Chemical sciences	ANALYTICAL CHEMISTRY	ANAL CHEM	2533	2850.0	0.6	0.00491
	Other natural sciences	ANNALS OF THE NEW YORK ACADEMY OF SCIENCES	ANN NY ACAD SCI	2513	784.2	0.6	0.00647
	Biological sciences	FEBS LETTERS	FEBS LETT	2509	1934.3	0.6	0.00313
	Chemical sciences	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	J AM CHEM SOC	2496	7304.2	0.6	0.00548
	Biological sciences	NUCLEIC ACIDS RESEARCH	NUCLEIC ACIDS RES	2492	2528.4	0.6	0.00470
	Other natural sciences	NATURE	NATURE	2490	1649.0	0.6	0.00491
	Biological sciences	BIOCHEMICAL JOURNAL	BIOCHEM J	2354	1666.7	0.6	0.00219
	Other natural sciences	PLOS ONE	PLOS ONE	2236	651.1	0.6	0.00376
	Earth and related environmental sciences	ENVIRONMENTAL SCIENCE & TECHNOLOGY	ENVIRON SCI TECHNOL	2196	4501.4	0.6	0.00436
	Biological sciences	FASEB JOURNAL	FASEB J	2136	993.9	0.6	0.00187
	Biological sciences	PHYTOCHEMISTRY	PHYTOCHEMISTRY	2101	1939.0	0.6	0.00238
	Chemical sciences	JOURNAL OF CHROMATOGRAPHY A	J CHROMATOGR A	2101	2037.1	0.6	0.00251
	Biological sciences	BIOCHEMISTRY	BIOCHEMISTRY-US	2097	1529.0	0.6	0.00148
	Biological sciences	MOLECULAR CELL	MOL CELL	1987	1669.0	0.6	0.00144
Engineering and Technology	Environmental biotechnology	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	APPL ENVIRON MICROB	2663	6155.7	0.6	0.00619
	Other engineering and technologies	FOOD CHEMISTRY	FOOD CHEM	2343	4788.8	0.6	0.00322

	Industrial biotechnology	BIOMATERIALS	BIOMATERIALS	2342	3358.4	0.6	0.00461
	Environmental biotechnology	NATURE BIOTECHNOLOGY	NAT BIOTECHNOL	2315	1490.1	0.6	0.00320
	Other engineering and technologies	FOOD AND CHEMICAL TOXICOLOGY	FOOD CHEM TOXICOL	2157	1405.1	0.6	0.00233
	Environmental biotechnology	APPLIED MICROBIOLOGY AND BIOTECHNOLOGY	APPL MICROBIOL BIOT	2136	2613.4	0.6	0.00231
	Other engineering and technologies	BIOSCIENCE BIOTECHNOLOGY AND BIOCHEMISTRY	BIOSCI BIOTECH BIOCH	2065	1705.5	0.6	0.00170
	Environmental biotechnology	JOURNAL OF MICROBIOLOGY AND BIOTECHNOLOGY	J MICROBIOL BIOTECHN	1962	1877.4	0.6	0.00153
	Environmental biotechnology	BIOTECHNOLOGY AND BIOENGINEERING	BIOTECHNOL BIOENG	1934	1701.9	0.6	0.00186
	Materials engineering	LANGMUIR	LANGMUIR	1920	3440.6	0.6	0.00221
	Civil engineering	JOURNAL OF HAZARDOUS MATERIALS	J HAZARD MATER	1871	4218.3	0.6	0.00312
	Environmental biotechnology	TRENDS IN BIOTECHNOLOGY	TRENDS BIOTECHNOL	1840	798.1	0.6	0.00155
	Medical engineering	CLINICAL CHEMISTRY	CLIN CHEM	1772	621.1	0.6	0.00166
	Environmental biotechnology	JOURNAL OF BIOTECHNOLOGY	J BIOTECHNOL	1749	1108.1	0.6	0.00123
	Other engineering and technologies	JOURNAL OF FOOD SCIENCE	J FOOD SCI	1682	2779.7	0.6	0.00159
	Chemical engineering	PROCESS BIOCHEMISTRY	PROCESS BIOCHEM	1640	1805.6	0.6	0.00101
	Other engineering and technologies	FOOD SCIENCE AND BIOTECHNOLOGY	FOOD SCI BIOTECHNOL	1631	1734.2	0.5	0.00094
	Other engineering and technologies	JOURNAL OF BIOSCIENCE AND BIOENGINEERING	J BIOSCI BIOENG	1619	759.9	0.6	0.00086
	Chemical engineering	INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH	IND ENG CHEM RES	1606	2635.8	0.6	0.00244
	Environmental biotechnology	ENZYME AND MICROBIAL TECHNOLOGY	ENZYME MICROB TECH	1593	1486.3	0.5	0.00098