A Study of the Evolution of Interdisciplinarity in Library and Information Science: Using Three Bibliometric Methods

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This study uses three bibliometric methods: direct citation, bibliographic coupling, and co-authorship analysis, to investigate interdisciplinary changes in library and information science (LIS) from 1978 to 2007. The results reveal that LIS researchers most frequently cite publications in their own discipline. In addition, half of all co-authors of LIS articles are affiliated with LIS-related institutes. The results confirm that the degree of interdisciplinarity within LIS has increased, particularly co-authorship. However, the study found sources of direct citations in LIS articles are widely distributed across 30 disciplines, but co-authors of LIS articles are distributed across only 25 disciplines. The degree of interdisciplinarity was found ranging from 0.61 to 0.82 with citation to references in all articles being the highest and that of co-authorship being the lowest. Percentages of contribution attributable to LIS show a decreasing tendency based on the results of direct citation and co-authorship analysis, but an increasing tendency based on those of bibliographic coupling analysis. Such differences indicate each of the three bibliometric methods has its strength and provides insights respectively for viewing various aspects of interdisciplinarity, suggesting the use of no single bibliometric method can reveal all aspects of interdisciplinarity due to its multifaceted nature.

Introduction

The past decade has seen the rapid development of interdisciplinary research within many disciplines for solving complex problems and advancing fundamental understanding. The amount of interdisciplinary literature (Braun & Schubert, 2003) as well as the number of interdisciplinary centers (Ortega & Antell, 2006) have increased. The concept of interdisciplinarity has been discussed by many researchers and can be defined as scientific output or activity using knowledge, methods, and tools from two or more disciplines (Huutoniemi, Klein, Bruun, & Hukkinen, 2010; Klein, 1996; Rosenfield, 1992). Interdisciplinarity, multidisciplinarity, and transdisciplinarity are regarded as related, but different concepts based on the level of integration involved in research output (Rosenfield, 1992). This study, which does not attempt to identify the differences among the concepts of interdisciplinarity, multidisciplinarity, and transdisciplinarity, uses the term "interdisciplinarity" to refer to all multidisciplinary or transdisciplinary activities.

A common feature of interdisciplinarity as it is manifested in a variety of research activities is the transfer of information across disciplines (Porter, Roessner, Cohen, & Perreault, 2006). Pierce (1999) grouped interdisciplinary information transfer into three types: the citation of references from different disciplines, the co-authoring of articles by researchers from different disciplines, and the publishing of works within other disciplines. Such transfer implies that the degree of interdisciplinarity of a specific discipline can be determined by analyzing the discipline distribution of references and co-authors in publications.

All researchers must review the works of previous researchers and acknowledge the contributions of these researchers via the practice of citing references. When the method of direct citation is used to identify the disciplinary distribution of references in the literature of a discipline, the source disciplines of the references and their degree of influence can be identified, and the results used to verify an interdisciplinary relationship from the point of view of information flow. However, not all references that are cited make the same contribution to the literature of a discipline.

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The references that are merely cited in an article have little influence on the discipline of the citing article. Therefore, articles without bibliographic coupling links to other articles can be excluded from analysis to focus on the information flow from disciplines with greater influence. The method of bibliographic coupling can help researchers to filter out a group of articles with a particular type of connection. Two articles with at least one common reference are identified as articles with a bibliographic coupling relationship (Kessler, 1963). However, no study to date has explored the interdisciplinary results based on articles with bibliographic coupling, and further compared the results with those generated by direct citation.

As most forms of co-authorship reflect a division of labor (Laudel, 2002), they indicate that a certain degree of communication and coordination has occurred. Specifically, co-authorship represents one type of social network that develops through interpersonal relationships. Whereas the citation of literature is determined by the citing authors themselves, requiring little interaction between the citing and cited authors and only indicating the origin of information flow, co-authoring requires and indicates substantial collaboration among disciplines. As such, collaboration across disciplines can be identified using co-authorship analysis.

According to numerous studies of interdisciplinarity, survey and bibliometric methods are two major approaches to identifying interdisciplinary characteristics in many disciplines (Hargens, 1986; Morillo, Bordons, & Gomez, 2001; Sanz-Menendez, Bordons, & Zulueta, 2001; Schummer, 2004; Song 2003; Urata, 1990). Bibliometric methods have been used in prior studies, with direct citation analysis as the dominant method. Several studies have focused on a specific discipline (Cheung, 1990; Choi, 1988; Grover, Ayyagari, Gokhale, Lim, & Coffey, 2006; Hammarfelt, 2011; Peritz & Bar-Ilan, 2002; Ponzi, 2002; Steele & Stier, 2000), whereas others have analyzed several disciplines and compared the differences among the results (Neeley, 1981; Pieters & Baumgartner, 2002; Porter & Rafols, 2009; Rigney & Barnes, 1980; Rinia, Van Leeuwen, Bruins, Van Vuren, & Van Raan, 2002). Regarding co-authorship research, although collaboration has become common in scientific research, quite few efforts have focused on analyzing collaboration across disciplines (Chen & Liang, 2004; Qiu, 1992).

Interdisciplinarity is a multifaceted issue manifested in citation behavior and co-authorship, both of which illustrate information exchange across disciplines. However, previous studies using bibliometric methods have primarily used only the method of direct citation analysis. To probe different aspects of interdisciplinarity and understand the differences among the results identified from direct citation and other bibliometric methods, this study conducted co-authorship analysis to determine the extent of collaboration across disciplines. Additionally, it applied the method of bibliographic coupling to filter out articles without evident links to other articles.

This study focused on library and information science (LIS), a typical interdisciplinary field, as the subject of analysis. Library and information science emerged as information science was incorporated into the field of library science and library science reacted to the impact of information technology. Therefore, some of the past research focusing on LIS interdisciplinarity selected journals in only library science or information science and found that (a) LIS researchers often cite publications across disciplines (Al-Sabbagh, 1987; Bracken & Tucker, 1989; Buttlar, 1999; Chen & Liang, 2004; Cheng, 1995; Chikate & Patil, 2008; Chung, 1995; Gatten, 1991; LaBoire & Halperin, 1976; Pluzhenskaya, 2008; Shi, 2002; Tsay, 2008), (b) LIS publications are cited by researchers from various disciplines (Goodall, Julien, Lajoie-Paquette, & McKechnie, 2005; Meyer & Spencer, 1996; Odell & Gabbard, 2008; Tang, 2004), and (c) that LIS researchers collaborate with researchers from different disciplines (Chen & Liang, 2004; Qiu, 1992). However, most studies have used only direct citation analysis and focused exclusively on the journals cited. Few studies have tracked changes in interdisciplinarity, and none has examined the trend in LIS interdisciplinarity over the years. To address this research gap, this study investigated a large number of reference samples between 1978 and 2007, including citations to books and journals, employing three bibliometric methods to investigate the interdisciplinary changes that have occurred within LIS. By such means, this study compares the differences among the results obtained using the different bibliometric methods. Moreover, by applying the Brillouin index, it measures the degree of interdisciplinarity in each year to illustrate the trend in LIS interdisciplinarity. By employing such means, this study addresses the following research questions:

1. From which disciplines do the sources cited by LIS researchers of all articles originate? From which disciplines do the sources cited by LIS researchers of articles with a bibliographic coupling relationship originate? From which disciplines do the co-authors of LIS articles originate? Are there differences among the disciplines (a) from which the sources of references in all articles, (b) from which the sources of references in articles with bibliographic coupling links, and (c) from which the co-authors originate?
2. Which disciplines have had the greatest impact on LIS over time?
3. Has the degree of interdisciplinarity within LIS increased over the years?

Methodology

Three bibliometric methods—direct citation, bibliographic coupling, and co-authorship analysis—were used to study the interdisciplinary characteristics of and trends in LIS from 1978 to 2007. Thus, three data sets—references in all articles, references in articles with bibliographic coupling links, and authors' institutional affiliations in co-authored articles—were extracted from the same group of articles in 10 selected LIS journals. Specific disciplinary attributes of references and author were determined based on their

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TABLE 1. Ten library and information science (LIS) journals used for this study.

Journal title	No. of articles	No. of LIS articles	No. of 20% LIS articles with systematic sampling
College & Research Libraries	1,044	1,044	208
Information Processing & Management	1,466	329	65
Journal of the American Society for Information Science and Technology	2,224	828	165
Journal of Academic Librarianship	1,263	1,263	252
Journal of Documentation	550	255	51
Journal of Information Science	1,072	484	96
Library and Information Science Research	427	427	85
Library Quarterly	436	436	87
Library Resources & Technical Services	672	672	134
Scientometrics	1,966	1,966	393
Total	11,120	7,704	1,536

classification number and institutional affiliations. The Brillouin index was used to measure the degree of interdisciplinarity within LIS each year to identify changes and trends in interdisciplinarity.

Journal Selection

Data regarding references and the institutional affiliations of the co-authors analyzed in this study were retrieved from 10 LIS journals. The field of LIS consists of two subfields, library science and information science, which differ in several respects (Astrom, 2010). To present a more complete depiction of the characteristics of LIS, the same number of library science and information science journals were examined. In addition, the impact factor, an indicator of the frequency of citation that is applied to journal ranking (Tomer, 1986), was identified. Journals with a high impact factor are widely considered core journals disseminating essential knowledge of a discipline. Thus, articles in core journals are often regarded as important publications, and are associated with higher frequency of citation. In addition, the references cited by core journal articles may make essential contributions to the development of a discipline because the authors of these articles evaluate and cite literature of high quality (Peters & Van Raan, 1994).

The 10 LIS journals selected for examination had to meet four criteria. First, the LIS journal candidates had to be included in the subject category, Information Science and Library Science in the 2006 *Journal Citation Reports* (*JCR*) social science edition. Second, they had to be covered by major bibliographic databases, such as Library and Information Science Abstracts, Library Literature and Information Science, and Library/Information Science and Technology Abstracts. Third, the journals had to have been published between 1978 and 2007. Fourth, both the top five library science journals and the top five information science journals had to have the highest impact factor. The 10 LIS journals selected for this study are listed in Table 1.

Data Collection

Only the research articles classified under the category, Articles, by the Social Science Citation Index (SSCI; Thomson Reuters, Philadelphia, PA) database were examined in this study. Five of the 10 selected LIS journals are multidisciplinary. Four journals, including *Information Processing & Management, Journal of the American Society for Information Science and Technology* (*JASIST*), *Journal of Information Science*, and *Scientometrics*, are also classified as computer science journals by *JCR*. Another journal, *Journal of Documentation,* is indexed and abstracted in two databases related to computer science, the Computer Science Index and Computers and Applied Science Complete. Because computer science and LIS are regarded as two independent disciplines in this study, the computer science articles needed to be distinguished from the LIS ones to illustrate interdisciplinary characteristics of LIS. We identified computer science articles by examining the title, the abstract, and even full text if needed. We excluded 3,416 non-LIS articles from the discipline of computer science from 11,120 articles identified by the SSCI.

The database identified 7,704 LIS articles; systematic sampling was used to select a representative sample of 1,536 LIS articles (20% of 7,704 articles; see Table 1). To achieve a confidence level of 95%, a sample size of 1,281 articles is required out of a population of 7,704 articles. In systematic sampling, the researcher first picks the first subject from the population and then selects each sixth additional subject. For example, this would involve selecting the 6th, 12th, 18th, 24th, 30th, and 36th subjects, etc. Because it is easier to select each 5th subject, namely, the 5th, 10th, 15th, 20th, and 25th subjects, etc., which also yields a larger sample size, we decided to take 20% of the 7,704 articles.

Before conducting systematic sampling, all articles were listed by publication year and sorted by journal name so that the sample contained an even distribution of articles per year of publication. A reference that appeared more than one time in a single article was counted only once. Among the 10 LIS

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journals, several duplicate references that appeared in the same articles were filtered out because the citations in *College & Research Libraries* and *Journal of Academic Librarianship* are presented in the format of notes.

References to books and journals were then marked by discipline as indicated by their Library of Congress classification (LCC) number. The classification numbers of references were distributed across all 21 main classes of LCC. However, due to differences in scope among the main classes and the assignment of similar subjects in different classes, we examined the category name of each subclass and identified the class numbers with similar subjects. As a result, 8 disciplines were produced from one or more main classes in LCC, 4 disciplines were produced by combining one main class and some subclasses (e.g. education), 15 disciplines were yielded by combining two or more subclasses (e.g., literature), 2 disciplines were established based on a partial subclass (e.g., computer science), and 1 discipline (general science) was developed by combining one main class and a partial subclass. Thirty disciplines were thus established. By such means, the LCC system was used to divide all of the sample data into 30 disciplines (see the Appendix).

The classification numbers were obtained by searching the Library of Congress online catalog for the titles of books and journals contained in references. Because *Research Evaluation* and *Scientometrics* are each classified as LIS journals by *JCR*, each of these two journals was changed to an LIS classification number from a general science number. References for which classification numbers could not be found were excluded from the sample. This procedure resulted in 27,678 references (83.68% of 33,076 references) used for direct citation analysis after 5,398 references (16.32% of 33,076 references) were eliminated as previously described. Because most of the 5,398 disqualified references were Internet resources, proceedings papers, and theses, their exclusion will not change the results. Next, articles with bibliographic coupling links were identified by examining references cited in two or more articles, resulting in 8,906 references (32.18% of 27,678 references) being extracted from articles for bibliographical coupling analysis.

The disciplines of the co-authors were identified according to the institutional affiliation listed in the articles and were mapped to the same classification scheme used for the references (see Appendix for details). For example, authorial affiliations with a department of economics were mapped to the discipline of economics. Authorial affiliations with centers of science and technology were classified in the discipline of general science. Among the 1,536 LIS articles, 644 were co-authored articles written by 1,653 authors. Of these 1,653 authors, incomplete affiliation data were provided for 117 authors. These authors were excluded from the sample, yielding 1,536 authors for further analysis.

Interdisciplinary Indicator

Compared to the citation outside category (COC), wherein a citation-based indicator measures the percentage of citations outside a specific source category, the Brillouin index is a proper indicator of interdisciplinarity because it considers the number of observations and the distribution of observations among categories (Steele & Stier, 2000). Although originality is also an interdisciplinary indicator based on the number of observations and the distribution of observation among categories, it is applied to a large sample size or to categories of large scope (Huang & Ho, 2009; Trajtenberg, Henderson, & Jaffe, 1997). Therefore, the Brillouin index was applied in this study to measure the degree of interdisciplinarity. The greater the degree of the interdisciplinarity of a discipline, the higher the value assigned to it by the index. To determine the value, the index uses the following algorithm:

$$\frac{\log N! - \sum(\log n_i!)}{N}$$

where N refers to the number of observations, and n_i refers to the number of observations in category i. In measuring the references, N refers to the quantity of references and n_i refers to the quantity of references in i discipline. In measuring the co-authors, N refers to the quantity of co-authors and n_i refers to the quantity of co-authors for i discipline.

Results

Number of Disciplines

Table 2 shows that the number of disciplines in references in all articles and in references in articles for which there is a bibliographic coupling relationship is 30 and 28, respectively. The two disciplines of military science and zoology were not included in the results obtained by bibliographical coupling analysis. Co-authorship analysis identified only 25 disciplines; it did not identify the five disciplines of literature, law, botany, zoology, and recreation. The results demonstrate that the scope of disciplines generated by the three bibliometric methods is different. The number of disciplines identified by direct citation comes to 30, which is more than that generated by the other two bibliometric methods (bibliographic coupling and co-authorship).

Top Five Disciplines

Table 3 shows that the results of all three bibliometric methods identified LIS as the discipline with the highest contribution. This finding indicates that the LIS researchers rely heavily on the works of fellow LIS researchers and that most co-authors of LIS articles are affiliated with LIS-related institutes. However, the percentage of contribution attributed to LIS identified by the three methods differed, ranging from 50.33% to 66.91%. The results of all three methods also identified general science as the second ranking discipline, with percentages ranging from 7.11% to 13.22%. The results of all three methods identified different disciplines in third, fourth, and fifth top discipline, with computer science being the only common discipline among them.

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TABLE 2. Disciplines generated by the three bibliometric method.

No.	Discipline	Direct citation	Bibliographical coupling	Co-authorship
1	Agriculture	•	•	•
2	Anthropology	•	•	•
3	Arts	•	•	•
4	Astronomy	•	•	•
5	Biology	•	•	•
6	Business/management	•	•	•
7	Chemistry	•	•	•
8	Computer science	•	•	•
9	Earth science	•	•	•
10	Economics	•	•	•
11	Education	•	•	•
12	General science	•	•	•
13	General social science	•	•	•
14	History	•	•	•
15	Library & information science	•	•	•
16	Linguistics & language	•	•	•
17	Mathematics	•	•	•
18	Medicine	•	•	•
19	Philosophy & religion	•	•	•
20	Physics	•	•	•
21	Political science	•	•	•
22	Psychology	•	•	•
23	Sociology	•	•	•
24	Technology	•	•	•
25	Literature	•	•	
26	Law	•	•	
27	Botany	•	•	
28	Recreation	•	•	
29	Military science	•		•
30	Zoology	•		

TABLE 3. Distributions of the top five source disciplines.

	Direct citation		Bibliographic coupling		Co-authorship	
Discipline	%	Rank	%	Rank	%	Rank
Library & information science	**56.84**	**1**	**66.91**	**1**	**50.33**	**1**
General science	**7.11**	**2**	**11.34**	**2**	**13.22**	**2**
Business/management	**4.40**	**3**	1.80	9	**7.16**	**4**
Computer science	**3.65**	**4**	**2.36**	**4**	**7.62**	**3**
Education	**3.44**	**5**	0.90	11	2.21	7
Sociology	3.32	6	**2.90**	**3**	0.59	15
Medicine	2.76	8	0.84	12	**5.34**	**5**
Economics	2.10	10	**2.32**	**5**	0.33	19
Accumulated percentage of top 5 disciplines (marked in bold)	75.54		85.83		83.67	

Examination of the distribution of the top five disciplines reveals a great difference between the first rank of LIS and the second rank of general science. As expected, the contribution of LIS is large—over 50%—whereas the contribution of general science is from 7% to 13%. Moreover, the discrepancy among the remaining top disciplines—2% to 7%—is small. This means that although LIS was influenced by many disciplines, the influence of disciplines outside LIS was much less than that of LIS itself. In addition, the high accumulated percentages of the top five disciplines range from 75.54% to 85.83%, implying that few disciplines influence LIS.

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TABLE 4. Distributions and rankings of disciplines with percentages over 1% (Excluding the top five disciplines).

	Direct citation		Bibliographic coupling		Co-authorship	
Discipline	%	Rank	%	Rank	%	Rank
Business/management	4.40	3	**1.80**	**9**	7.16	4
Education	3.44	5	0.90	11	**2.21**	**7**
Sociology	**3.32**	**6**	2.90	3	0.59	15
Engineering	**3.10**	**7**	**2.23**	**6**	**2.93**	**6**
Medicine	**2.76**	**8**	0.84	12	5.34	5
Psychology	**2.36**	**9**	**1.89**	**8**	**1.56**	**9**
Economics	**2.10**	**10**	2.32	5	0.33	19
General social science	**1.88**	**11**	**1.98**	**7**	**1.69**	**8**
Linguistics & language	**1.69**	**12**	**1.04**	**10**	0.65	13
Philosophy & religion	**1.02**	**13**	0.83	13	0.46	16
Physics	0.69	17	0.45	15	**1.24**	**11**
Chemistry	0.28	23	0.11	19	**1.56**	**9**
Accumulated percentage and number of disciplines with percentages over 1 but excluding the top 5 disciplines (marked in bold)	18.23 (8)		8.94 (5)		11.19 (6)	

Disciplines Other Than the Top Five With Percentages of More Than 1%

As indicated in Table 4, the results of the three bibliometric methods reveal that only three disciplines not within the top five—engineering, psychology, and general social science—have percentages exceeding 1%. Although the ranking of chemistry in terms of co-authorship is higher than its ranking in terms of direct citation and bibliographic coupling, the differences among these percentages is small. The differences among the percentages of disciplines, other than those in the top five, are also small, especially disciplines with percentages under 1% (see Table 4).

Disciplines With Percentages Between 0% and 1%

Table 5 lists the disciplines with percentages under 1% but higher than 0%. The number of disciplines with references in all articles, with references in articles with a bibliographic coupling relationship, and with a co-authorship is 17, 18, and 13, respectively. This reveals that more than half of disciplines have percentages higher than 0% but less than 1%, indicating that many disciplines have had little influence on LIS.

Rankings of Disciplines

The use of the three bibliometric methods resulted in different rankings of the 30 disciplines analyzed. To evaluate the degree of consistency among the three sets of rankings, the Kendall coefficient of concordance was determined, with a value of 0.878 ($p < 0.000$) indicating a significant degree of concordance. In addition, the Spearman's rank correlation coefficient is used to compare further the consistency of ranking revealed by pairs of bibliometric methods.

Table 6 shows that the Spearman's rank correlation coefficient of the ranking results of direct citation and bibliographical coupling analysis is 0.933 ($p = 0.01$), indicating that these methods have the highest degree of concordance, followed by direct citation and co-authorship analysis, which have a Spearman's rank correlation coefficient of 0.756, and then by bibliographic coupling and co-authorship analysis, which have a Spearman's rank correlation coefficient of 0.748. The contrasting values of Spearman's rank correlation coefficient between the results generated by each pair of bibliometric methods reveal that the results produced by co-authorship analysis are markedly different from the results produced by the other two bibliometric methods. This indicates that the nature of co-authorship differs from that of citing literature.

Interdisciplinary Changes in Library and Information Science

Growth trend in number of disciplines. Figure 1 displays the number of disciplines identified by the results of the three bibliometric methods for each year. As can be observed, the largest number has always been identified by direct citation analysis and the smallest by co-authorship analysis. The findings indicate that it is more difficult for researchers to collaborate with researchers from other fields. There are more limitations for interdisciplinary collaboration than citing publications across disciplines. Although the number differs among the results using the three bibliometric methods, all the results indicate an increasing trend: The authors of LIS articles cite publications from more disciplines and co-authors of LIS articles come from more disciplines.

Trend lines of percentages of the top five disciplines. Because the top five disciplines have the greatest influence on LIS, the changes in their percentage each year were closely observed in this study. Figures 2 to 4 exhibit the trend lines of

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TABLE 5. Distributions and rankings of disciplines with percentages under 1% but higher than 0%.

	Direct citation		Bibliographic coupling		Co-authorship	
Discipline	%	Rank	%	Rank	%	Rank
Education	3.44	5	**0.90**	**11**	2.21	7
Medicine	2.76	8	**0.84**	**12**	5.34	5
Economics	2.10	10	2.32	5	**0.33**	**19**
Linguistics & language	1.69	12	1.04	10	**0.65**	**13**
Philosophy & religion	1.02	13	**0.83**	**13**	**0.46**	**16**
Literature	**0.98**	**14**	**0.34**	**16**	–	–
Mathematics	**0.83**	**15**	**0.83**	**13**	**0.85**	**12**
History	**0.69**	**16**	**0.07**	**21**	**0.13**	**21**
Physics	**0.69**	**17**	**0.45**	**15**	1.24	11
Anthropology	**0.51**	**18**	**0.15**	**18**	**0.07**	**23**
Political science	**0.50**	**19**	**0.06**	**25**	**0.46**	**16**
Law	**0.47**	**20**	**0.10**	**20**	–	–
Arts	**0.44**	**21**	**0.07**	**21**	**0.07**	**23**
Biology	**0.38**	**22**	**0.27**	**17**	**0.26**	**20**
Chemistry	**0.28**	**23**	**0.11**	**19**	1.56	9
Earth science	**0.17**	**24**	**0.07**	**21**	**0.65**	**13**
Agriculture	**0.10**	**25**	**0.02**	**27**	**0.46**	**16**
Astronomy	**0.10**	**26**	**0.07**	**21**	**0.07**	**23**
Botany	**0.09**	**27**	**0.04**	**26**	–	–
Recreation	**0.04**	**28**	**0.02**	**27**	–	–
Military science	**0.03**	**29**	–	–	**0.13**	**21**
Zoology	**0.02**	**30**	–	–	–	–
Accumulated percentage and number of disciplines under 1% but higher than 0% (marked in bold)	6.32 (17)		5.24 (18)		5.18 (13)	

Note. "–" indicates no connection with the discipline.

TABLE 6. Spearman's rank coefficients.

Bibliometric methods	Value
Direct citation vs. bibliographic coupling	0.933
Direct citation vs. co-authorship	0.756
Bibliographic coupling vs. co-authorship	0.748

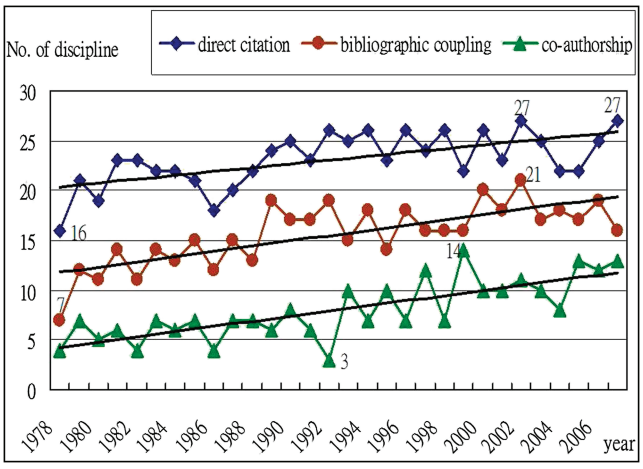


FIG. 1. Number of disciplines identified by three bibliometric methods by year.

the percentages of the top five disciplines based on data obtained through use of the three analysis methods. As can be observed, despite obvious fluctuations in its percentage over the years, LIS was the top one discipline examined, having percentages consistently much higher than those of the other disciplines. The percentage of LIS contributions decreases based on the results of direct citation and co-authorship analysis, particularly based on the latter, but an increase based on the results of bibliographic coupling analysis. Computer science increases steadily based on the results of direct citation and bibliographic coupling analysis. Whereas closer observation of the direct citation and bibliographic coupling analysis results for general science reveal a gradually decreasing trend, the co-authorship analysis results reveal a slight increase. If we compare the trend lines displayed in Figures 2, 3, and 4, there is virtually no consistency in the fluctuation of percentages, even among the three most dominant disciplines (LIS, computer science, and general science). This means the trend of which disciplines most influence LIS depends on which aspect of interdisciplinarity (literature citing or co-authorship) is studied. The nature of literature citation and co-authorship needs to be noted and distinguished. Regarding the remaining top disciplines, the percentages of business/management, economics, and education are almost the same, whereas the percentages of

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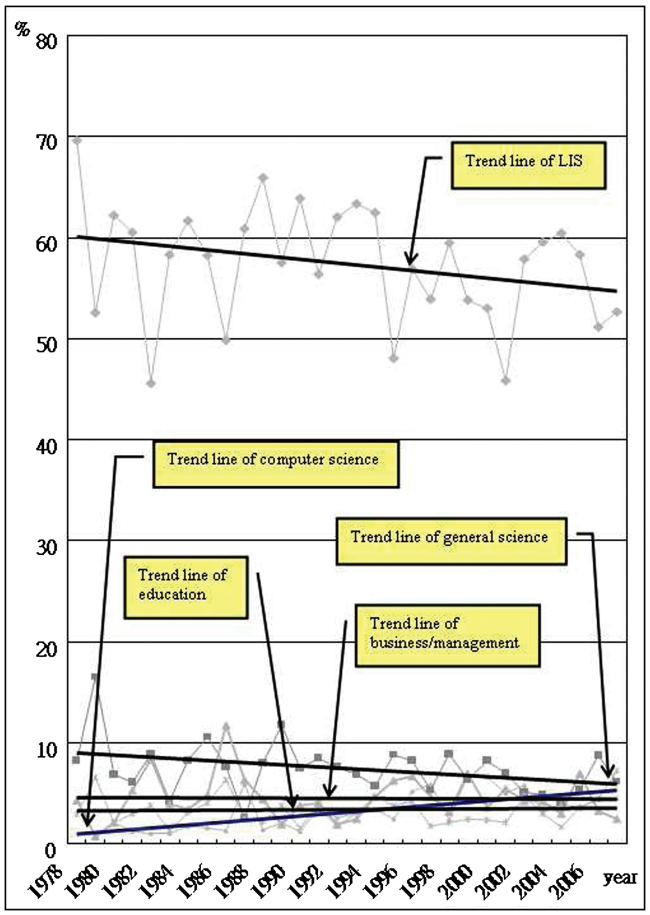


FIG. 2. Trend lines of percentages of the top five disciplines according to direct citation analysis.

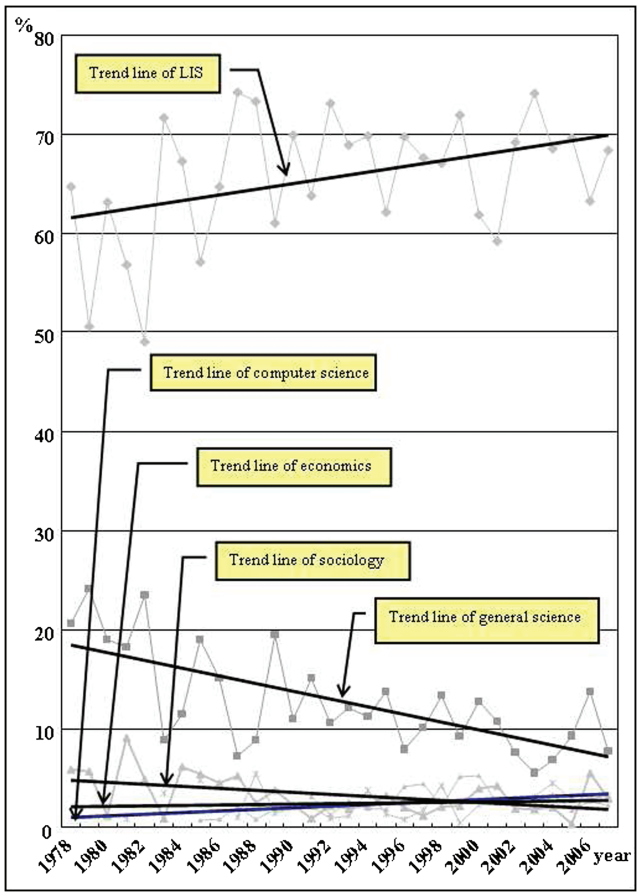


FIG. 3. Trend lines of percentages of the top five disciplines according to bibliographic coupling analysis.

medicine and sociology decrease based on the co-authorship and bibliographic coupling analysis results, respectively.

Degree of LIS Interdisciplinarity

Based on the results, the degree of interdisciplinarity pertaining to references in all articles is the highest (0.82), followed by that pertaining to references in articles with a bibliographic coupling relationship (0.79) and that pertaining to institutional affiliations in articles with co-authorship relationship (0.61). This finding indicates that the interdisciplinary degree of references in all articles is the highest, and that of co-authors is the lowest. Although the interdisciplinary degree of co-authors is the lowest, it was higher than that of references in all articles of 2005. The obvious fluctuation in degree of interdisciplinarity generated by co-authorship analysis may mean that the development of interdisciplinary collaborations is not stable. It is more difficult to seek a partner from other fields than to cite literature in other fields. The results obtained by computing the annual degree of interdisciplinarity and visualizing the trends in interdisciplinarity, particularly the results obtained by co-authorship analysis, reveal an increasing trend in interdisciplinarity overall (see Figure 5).

Discussion

In this study, we examined the characteristics of and changes in LIS interdisciplinarity over a 30-year period by comparing the results obtained by the use of three bibliometric methods. The findings of all three methods reveal that the level of LIS interdisciplinarity has been increasing over time, indicating that LIS researchers have been increasingly citing more sources outside the discipline of LIS and co-authoring more articles with co-authors from other disciplines. This trend is reinforced by the gradually increasing number of non-LIS sources cited by LIS researchers, as well as by the increasing number of LIS articles co-authored by researchers from other disciplines each year. The upward trend in the degree of interdisciplinarity in co-authorship, the most remarkable trend revealed by the results of the three bibliometric methods, may have been affected by the growing trend of co-authorship within LIS (Lipetz, 1999; Metz, 1988; Qiu, 1992; Terry, 1996).

The findings of this study identified the core disciplines contributing to the LIS knowledge base. In accordance with the findings of numerous citation analysis studies (Al-Sabbath, 1987; Buttlar, 1999; Cheng, 1995; Chikate & Patil, 2008; Chua & Yang, 2008; LaBoire & Halperin, 1976; Levitt & Thewall, 2009; Pluzhenskaya, 2008), this study

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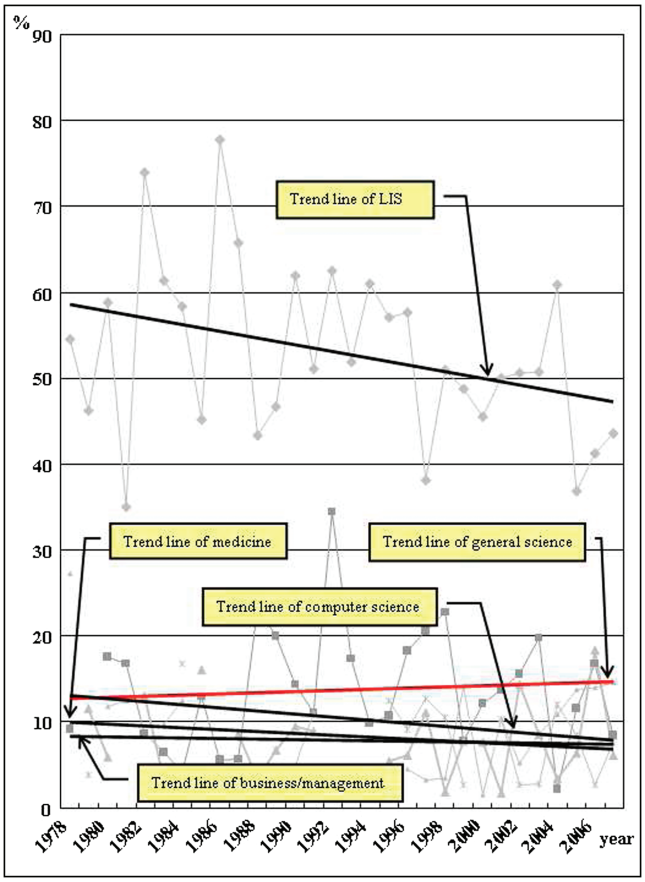


FIG. 4. Trend lines of percentages of the top five disciplines according to co-authorship analysis.

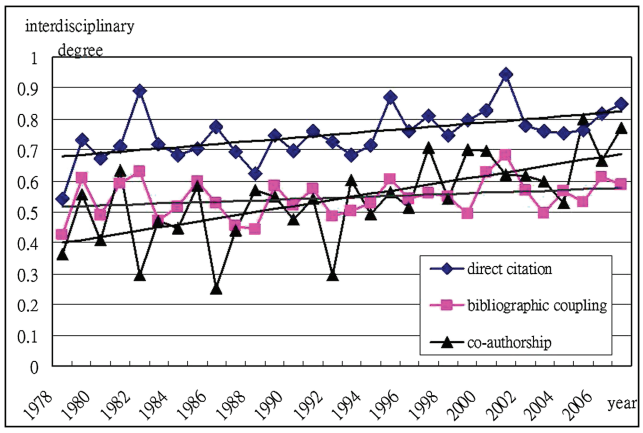


FIG. 5. Degree of interdisciplinarity per year based on results of the three bibliometric methods.

revealed that LIS is expected to continue to be the most-cited discipline and to have a large contribution. However, the rankings of the top disciplines outside LIS are different. This was evident in that when the selected source materials focused on information science, the top disciplines listed were general science, computer science, and technology (Al-Sabbath, 1987; Buttlar, 1999; Chua & Yang, 2008; Levitt & Thelwall, 2009; Pluzhenskaya, 2008). However, if the selected source materials focused on library science, the percentage of references to education, business/management, and sociology often ranked relatively higher (Cheng, 1995; Shi, 2002). Due to the close number of source materials from library science and information science, it could be anticipated that the top disciplines in this study included general science, business/management, computer science, and sociology. This study confirms that the core disciplines outside LIS contributing to LIS do not focus on disciplines in the social sciences or natural sciences. Furthermore, the direct citation analysis results indicate a decreasing tendency within LIS to cite LIS sources, meaning that LIS researchers have reduced their reliance on literature within their own discipline. This finding has not been reported by prior studies. In addition, the finding that bibliographic coupling analysis revealed a higher percentage of LIS than did direct citation analysis suggests that the authors of articles with bibliographic coupling links are drawing on an increasing number of sources from within LIS.

The accumulated percentage of the top five disciplines is over 75%, indicating that LIS has been influenced primarily by the top five disciplines. Even though not all these disciplines have had an increasingly stronger influence on LIS over the years, they were the focus of interdisciplinary development over the 30-year period examined. The contribution of the top three to five disciplines, with a percentage between 7% and 2%, is not large and is generally not much different from the contribution of disciplines outside the top five. However, the finding of this study that LIS researchers have been increasingly citing more publications from computer science and fewer from general science accords with those of Al-Sabbath (1987) and Cheng (1995).

Although the discipline rankings identified by use of the three bibliometric analysis methods appear to have a significant degree of consistency, they differ in several respects, such as discipline distribution, discipline scope, trends in the percentages of the top disciplines, and the degree of interdisciplinarity. A possible explanation for these differences may be the nature of literature citation and co-authorship. From the perspective of interdisciplinarity, both citing publications outside one's discipline and co-publishing an article with a researcher from another discipline are scientific cross-disciplinary activities (Pierce, 1999; Steele & Stier, 2000). However, these are different types of behavior. As references are usually selected by the citing authors themselves without the involvement of the cited authors, citing publications outside one's discipline requires no communication between one and the cited authors. Such a situation increases the risk that the citing authors may misunderstand the information that they cite. In contrast, co-authorship involves interaction between co-authors, at least to some extent, and, as such, has a more positive impact on fostering collaboration across disciplines.

An important consideration is that it is more difficult for researchers to engage in co-authoring than simply citing sources by other authors. Thus, the number of disciplines identified by co-authorship analysis would be anticipated to

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be less than that identified by direct citation and bibliographic coupling analysis. Regarding the number of disciplines identified by bibliographic coupling analysis, the exclusion of articles without a bibliographic coupling relationship will increase the proportion of exclusive references from the disciplines with little influence on LIS. Therefore, it is possible that the number of disciplines identified by bibliographic coupling analysis is lower than that identified by direct citation analysis, a claim supported by the findings of this study.

Due to the different nature of the practices of citation and co-authorship, this study used three bibliometric methods to filter and analyze different attributes of bibliographic information provided by an article. The results of all three bibliometric methods identified the source disciplines from which the LIS literature borrows knowledge, the source disciplines that contribute to the LIS literature with a bibliographic coupling relationship, and the disciplines represented by the co-authors of LIS articles. Although all the results from the three bibliometric methods reveal an increasingly interdisciplinary trend in LIS, the results obtained from the three methods differ regarding the number of disciplines, the rankings of disciplines, and the trend lines in the percentages of the top five disciplines. Such differences imply that citing literature and engaging in co-authoring are different aspects of interdisciplinarity. The results should therefore be treated with circumspection.

Conclusion

To investigate the nature of citation and collaboration, this study used three bibliometric methods to explore the interdisciplinary characteristics and tendencies of the discipline of LIS from 1978 to 2007. The results indicate that although LIS researchers remain strongly dependent on sources from their own discipline, they are citing references to LIS journal articles and co-authoring articles with researchers affiliated with LIS-related institutes less frequently. Of the 30 disciplines identified by bibliometric analysis, most have had little impact on LIS, and their distribution in terms of interdisciplinarity has changed only slightly over time. This finding reflects that fact that, although the discipline of LIS primarily relies on publications and researchers of its own discipline, it has been forging a stronger relationship with the top disciplines, including general sciences, computer science, business/management, education, and sociology.

However, the trends in the percentages of the top disciplines as identified by the results of the three bibliometric methods differ to some degree. Although the results of all three methods reveal that the degree of LIS interdisciplinarity increased between 1978 and 2007, the results differ regarding the trends in the degree of interdisciplinary. Moreover, the rankings of 30 disciplines as generated by co-authorship analysis are significantly different from those generated by the other two methods. Such differences indicate that the characteristics of interdisciplinarity identified by the three bibliometric methods may not reveal the same patterns. The result has indicated that only one bibliometric analysis method could not conduct a perfect research of interdisciplinarity. In other words, bibliometric analysis is multifaceted. Throughout this study, we realize that each of the three bibliometric methods complements each other, which might be a signpost for different thinking in interdisciplinarity research.

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Appendix

Discipline code list of references.

No.	Discipline	Main class(es)/ subclass(es) of Library of Congress classification	Institutional affiliations
1	Arts	M, N, TR, TT	Center for art
2	Literature	PN–PZ	–
3	Linguistics & language	P–PM	Department of communication and language
4	Philosophy & religion	B	Institute for philosophy
5	History	D, E, F	Department of history
6	Anthropology	C, GF–GT	Institute of anthropology
7	Business/management	HD, HF	School of management/school of industrial management/department of information management
8	Sociology	HM–HX	Department of sociology
9	LIS	A, Z	Department (school) of LIS/libraries/department of information studies
10	Economics	HB–HJ	Department of (applied) economics
11	Education	L	Department of education/Institute for studies in research and higher education
12	Political science	J	Public administration and public policy
13	Law	K	Department of law
14	Psychology	BF	Laboratory of psychology
15	General social science	H–HA	Human affairs research centers
16	Medicine	QM–QR, R	Department of medicine
17	Astronomy	QB	Kitt Peak National Observatory
18	Biology	QH301–	Department of biology
19	Agriculture	S	Department of agriculture
20	Botany	QK	–
21	Zoology	QL	–
22	Computer science	QA75–76	Department of computer science/school of computing and information technology
23	Mathematics	QA(excluding QA75–76)	Department of (applied) mathematics
24	Chemistry	QD	Department of chemistry/institute of macromolecular chemistry/department of inorganic chemistry
25	Military science	U, V	Office of Naval Research
26	Technology	HE, T (excluding TR, TT)	Institute of technology/industrial engineering/department of civil engineering
27	Physics	QC	Department of physics/National Physical Laboratory
28	Earth science	G–GE, QE	College of environmental science
29	Recreation	GV	–
30	General science	Q, QH1–278.5	Institute of Science Policy/Institute of Science and Technology/National Institute of Science Technology and Development Studies

Note. "–" indicates the exclusive discipline.

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