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Knowledge flow out of the domain of information science: a bibliometric and citation analysis study

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Abstract Through the bibliometric approach and citation analysis, this study analyzes the disciplines and subjects of literature citing important information science journals during the period from 1998 to 2010. The four information science journals under study include *Journal of the American Society for Information Science and Technology, Information Processing and Management,* the *Journal of Information Science,* and *the Journal of Documentation*. The Ulrich's Periodical Directory, Library of Congress Subject Headings retrieved from WorldCat and the LISA database were used to identify the main classes, subclasses, and subjects of citing journals. We also indentify and analyze the highly citing journals, the main classes and subclasses of citing journals for the four journals under study as well as highly cited subjects in journals related to library and information science. Overall, the knowledge flow out of the domain of information science mainly includes information science itself, and also science and technology at a lower percentage. Moreover, there are minor outputs for various other subjects. The comparison of knowledge flow into and out of the domain of information science reveals the main knowledge flow is into information science itself. This comparison also reveals significant knowledge flow from computer science to information science.

Keywords Bibliometric study · Citation analysis · Subject analysis · Knowledge output · Information science journal

Introduction

It is well-accepted that information science is an interdisciplinary science involving the interaction of many other disciplines, such as mathematics, logic, linguistics, psychology,

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computer technology, operations research, the graphic arts, communications, library science, management, and other similar fields. Saracevic (1999) pointed out that "information science is interdisciplinary in nature," "is connected to information technology" and is "an active participant in the evolution of the information society with a strong social and human dimension, above and beyond technology." Through the study of the origin of information from various perspectives, Saracevic also found information science is related to other fields based on several aspects, including "historical, sociological, philosophical, technological, educational, and interdisciplinary." Knowledge flow is a phenomenon of knowledge in a specific subject field used by another subject field. Knowledge flow can be measured through citation analysis. Knowledge flow out of the subject being cited occurs when the knowledge in a subject field is cited by a paper or book in another subject field. On the other hand, if a subject is citing the knowledge of another subject field, it can be treated as knowledge flow into the citing subject. Exploring the knowledge flow between information science and other related disciplines through the study of interaction between information science and various related disciplines is, therefore, of significant interest.

Bibliometric techniques using citation analysis may facilitate the study of scholarly communication flow. For example, citations can be clustered to identify the flow of topics within and among disciplines. Such techniques can also be used to map relationships among documents, journals or other channels of scholarly communications (Borgman 1999). Indeed, citation analysis is an important area of library and information science (LIS). From studies of citation analysis, one can understand which scholars from which disciplines cite which articles, which journals are cited more often and which disciplines cite the journals of other disciplines (Desai 2003). The results of citation analysis can serve many purposes, for example, to determine the impact of specific articles or journals on subsequent research and to document the interdisciplinary applicability of various journals (Harter 1996).

Tsay (2011) explored and compared bibliometric characteristics and subject relationship with other disciplines of and among three information science journals, including the *Journal of the American Society for Information Science and Technology* (JASIST), *Information Processing and Management* (IPM) and the *Journal of Documentation (JOD)*. Their study confirmed that all three journals are information science oriented, while JOD is library science oriented. JASIST and IPM are very common and diffuse to other disciplines more deeply than does JOD. Tsay (2013) further explored the knowledge flow input for the domain of information science through the analysis of the cited references of each article of four information science journals, JASIST, IPM, JOD and the *Journal of Information Science* (JIS) from 1998 to 2008. Their study revealed the knowledge flow into the domain of information science mainly includes information science itself and social sciences, and also general science at a lower percentage. In addition, there are minor inputs from various subjects.

Following our previous study on knowledge input to the domain of information science, the present study investigates the knowledge flows out of information science, and conducts bibliometric and citation analysis of four representative journals in this subject, namely, JASIST, IPM, JOD and JIS. These four journals are recognized as general-purpose journals, which publish articles about and from most areas of disciplines related to information science as revealed in the scope statements of the journals. Based on the bibliometric and citation analysis of these four representative journals in the field of information science, the present study may enhance our understanding of the interactions among the disciplines relating to information science and further reveal the major kinds of knowledge flowing out of the domain of information science. Moreover, a comparison

between the knowledge flow into (in Tsay's study) and knowledge flow out of information science is also given in the present study.

Literature review

There are many studies examined the insights and outsights of the subject field based on references and citations. Some bibliometric studies have analyzed the citing references of one or more of the four representative information science journals selected in the present study, i.e., JASIST, IPM, JOD and JIS. These relevant previous studies would be reviewed in the following:

For the purpose of exploring the nature of research in librarianship, Nour (1985) conducted a study based on a total of 343 research articles published in 41 core library journals during 1980 on subject, research methodology, and number of references. The study revealed that (1) the source articles were mainly from six subjects: administration (21 %), library service (20 %), materials (16 %), automation (14 %), technical processes (13 %) and history (7 %). (2) The research articles cited by the sample source articles were mainly (80 %) in the field of LIS. (3) The references made by the sample source articles were to journals outside the 41 core journals accounts for only about 38 %.

Employing a concept analysis method, Houser (1988) used the first 15 volumes of the Journal of the American Society for Information Science (JASIS) to explore the nature of information science and to examine the relationship between the domains of information science and library science. It was found that the majority of JASIS authors which could be identified were from library science and a majority of them taught in library science. It was also found that information science is merely library science and there is no inter- or multidisciplinarily in the field of information science.

Jarvelin and Vakkari (1990) **r**eported a study analyzing the content of research articles in the field of LIS to find out how international research in LIS is distributed over various topics and what approaches and methods have been used to investigate these topics. The study revealed that the contribution of library and information service activities and information storage and retrieval among the topics of the research articles were each nearly 30 %. Research on information seeking (6 %) and scientific communication (7 %) were comparatively insignificant.

Moreover, Jarvelin and Vakkari (1993) conducted a content analysis of the research of LIS from 1965 to 1985. The aim was to find out how international research in LIS was distributed over topics, and what approaches and methods had been used to investigate these topics. The study samples were 142, 359, and 449 full-length research articles published in 1965, 1975, and 1985, respectively, in core LIS journals. The library and information service activities, and information storage and retrieval among the topics of the research articles contributed each about 25–30 % through the years, while the contribution of research on methodology (1–8 %), information seeking (6–8 %), and scientific communication (5–7 %) were relatively small.

White and McCain (1998) explored the domain knowledge of the information science field from 1972 to 1995 by author co-citation analysis of highly cited authors. They identified 12 subjects of information science as follows: experimental retrieval, citation analysis, practical retrieval, bibliometrics, general library systems theory, user theory, scientific communication, OPAC, imported ideas, indexing theory, citation theory and communication theory. Their findings demonstrate the development of information science within these various subjects during the study period. Peritz and Bar-Ilan (2002) investigated the extent to which the field of bibliometrics and scientometrics makes use of sources

outside the field in 1990 and 2000, respectively. The results revealed that in 2000, 57 % (and 47 % in 1990) of references originated from three fields: scientometrics and bibliometrics; library and information science; and the sociology, history and philosophy of science.

Astrom (2007) analyzed articles from 21 LIS journals, including the four journals selected in the present study, covering the years 1990–2004, and analyzed references found in these articles as indexed in the Web of Science to determine what research topics dominated LIS during the study period. The 66 most-cited documents receiving 50 citations or more were selected for further analysis. His analysis was conducted on a document level as opposed to an analysis on the author level. The findings of Astrom's study revealed that the two main areas of LIS research are information-seeking and retrieval and informetrics. His cluster analysis resulted in eight clusters, i.e., experimental information retrieval (IR), IR/information search, IR/relevance, information seeking and use/cognitive IR, information seeking and use/information behavior, bibliometric mapping, bibliometric distributions and World Wide Web/webometrics.

By employing bibliometric techniques and incorporating with methods of reference analysis, content analysis and faceted classification, Gornstein and Periz (2013) explored the concepts of LIS during the years 1985–2006. The results of their reference analysis revealed that LIS cite references mostly within LIS (84 %), while much less for other fields (15 %). Moreover, LIS is influenced mostly by the social science disciplines.

Objectives

The literature review above reveals that most previous studies carried out bibliometric analysis of a single journal or two or three of the four journals studied here, i.e., JIS, JOD, IPM, and JASIST. Some studies built domain knowledge structure by co-citation analysis based on authors or journals. However, subject analysis of the citing literature has seldom been studied. The main objective of the present study is to explore the knowledge output from the domain of information science, based on the analysis of the subjects of citation received by JASIST, IPM, JOD and JIS from 1998 to 2010.

McCarthy (2000) selected JASIST, IPM and JIS as the three representative research journals of the century in information science on the basis of the following three studies: (1) an open-ended survey of colleagues at the University Library and Graduate School of Library and Information Science of the University of Rhode Island, (2) literature review and (3) inclusion at least two well-established indexes, e.g., *Library Literature*; *Library and Information Science Abstracts*; *Information Science Abstracts*; and *Social Science Citation Index Journal Citation Reports*. A search of *Web of Knowledge, Social Sciences Citation Index Journal Citation Reports* (2011) show that JASIST, IPM, JIS and JOD are related journals. In particular, JOD is the journal with the highest correlation with JASIST. Therefore, JOD is also included in the present study. Moreover, Paisley (1990) also proposed that IPM, JASIST and JOD broadly represent the information science field, according to a comment by DeHart (1992).

As stated earlier, these four journals are well recognized as being information science oriented. Indeed, JASIST, IPM, JOD and JIS are considered to represent the information science discipline. A study of the citations of these four information science journals would identify which disciplines cite information science journals and could be very helpful in understanding the relationship between subject areas of information science and other subject disciplines and further reveal the knowledge flowing out of this field. The results of this study may help answer the following questions:

(1) What core journals cite information science journals the most?
(2) What main class, sub-class and subject of journal papers cite information science journals?
(3) What are the subjects of highly cited articles and authors of information science journals?

The answers to these questions may bring to light the knowledge output for the domain of information science. In particular, answering question (3) may identify the subjects and authors contributing most to the knowledge flow out of the domain of information science.

Methodology

The present study employs the cited reference search in WOS to retrieve the articles from the databases of SCIE, SSCI, and AHCI citing a work in one of four information science journals focused on in this study, namely, JIS, JOD, IPM and JASIST, which are abbreviated in the following way during the search:

(1) j am soc inform sci or j am soc inf sci tec (for JASIST)
(2) j inf sci (for JIS)
(3) inform process manag (for IPM)
(4) j doc (for JOD)

Moreover, the cited years range from 1998 to 2010. In total, 2,054 articles in these four journals were cited. In addition, there are 9,579 articles, of which 8,637 (90.2 %) are in journal articles and 942 are non-journal articles citing the four information science journals.

Data collection

Among the 8,637 full-length scholarly papers citing journal articles from 1998 to 2010, 7,616 are research articles and review articles which constitute the samples for this study. In addition, brief communications are identified and their citations are studied in the present work. The electronic version of the citations (bibliographic data) of each article was downloaded and processed using Excel. Other type of materials, such as bibliographies, abstracts sections, book reviews, letters, obituaries, announcements, news items, conference reports, committee reports, features, and editorials are excluded from the analysis.

Some of the data collection activity requires clarification. For subject analysis, only journal citations are considered. Citations other than this type, such as proceedings, theses or reports, are excluded.

Data analysis

With the data collected, the total number of citations received by the four studied journals in the study period and the nature of the citations they received are analyzed. The present work focuses on the subjects of citations of the four journals under study obtained from 1998 to 2010. The present study also identifies the number of citing journals for the four studied journals and the subject matter of these publications.

We further retrieved the main class and subclass of the citing journals from Ulrich's International Periodical Directory (2011) and OCLC WorldCat (2011) on the basis of Library of Congress Classification (LCC). The classification is mainly based on LCC, and supplemented by Dewey Decimal Classification (DDC). In LCC, the first character symbolizes the main class, and the first and second character together represents the subclass. For example, the LCC number for *D-Lib Magazine* is ZA4080, where Z is the main class (Bibliography, Library science, Information resources (General), ZA is the subclass (Information resources, General). If journals were classified by DDC, the corresponding LCC number was examined according to the Dewey-LC Conversion (2011) table made by OCLC. If the corresponding LCC number could not be found, the data was not analyzed. The subject of the citing journals was identified by Library of Congress Subject Headings (LCSH) searched for in OCLC WorldCat. For example, the LCSH of *D-Lib Magazine* includes digital libraries, libraries and electronic publishing, library information networks and electronic publishing. The subject scope of the core citing journals was also identified by Ulrich's International Periodical Directory database of Ulrichsweb as well as the web page of the journal.

The subjects of highly cited journal articles in the four studied journals during the study period for LIS were examined on the basis of the descriptor field of each record in the Library and Information Science Abstracts (LISA) (2011). For example, the descriptors assigned for the article entitled "Information science as 'little science': the implications of a bibliometric analysis of the *Journal of the American Society for Information Science*" by LISA are: bibliometrics, information science, periodicals, articles and *Journal of the American Society for Information Science*. The descriptor field utilized controlled vocabulary from a thesaurus or from a subject headings list created by the database producer. As indicated by Lancaster (1979), a controlled vocabulary controls the synonyms, nearly synonyms, homographs, and related terms; therefore, the search for a descriptor field retrieve items with particular and comprehensive subject meanings.

Results and discussion

Analysis of citing journals

This study first explores the distribution and subjects of citations received by four information science journals during the study period, i.e., from 1998 to 2010. In total, there are 7,616 research articles, published in 833 journals, citing the four information science journals during the study period. As shown later in Table 1, the top ten most citing journals cite at least 121 papers and contribute about 50 % of total citations. These journals are the major citing sources for the four representative journals in the information science domain. This suggests those citing the articles in the four journals under study are concentrated on specific journals and these ten most citing journals may be regarded as highly citing journals. The data also demonstrate about 90 citing journals are needed to cover more than 80 % of citations. Significantly, among the 833 citing journals, 442 or 53.1 % of all citing journals, though not shown in Table 1, cite only a single article in the four journals under study. This suggests journals citing the four represented journals are quite dispersed.

Table 1 Journals contributing the top 50 % of the cumulative citations received by the four journals under study

Rank	Title	No. citing	Citing (%)	Cumulative no. citing	Cumulative citing (%)
1	Journal of the American Society for Information Science and Technology	1,293	16.98	1,293	16.98
2	Information Processing and Management	641	8.42	1,934	25.39
3	Journal of Documentation	418	5.49	2,352	30.88
4	Scientometrics	360	4.73	2,712	35.61
5	Journal of Information Science	315	4.14	3,027	39.75
6	Annual Review of Information Science and Technology	196	2.57	3,223	42.32
7	Library and Information Science Research	176	2.31	3,399	44.63
8	Online Information Review	146	1.92	3,545	46.55
9	Information Research	138	1.81	3,683	48.36
10	Aslib Proceedings	121	1.59	3,804	49.95
Other	823 titles	3,812	50.05	3,812	50.05
Total	833 titles	7,616	100	7,616	100

Highly citing journals

For the highly citing journals, the number of citations, citing percentage, and cumulative number of citing and citing percentage are demonstrated in Table 1. As stated earlier, these top 10 highly citing journals constitute 50 % of all citations. Table 1 indicates these highly citing journals cite at least 120 times the four journals under study. Table 1 also indicates the top five citing journals are JASIST(17 %), IPM(8.4 %), JOD(5.5 %), *Scientometrics*(4.7 %), JIS(4.1 %). The other highly citing journals include *Annual Review of Information Science and Technology* (ARIST), *Library and Information Science Research* (LISR), *Online Information Review*, *Information Research* and *Aslib Proceedings*. JASIST, IPM, JOD and JIS are the source journals of this study. They themselves comprise four of the top five citing journals, contributing about 35 % of citations. This demonstrates a high tendency of self-citation for these journals. This observation is consistent with the findings of Tsay (2013) from a study of citations cited by these four journals during the period from 1998 to 2008.

Bradford distribution and the core of the citing journals

The distribution of the journal literature citing the four journals during the study period was fit to Bradford's law, which is widely used to study journal literature distribution, by plotting the cumulative number of papers for each journal versus the logarithm of its rank. The plot thus obtained, as shown in Fig. 1, is not quite similar to the typical Bradford-Zipf plot, developed by Brookes (1969), which has a characteristic smooth S-shaped curve, with a final droop portion lying below the linear portion of the curve. The figure indicates the curve rises gradually and nonlinearly for about the first top five journals, which make up 40 % of the total citations, followed by an approximately linear portion, from rank 6 to about 100, after which, the curve goes through a droop portion. The top five journals, constituting 3,027 citations (about 40 % of the 7,616 citing literature) may be considered

the core journals citing the four journals, i.e., in the information science domain. The other 828 journals contribute the remaining 60 % of citations. The characteristics of the core citing journals are further investigated in the following section.

The presence of the final droop portion indicates the citing journal literature of the information science domain is widely dispersed to many different journals. Hawkins (1978) suggested this phenomenon might be due to the dispersion of the citing literature. This is consistent with the fact that 442 journals, nearly 53.1 % of the citing journals, cite only once. The scattering of citing journal literature confirms that information science is a multidisciplinary subject broadly influencing literature in various journals though each with a very small percentage compared with that for the core citing journals.

Core and highly citing journals

Descriptions of the subject scopes of the five core citing journals, identified from the Bradford-Zipf plot, and other five highly citing journals are summarized in Table 2. As indicated earlier, eight out of these ten highly citing journals, namely, the JASIST, IPM, JOD, JIS, ARIST, LISR, *Online Information Review* and *Information Research* cover subjects dealing with information science. The fact that most of the highly citing journals are information science oriented is another phase of "self-citation" from the subject point of view. ISI (2004) defines journal self-citation as "when a journal article cites an article from the same journal." In fact, self-citations often make up a significant portion of the citations a journal gives and receives each year. Researchers in information science have more research impact in their own subject fields. In other words, the information science domain has minor influence on other disciplines. The subjects of the highly citing journals demonstrate the main stream of knowledge flow is within the field of information science itself.

Table 2 also illustrates that *Scientometrics* and *Aslib Proceedings* are also on the highly citing journal list, indicating information science also gives knowledge to library science and the quantitative study of science. Indeed, *Aslib Proceedings* is a journal in the broad area of information work and *Scientometrics* is a journal focusing on quantitative aspects of science communication and science policy.

Main classes and subclasses of citing journals

In total, there are 19 main classes of journal papers citing four information science journals, as shown in Table 3. Among them, "bibliography, library science and information resources (general)" is the most dominant, contributing nearly half (60.9 %). This is consistent with the top 10 citing journals which contribute 50 % of all citations. Five out of these 10 journals belong to Z665-718.8, i.e., library science and information science. Two journals categorized into Z662-1000.5, i.e., "libraries". The rest three journals belong to Z671, i.e., libraries-library science-information science-periodicals. The second and third highly citing journals were those categorized under "science" (18.6 %) and "technology" (7.1 %). This table suggests library science is the most citing class of journals, followed by science and technology.

These three most dominant classes of citing journals contribute 86.6 %. The contribution of social sciences (general), medicine, education, etc. account for <6 %. However, this illustrates other disciplines are also influenced by information science to some extent.

On the other hand, there are 86 subclasses of journals citing papers published in the four journals studied here. Table 4 presents the top ten subclasses of the citing journals. Again,

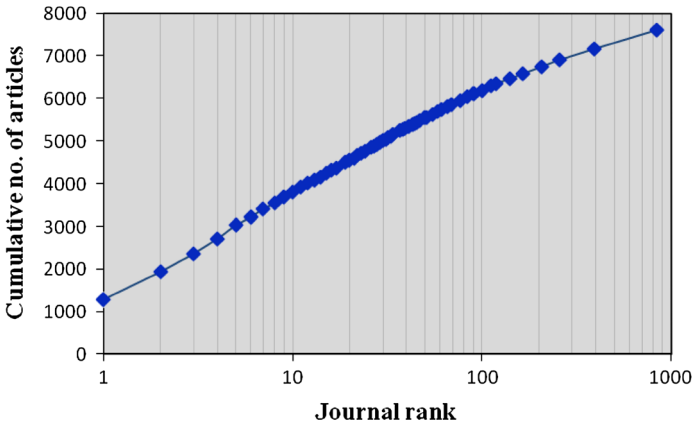

Fig. 1 Bradford-Zipf's distribution of journal literature citing the four journals under study

the most dominant subclass is library science related: "books (general), writing, paleography, book industries and trade, libraries and bibliography" (60.9 %), followed by "mathematics, and computer science" (8.7 %). Note, highly citing journals, e.g., JASIST and JOD are classified in the general bibliography class. Generally, the result is consistent with that of the main classes. Papers published in the four journals cited by the journals mainly dealt with general bibliography, libraries, book industries and trade, and computer science during the study period. Table 4 demonstrates that the top five subclasses contribute 82.3 % of citing journals; the top ten subclasses account for 90.6 %. The rest of the 76 subclasses contribute 9.4 %.

Subjects of citing journals

By examining the LC subject heading of each citing journal, Table 5 illustrates the percentages, in descending order, of citing frequency for each subject of the journals citing the four journals under study here. There were 10,604 citations of the subjects received by the information science journals. The most citing subject is "library and information sciences" (41.9 %), followed by "computers"(23.5 %) with sub-subjects of information science and information theory (15.8 %), artificial intelligence (2.4 %), Internet (2.2 %), computer systems, cybernetics and software. "Library and information sciences-computer applications", "science-comprehensive works", come next in that order. The top two most citing subjects contribute more than half of the citing (65.4 %), while the contribution of each citing subject is <5 % for the rest of the subjects listed in Table 5.

Table 5 suggests information science papers mainly tend to influence issues related to general issues and computer application in library and information science. The second major subject area citing the knowledge of information science is the application of computers in information science and information theory. However, other computer issues related to artificial intelligence, cybernetic and the Internet constitute the other main stream of knowledge flow out of information science. Table 5 also shows other subjects, such as science, business and economics-management, psychology, medical sciences, sociology and education pay some attention to information science. Their citing contribution ranges from 0.6 to 4.5 %.

Table 2 Subject scope of core citing journals for the four journals under study

Rank	Journal title and number of citations	Subject scope
1	Journal of the American Society for Information Science and Technology, (1,293)	Theory of information; communication; management, economics and marketing; applied information science; social and legal aspects of information
2	Information Processing and Management, (641)	Theory, principles, and procedures in information processing; processes of communication among humans and between humans and machines; modeling and evaluation of information system performance; management and economics of information and information systems; information policies
3	Journal of Documentation, (418)	Information science, librarianship; information and knowledge management; information and knowledge organization; information seeking and retrieval, and human information behavior; information and digital literacies
4	Scientometrics, (360)	Quantitative aspects of the science of science, communication in science and science policy
5	Journal of Information Science, (315)	Information science theory, policy application and practice; information creation, organization, storage, communication and utilization of information and knowledge resources
6	Annual Review of Information Science And Technology, (196)	New trends and significant developments in information science and technology
7	Library and Information Science Research, (176)	Research process and research findings in library and information science
8	Online Information Review, (146)	Focuses on information retrieval on the Internet and the latest developments in this rapidly changing field of research. Articles on professional web research, analysis and use
9	Information Research, (138)	Disseminates findings in library and information studies resulting from recent research
10	Aslib Proceedings, (121)	Brings currency, authority and accessibility to the reporting of current research, issues and debates in the broad area of information work

Highly cited journal articles and authors

To understand what knowledge of information science flows out and is highly cited and which subject is of high impact, the present study further investigates the 70 articles which were cited over 50 times through the descriptors indexed by the *Library and Information Science Abstract* (LISA) database. However, three of them are not included in LISA; therefore, only 67 of these 70 highly cited articles are studied to identify the subject distribution. In total, these 67 highly cited articles cover 140 subjects with a total of 272 citations. On average, each of these highly cited articles covers four to five subjects and each subject was investigated by one of these highly cited articles. More discussion is given below.

Table 3 Main classes of journals citing the four journals under study

Rank	Main class	No. citing	%	Cumulative (%)
1	Z—Bibliography, Library Science, Information Resources (General)	4,631	60.85	60.85
2	Q—Science	1,418	18.63	79.48
3	T—Technology	541	7.11	86.59
4	H–Social sciences (General)	434	5.70	92.29
5	R—Medicine	237	3.11	95.40
6	L—Education	105	1.38	96.78
7	B—Philosophy, Psychology and Religion	86	1.13	97.91
8	P–Language and Literature	53	0.70	98.61
9	G—Geography, Anthropology, Recreation	36	0.47	99.08
10	K—Law	22	0.29	99.37
11	A–General Works	8	0.11	99.47
11	J–Political Science	8	0.11	99.58
11	S—Agriculture	8	0.11	99.68
14	M—Music	7	0.09	99.78
15	D–History (General) and History of Europe	6	0.08	99.86
16	N–Fine Arts	5	0.07	99.92
17	C–Auxiliary Sciences of History	4	0.05	99.97
18	F–American History	1	0.01	99.99
18	V–Naval Science	1	0.01	100
Total		7,611		100.00

Table 4 Top ten subclasses of journals citing the four journals under study

Rank	Subclass	No. citing	%	Cumulative (%)
1	Books (General), Writing, Paleography, Book industries and trade, Libraries, Bibliography	4,631	60.85	60.85
2	Mathematics, Computer science	663	8.71	69.56
3	Science (General)	601	7.90	77.45
4	Industries, Land use, Labor	189	2.48	79.94
5	Technology (General)	180	2.36	82.30
6	Electrical engineering, Electronics, Nuclear engineering, Computer hardware	169	2.22	84.52
7	Engineering (General), Civil engineering (General)	130	1.71	86.23
8	Medicine (General)	129	1.69	87.93
9	Commerce	113	1.48	89.41
10	Theory and practice of education	93	1.22	90.63
Other 76 subclasses		713	9.37	100.0

Table 5 Top 14 LC subjects of journals citing the four journals under study

Rank	LC subject	No. citing	%	Cumulative (%)
1	Library and Information Sciences	4,439	41.86	41.86
2	Computers–Information Science and Information Theory	1,671	15.76	57.62
2	Computers–Artificial Intelligence, Internet, Computer Systems, Cybernetic, Software	822	7.75	65.37
3	Library and Information Sciences–Computer Applications	533	5.03	70.40
4	Sciences: Comprehensive Works	477	4.50	74.90
5	Business and Economics—Management	196	1.85	76.75
6	Business and Economics–Computer Applications	190	1.79	78.54
7	Psychology	143	1.35	78.89
8	Medical Sciences	123	1.16	81.05
9	Sociology	121	1.14	82.19
10	Medical Sciences–Computer Applications	83	0.78	82.97
11	Sociology–Computer Applications	78	0.74	83.71
12	Social Sciences: Comprehensive Works	75	0.71	84.42
13	Education–Computer Applications	73	0.69	85.11
14	Education–Higher Education	59	0.56	85.67
Other subjects		1,521	14.34	100.01
Total		10,604	100	

Subject distribution of highly cited articles in information science

By examining the descriptor field of each record in the LISA database, Table 6 illustrates the percentages, in descending order, of citation frequency for each subject term of LIS papers. The most cited subject is "World Wide Web" (7.7 %), followed by "online information retrieval" (7.0 %) and "searching" (6.3 %). Citation analysis areas, including "information seeking behavior" and "research" come next, each with seven citations. There are 17 subjects, about 12 % of the 140 subjects being studied, cited more than two times. The total number of citations of these 17 subjects is 127, accounting for 47 % of all citations. This indicates these 17 subjects are of high impact in the field of information science.

Table 6 suggests the highly cited information science papers tend to deal with issues related to the World Wide Web (including the Internet, websites, search engines, etc.). Table 6 further illustrates the subjects of these highly cited articles are usually accompanied by the World Wide Web or the Internet, indicating that the development of the Internet has significantly affected the research subjects of information science. Indeed, for highly cited articles in information science, researchers prefer to cite subjects related to IR. This is particularly the case for IR in the Internet environment. Many researchers are also interested in informetrics and citation analysis of cited literature. Information seeking behavior, though it contributes only 2.6 % of citations, received continuous attention from researchers. Through quantitative analysis, one may predict the development trend of a particular subject, evaluate the collection in a library, and plan for collection development.

Table 6 Subject distribution of highly cited articles in information science

Rank	Subject	Cited times	%
1	World Wide Web	21	7.7
2	Online information retrieval	19	7.0
3	Searching	17	6.3
4	Citation analysis	7	2.6
4	Information seeking behavior	7	2.6
4	Research	7	2.6
7	Evaluation	6	2.2
8	Internet	5	1.8
8	Links	5	1.8
8	Relevance	5	1.8
8	Search engines	5	1.8
8	Web sites	5	1.8
13	Information science	4	1.5
13	Relevance feedback	4	1.5
13	Scientometrics	4	1.5
16	Children	3	1.1
16	Search strategies	3	1.1
17 subjects with more than two citations		127	47
22 subjects with two citations		44	16
101 subjects with one citation		101	37
Total citations		272	100
Total cited subjects		140	

Author analysis of highly cited articles

There are 1,315 authors of the 2,054 articles cited under information science in this study. This study indentifies twenty-one authors of highly cited articles and compares the number of times cited and the number of articles cited for each author. These 21 authors are all among the top 35 authors on the lists of both number of times cited and number of articles cited. Therefore, these 21 authors may be regarded as the core authors in information science. The main research fields of these 21 core authors in information science include IR, informetrics and information seeking and behavior. Most of these 21 core authors emphasize human–machine interactions, user-oriented studies, digital libraries, Internet mining, information visualization, BLOG and Web 2.0. In particular, webometrics and cybermetrics, which study Internet mining based on bibliometric techniques, are also among the main subjects. This suggests the diversified interests of the authors of information science and library science.

Comparison of knowledge flow into and out of the domain of information science

Based on Tsay's (2013) work and the present study, Table 7 summarize a comparison of knowledge flow into and out of the domain of information science through journal publications. For both knowledge flow in and out through journal publications, the primary

Table 7 Comparison of knowledge flow into and out of the domain of information science—through journals

	Knowledge flow in (Tsay's 2013 study)	Knowledge flow out (present study)
Primary knowledge flow	Ten most cited information science journals: JASIST, IPM, JOD, *Scientometrics*, JIS, *Communications of the ACM*, *Annual Review of Information Science and Technology*, *Library and Information Science Research*, *ACM Transactions on Information Systems*, *Library Quarterly*	Ten most citing information science journals: JASIST, IPM, JOD, *Scientometrics*, JIS, *Annual Review of Information Science and Technology*, *Library and Information Science Research*, *Online Information Review*, *Information Research*, *Aslib Proceedings*
Primary main class	Bibliography, Library Science, Information Resources (General)	Bibliography, Library Science, Information Resources (General)
Primary subclass	Books (General), Writing, Paleography, Book industries and trade, Libraries, Bibliography	Books (General), Writing, Paleography, Book industries and trade, Libraries, Bibliography

knowledge flow involves information science itself. Indeed, the primary main classes and subclasses are the same for both cited and citing journals. This, again, reflects the "subject field self-citation" nature of information science. In addition, seven out of 10 of the most cited journals are the same as the most citing ones. Moreover, the order is the same for the top most citing ones. *Communications of the ACM* and *ACM Transactions on Information Systems* are among the top most cited journals, though they are absent among the 10 most citing journals. This suggests significant knowledge flow from computer science to information science, while the flow is not so significant in the opposite direction.

Summary, conclusion and implications

The present study conducts a bibliometric and citation analysis of journals citing four information science journals from 1998 to 2010. The findings can be described as follows.

Excluding Scientometrics, four of the top five citing journals, namely JASIST, IPM, JOD and JIS, are information science oriented journals, as identified by Paisley (1990) and McCarthy (2000) in their studies on the multidisciplinary nature and evolution of information science. These four journals are the source journals of this study. This implies the domain of information science possesses strong self-knowledge flow.

The main class of the citing journals is "bibliography, library science and general information resources" which contributes 61 %, while the most citing subclass of citing journals is "books (general), writing, paleography, book industries and trade, libraries and bibliography", which also accounts for 61 %. This suggests library science, book industries and trade and general information resources make up the mainstream of knowledge flow out of information science on the basis of the LCC. On the other hand, the second and the third highly citing journals were "science" (19 %) and "computer science" (9 %), respectively.

As LIS is the main class contributing more than 50 % of journal literature to the knowledge flow out of the information science, further analysis indicates the highly citing subjects of LIS journals encompass library and information science, computers in information science and information theory, and computer applications in library and information science.

The results of the present study reveal the knowledge flow out of the information science field has two basic themes: experimental IR and the Web. The subjects related to IR include online IR, searching, information seeking behavior, search strategies, and relevance. This study also found that the Web has affected the knowledge structure of information science. New subjects such as the World Wide Web, links, websites, search engines, and the Internet have helped enhance information science research. Astrom (2007) also observed the dominance of Web-related studies in the LIS field. However, some bibliometric research developments, e.g., scientometrics and citation analysis, have also influenced the study of information science.

Moreover, information science, as represented by the four information science journals, i.e. JASIST, IPM, JOD and JIS, is found to be a developing interdisciplinary subject with an expanding citing literature. Increasingly, there has been great growth in the citing literature in "library and information science" as well as "computer science" and "science" papers. The knowledge flow out of information science mainly includes information science itself and general science, as well as computer science. Moreover, there have been minor outputs to various subjects.

The comparison of knowledge flow into and out of the domain of information science reveals the main knowledge flow is within information science itself. The comparison also demonstrates significant knowledge flow from computer science to information science. The findings of the present study should be of great interest for citation studies in the LIS field. The findings will also contribute to our understanding of the nature of the information science discipline, and how the domain knowledge of information science influences other disciplines.

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