FINAL REPORT

INDICATORS OF INTERDISCIPLINARY RESEARCH

Daryl E. Chubin
Alan L. Porter
Frederick A. Rossini
Terry Connolly

Technology and Science Policy Program
School of Social Sciences
and
School of Industrial and Systems Engineering

Georgia Institute of Technology
Atlanta, Georgia 30332

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EXECUTIVE SUMMARY

The primary aim of this project was to distinguish empirically interdisciplinary research (IDR) from traditional disciplinary research. A critical constraint was the use of the public scientific literature to allow development of potential science indicators. This means that one has only an indirect gauge on the research process per se. Indeed, the indicator we developed measures cross-disciplinary tendencies rather than distinguishing IDR from multidisciplinary work. Further, we recognize that restricting the domain of inquiry to the journal literature may miss the IDR likely to be reported disproportionately in project reports, books, and other non-serial outlets.

The project included three discrete component efforts. First, we examined "Citation Classics"; second, we constructed several candidate journal-based IDR indicators; and third, we applied the most promising such indicator to a publicly-available data base.

A sample of 285 "Classics" described in five _Current Contents_ in 1981 were examined for apparent IDR as evidenced in reports of how the research was performed or how it was used (cited). Only 10-20 percent appeared to be substantially interdisciplinary. Of these, 11 were chosen for compilation of a 10-year citation profile. Using the Institute for Scientific Information's (ISI) subject categories, we found a median of 39 percent of the citations in the same category as the classic article, with a mode of two categories accounting for 50 percent of the citations. The 3 Life Science classics exhibited the greatest citation dispersal (23-35 categories for the sampled citations; the next highest classic had 20). Two of these 3 articles showed a progressive spreading of citations over time. Overall, the striking finding was that the 11 articles were extremely idiosyncratic with respect to the amount of cross-category citing and the pattern over time.

Our approach in developing a journal-based indicator was to propose a set of potential such indicators drawing on ISI's _Journal Citation Reports_, then to validate these against a selected sample. We sought indicators reflective of research production (via reference patterns of the researchers in a set of articles), and of research utilization (via citation patterns to the articles under scrutiny). Our eventual sample was so much more robust on the production side (due to logistical problems in retrieving citation details) that we emphasized the production side of the validation effort. Consequently, we can recommend a matched pair of indicators--one for "citations by," the other for "citations to."

Predictably, the validation of IDR--its presence and extent--is not trivial. We utilized both a multi-rater "subjective" assessment of how interdisciplinary each sample article was, and more "objective" measures based on reference patterns peculiar to each article. The sample consisted of 2 journals in each of 10 ISI subject categories spanning Engineering, and the Physical, Life, and Social Sciences (a total of 19 as one category had only one journal meeting our criteria for selection). We analyzed 383 articles published in 1979.

A basic finding was that there are few "broad" cross-category citations in these basic and applied research areas. Rarely does one find, for example, citations by life scientists to engineering or social science. We probed further by assessing up to 20 references from each of the articles to ascertain whether they represented the same "specialty" (operationally defined by multiple common keywords indicative of substantive area and technique), an allied research specialty, or a remote one. Cumulating results for each article to the 19 journals showed that none had more than 2 percent of the references cited to "remote" research. The implication is that researchers draw on a variety of techniques and specialized knowledge bases, but only when those pertain directly to the research at hand. A neuroscientist studying chemical effects on hypothalamic cellular function pertinent to memory processes would probably not notice the "interdisciplinarity" of drawing on information generated by anatomists doing histological work, psychologists recording single cells, or physiologists monitoring neural transmitters. Over time, such a confluence of interests could create new "disciplines."

The Journal Citation Reports (JCR) publish counts of how many times a given journal cites, and is cited by, other journals. For many journals this listing is so extensive that cross-citing journals with five or fewer citations in the time period are consolidated into a residual category. ISI supplied us with a complete listing of these "all others" to explore whether they represent disproportionately more cross-category citation. They do. Our 19 journals seldom cite, for instance, across grand categories (e.g., engineering to social science), but they are more likely to do so in the set of journals which they cite five or fewer times (15.5% vs. 3.9% in the six or greater citations group). In a pattern revealed in several data manipulations, these journals cited more broadly than they were cited.

The two candidate IDR production indicators that appeared most promising were the dispersal of references (as the percentage of references in journals citing five or fewer times) and the cross-categorical referencing (as the percentage of references outside the source journal's ISI category, with subcategories such as atomic physics, consolidated into one category, such as physics). The latter correlated more strongly with the two prime validators--judgment of article interdisciplinarity (Pearson's r= .48) and the mean percentage of references cited by our sample articles falling outside the two most heavily cited categories (r= .67). This, then, is the indicator we recommend.

The final component of the project concentrated on using the indicator described above to examine three of the subject categories (Toxicology, Demography, and OR/MS--Operations Research/Management Science) at two points in time (1976 for Toxicology, 1977 for Demography and OR/MS, and 1982 for all). Because the printed JCR does not disaggregate the five or fewer cross-citations, we improvised two proxy measures for the cross-categorical citation percentage indicator. Above all, we can report that these measures performed sensibly. The "liberal" estimate ran consistently higher than the "conservative" one. The three areas showed remarkable stability in the percentage of cross-categorical citations over time and for citing/cited differences (all three areas cited more widely than they were cited). Individual journals showed some interesting shifts, with some (e.g., Population Studies London), increasing their citation within the subject category of Demography. This may also be a useful indicator of categorical self-identity (including its decline, as exemplified by Social Biology). For instance, on a citation map OR/MS journals would cross-link tightly with Behavioral Science, which is peripheral in its citing and cited patterns. Such common citation patterns contribute to ISI's definition of categories, but examination of individual journals in this light may elucidate prime IDR outlets such as Behavioral Science.

The validation and application components of the project suggest that we can feasibly extract and interpret useful information from the ISI data base about cross-disciplinary (if not explicitly IDR) literature relationships. In conclusion, we urge further investigation into the creation of specific indicators based on the percentage of cross-categorical citation derived from the ISI resource. Some possibilities include:

*tracking the proportion of cross-category citation over time for the U.S. literature;

*cross-national comparisons of same;

*comparison among categories, and journals, as to openness to information from other categories, over time;

* identification of "hot" techniques or substantive areas in terms of crossing into different categories of users;

* using the cross-category proportion to predict the emergence of new research areas; and

* micro-level studies, using cross-categorical citation, to track information dissemination of seminal articles, research techniques, key authors, a new theory, or the research program of a particular laboratory.

ACKNOWLEDGMENTS

A project devoted to fathoming interdisciplinary products and processes heightens self-consciousness about one's own research team. With four faculty investigators and various graduate student and professional support assistance, we have much to acknowledge and many to thank.

We first express gratitude to the Institute for Scientific Information (notably Henry Small and Susan Deutsch) for providing data when hard-copy was either inaccessible or unsuitable for our purposes. Closer to home, we acknowledge the data-collection efforts of Denise Dager, an M.S. recipient in Industrial and Systems Engineering (ISyE), who plumbed most of the public sources we employed for the codable information featured in Part II.A-D of this report. Elisabeth Kotzakidou, an M.S. candidate in the Technology and Science Policy (TASP) Program, succeeded Denise in September 1982, and conscientiously compiled the data analyzed in II.E-F. Perhaps the person who personified continuity in the project, however, was Choon Y. Park, whose status changed from doctoral candidate in ISyE to Ph.D. recipient and postdoctoral researcher during the final months of the project. Choon performed most of the computer analyses, conferring regularly with the project team to transform ideas into output, suggest interpretations, and propose modes of data presentation. We are most indebted to him and shall miss him. (Our loss is his native Korea's gain.)

Another kind of thanks is due Anita Wood Bryant who, pausing from her role as TASP Administrative Coordinator, guided D.E.C. on the Lanier Word Processor and herself produced all the typewritten tables. Aila Wartell of the Georgia Tech Printing and Photographic Center converted many felt-tip-scratched figures into informative and attractive graphics.

Finally, we praise, in an acutely self-conscious way, the forbearance of our project monitor, Jennifer Sue Bond. Jennifer understood both the intellectual and logistical challenges of the project, and indulged our penchant for delay (in the name of quality, of course). We hope the report is deemed worth the wait.

March 1983

D.E.C.
A.L.P.
F.A.R.
T.C.

INDICATORS OF INTERDISCIPLINARY RESEARCH

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INDICATORS OF INTERDISCIPLINARY RESEARCH

Introduction

This final report consists of three parts. The first two derive from our March 1982 Interim Report (see Appendix A for a rationale and description) and illustrate two approaches to the identification and characterization of interdisciplinary research (hereafter IDR).

Part I applies a "citation approach" to a heretofore unanalyzed public data source, ISI "Citation Classics" (for commentary, see Garfield, 1977;1979;1981). A sample of 285 "classics" published in five Current Contents in 1981 were randomly assigned to, and reviewed by, the four project investigators. Ten to twenty percent of these (across five broad fields) were rated high in IDR process (or production) and/or usage (utilization). A sample of eleven high IDR papers-cum-classics was selected for citation usage analysis. Ten years of citations were collected from the Science Citation Index and each citing paper was classified according to the subject category of the journal in which it appeared, as denoted in the 1981 Journal Citation Report (JCR). Our results focus on the subject category distribution and its change over the 10-year period. Part I, then, is merely heuristic; it is offered as a small-sample experiment that may indicate future uses for the Citation Classics. The tracing of citations by research audiences apparently quite removed from the paper's initial, or targeted, audience may reflect patterns in the passage of information from one subject area to another, some portion of which is more IDR than disciplinary.

Part II is a more elaborate attempt to operationalize a "journal approach" for developing and validating indicators of IDR. Nineteen journals with high or medium "impact factor" (Garfield, 1972), a measure of average citation of a journal's content, were selected from four broad fields of science and engineering. First, a sample of 20 articles published in each journal in 1979 was defined. Next, each reference in each article was coded in two ways--by our perception of its similarity to the subject of the article in question and by JCR subject category of the cited journal. (Only references to serials were coded.) Where appropriate, 2-3 independent raters were employed as part of the validation effort. The raters' judgments were compared to other measures aggregated to the article, journal, subject category, and broad field levels. Part II, then, describes an algorithm, the information it yields, and a pilot application of an IDR indicators to JCR data.

We have conducted our research mindful of the Science Indicators (SI) series and the public data sources featured therein. Our citation and journal approaches, respectively, seek to establish continuity with both the units and style of SI reporting. Yet our aim is to measure a research phenomenon that has eluded quantitative characterization in SI. This aim encompasses both process and product, intent and utilization. Our findings to date suggest that the phenomenon of IDR is not easily detected. Its dynamic is often obscured in short time-series and by subject classifications that lag behind emerging categories of research. (Retrieving literature and "recovering" IDR may require different research strategies; however, we are not convinced of this yet.) What we will present in this report, therefore, may be more retrospective than prospective, though certain principles of measurement (and validation) are recommended that allow a continuous, or longer-term, monitoring to occur. Such monitoring may be the only route to constructing sensitive literature-based indicators of IDR.

In Part III, we review our measures and findings in light of the research questions initially posed by this project. We conclude with a prospectus for developing such indicators and reiterate that our research is but a first approximation.

I. Results of the Citation Approach

Eleven Citation Classics published in the 1981 Current Contents were rated on production and/or utilization characteristics as having interdisciplinary content. This rating was an inference drawn from a reading of the classic author's "editorial" only. Two of the project investigators, in other words, nominated a set of classics as candidates for further study; they did so independently and converged on 11 of their nominations (see Appendix A, p. 5). The distribution of these classics across five Current Contents (CC) broad fields is as follows:

Physical, Chemical & Earth Science (PC&ES)	n= 3
Engineering, Technology & Applied Sciences (ET&AS)	= 2
Life Sciences (LS)	= 3
Social & Behavioral Sciences (S&BS)	= 1
Agriculture, Biology & Environmental Sciences (AB&ES)	= 2

A. Mode of Data Collection

The Author Index of the Science Citation Index was searched to construct 10-year citation histories of the 11 classics. Each classic author was located in the appropriate SCI five-year cumulative or annual index: 1965-69, 1970-74, 1975-79, 1980, and 1981. The following information was recorded:

- How many times the classic was cited from the year of publication to 10 years thereafter.
- How many times per year it was cited.

- In what journal the article citing the classic was published.

In classifying the citing journals into subject categories, we restricted our focus to the journals with the highest impact factors in the JCR. Unlike Small and Greenlee (1980), we performed no content analysis of the (cited) classic, the citing articles, or the context in which the classic was referred to. But our collection method did allow us to identify whether a classic was cited by articles/journals found in the same or a different subject category as the classic. (Note that the ISI subject categories are not static and would have been different, or at least fewer in number, for classics published 10-20 years ago. We used the 1980 JCR categories.) Recognize, too, that (1) no data on authors' educational background and past/present research activity were collected; (2) we assume that the journal which published the eventual classic thematically reflects the content of the paper, i.e., its disciplinary or other audience, and therefore, the intent of the author's communication can only be inferred; (3) if the same assumption is applied to the citing authors, we can draw inferences about the article's range of usage, subject to the correspondence of an article's content to the JCR category of the journal in which it appears.

The key to the analysis of our small sample of citation classics is time. We can search for common patterns--over time--in the usage of a paper. For example, we might find a paper which, during the first four years after publication, has been cited only by journals within the same (sub)discipline. We might also find that it has been cited multiple times by the same journals. As the paper ages, the pattern might change: more and more journals from other (sub)disciplines may begin citing the paper. Now the journals citing the paper extend beyond the disciplinary/subject category origin of the classic. Do the original citing journals cease to do so? Does the classic's information become assimilated into the collective wisdom of the subdiscipline's specialists? Or are the classic's findings or methods rendered obsolete by research advances in the specialty? Such questions have never been raised about so-called classic papers. The citation histories for our sample provide some preliminary answers.

B. Data and Analysis

For 8 of the 11 classics, the total number of citations per year was no more than 50; hence, their citation histories are a census for the 10-year period. In three cases, the annual citation counts in SCI were large and a random sample by citer's last name was drawn. Table 1 contains the 11 classics, their annual citation counts, and their CC sources and years. These are the raw data for our experiment.

Table 1

Eleven Citation Classics:
Authors, Annual SCI Citations, and CC Source Information

author/yr, journal	citation years 1	2	3	4	5	6	7	8	9	10	CC source/ vol, 1981 date
Reynolds/63 J Cell Biol	9	323	552	683	785	1003	948	1339	1039	902	LS/32,10 Aug
Shannon/69 Acta Crystal	2	34	87	87	145	123	155	187	175	147	PC&ES/21,25 May
Sawhney/69 Plant Phys	7	14	17	16	10	14	9	13	7	6	AB&ES/12,5 Oct
Director/69 IEEE Circ	7	24	9	11	13	8	5	4	3	1	ET&AS/12,3 Aug
Blundell/72 Adv Prof Chem	-	4	15	18	28	40	40	34	31	45	LS/16,20 Apr
Lands/67 Nahre	1	41	47	44	54	55	68	80	109	82	LS/24,23 Nov
Hynes/61 Arch Hydrobiol	-	1	2	8	11	14	5	8	4	8	AB&ES/12,10 Aug
Edwards/63 Psych Rev	7	11	17	11	8	8	10	11	7	4	S&BS/13,31 Aug

Table 1 (cont.)

Edmiston/63 Rev Mod Phys	5	13	14	21	16	19	16	32	33	31	PC&ES/21,2 Mar
Kneubuhl/60 J Chem Phys	-	24	21	26	30	1	26	27	25	27	PC&ES/21,19 Jan
Barker/67 J Chem Phys	-	21	26	31	23	25	30	40	38	15	ET&AS/16 Feb

source: Science Citation Index, 1965-69; 1970-74; 1975-79; 1980; 1981

Table 2 presents a summary of characteristics in the ten-year history of the classics. Specifically, the JCR subject category of the classic, the number of different categories in which citations to the classic were made, the percentage of citations in the same category as the classic, the number of categories that account for one-half of the citations received by the classic, and the other subject categories which were high citers of the classic are shown. Variability among these characteristics is the norm. For example, there is a range of 5-35 categories (median = 17) with a median of 38.8 percent of the citations coming from the same category as the classic, and a mode of 2 categories accounting for at least 50 percent of the citations. Of course, categorical "range" is indicative of literature diffusion rather than direct evidence of IDR usage. If we consider the number of categories that account for 50 percent and the percentage of citations in the same category as the cited classic, we find an inverse relationship. Reynolds/63 is the most intriguing example, but no strong inferences follow. We can examine, in graphic form, some other relationships.

Figure 1 displays the relationship between the number of citing categories and categorical "concentration" (the number of categories that account for at least 50 percent of the citations to each classic). The connected lines show how the classics "behave" by CC subject area. The LS classics are the most distinctive; the others are idiosyncratic regardless of their area.

Figures 2-5 track the proportion of citations in the same category as the classic's category against years since publication. Among the three LS classics in Figure 2, Blundell/72 and Lands/67 have similar citation histories. In Figure 3, although the three PC&ES classics have similar ten-year totals, the citation distributions display very different usage curves. This is even more dramatically seen in Figure 4: the two ET&AS curves bear no resemblance to one another. Figure 5 shows that the one S&BS classic, Edwards/63, faded within its "home" subject category after 8 years, while the two AB&ES classics are still going strong, especially Hynes/61 after 20 years.

In our last citation classics graph, Figure 6, we compared the three papers published in 1969, standardized--as it were--by year instead of subject area. The three classics come from three different CCs. Note the marked differences in magnitude of within subject category citation proportions. The ET&AS classic was cited almost exclusively within engineering; the PC&ES classic (crystallography) is just the opposite. Nevertheless, the peaks and valleys in this curve mirror those in the engineering classic. Finally, the AB&ES (botany) classic experienced a renaissance in citation usage <u>within</u> its immediate subject area in years 7-9 of its life.

Table 2
Ten-Year Citation Characteristics for Eleven Citation Classics

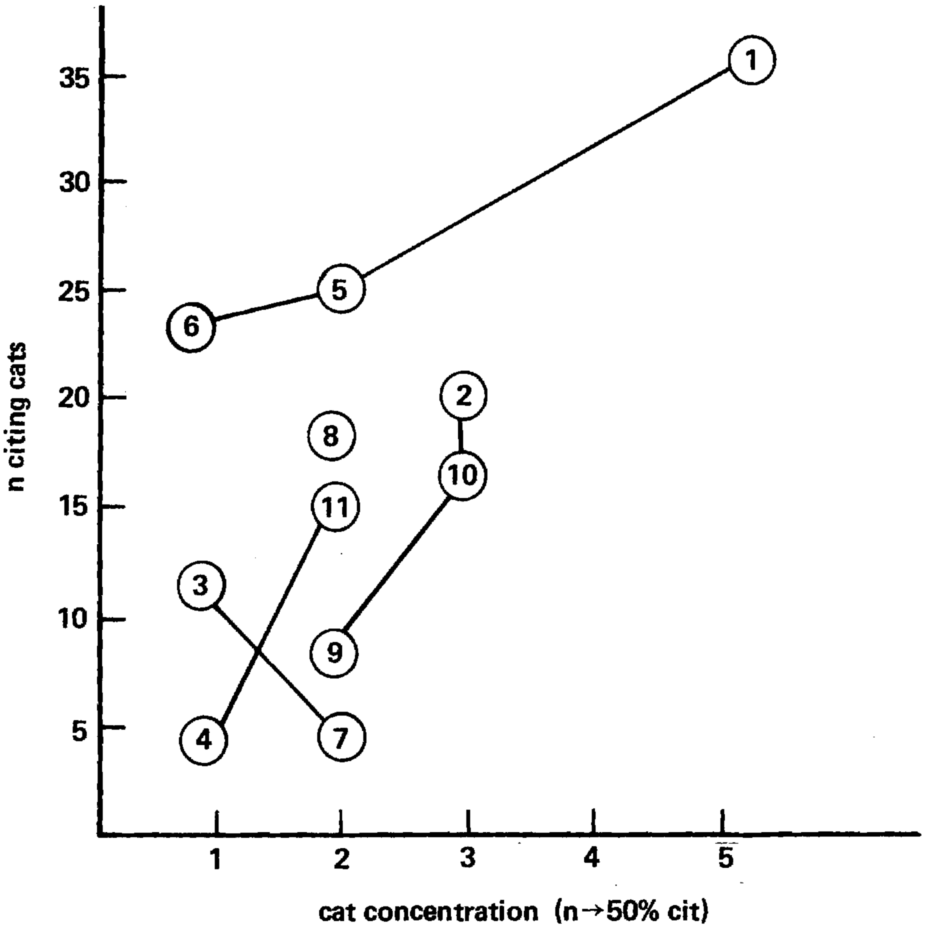
classic/yr	JCR subj cat	n cit*	n citing cats	% cits in classic cat	n cats acct for 50% cits	hi cite cats
Reynolds/63	cytology & histol.	157	35	22.9	5	neuro; anat & morph; path.
Shannon/69	crystal.	258	20	24.8	3	chem, inorg & nuc
Sawhney/69	botany	113	12	59.3	1	agric
Director/69	engin, elec	79	5	87.3	1	---
Blundell/72	biochem & mol bio	201	25	45.8	2	endoc & metabol
Lands/67	multidis# (pharm)	250	23	56.8	1	med, gen & intern
Hynes/61	marine & freshwater bio/ limnol	67	5	38.8	2	ecol & zool
Edwards/63	psych	77	17	48.0	2	stat & probab
Edmiston/63	physics	203	8	34.5	2	chem
Kneubuhl/60	chem, physical	219	17	14.2	3	chem; phys, atomic
Barker/67	chem, physical	258	15	16.3	2	phys, atomic

*total or sample

#journals in this category include Science and Nature; subject of particular article appears in parentheses

FIGURE 1

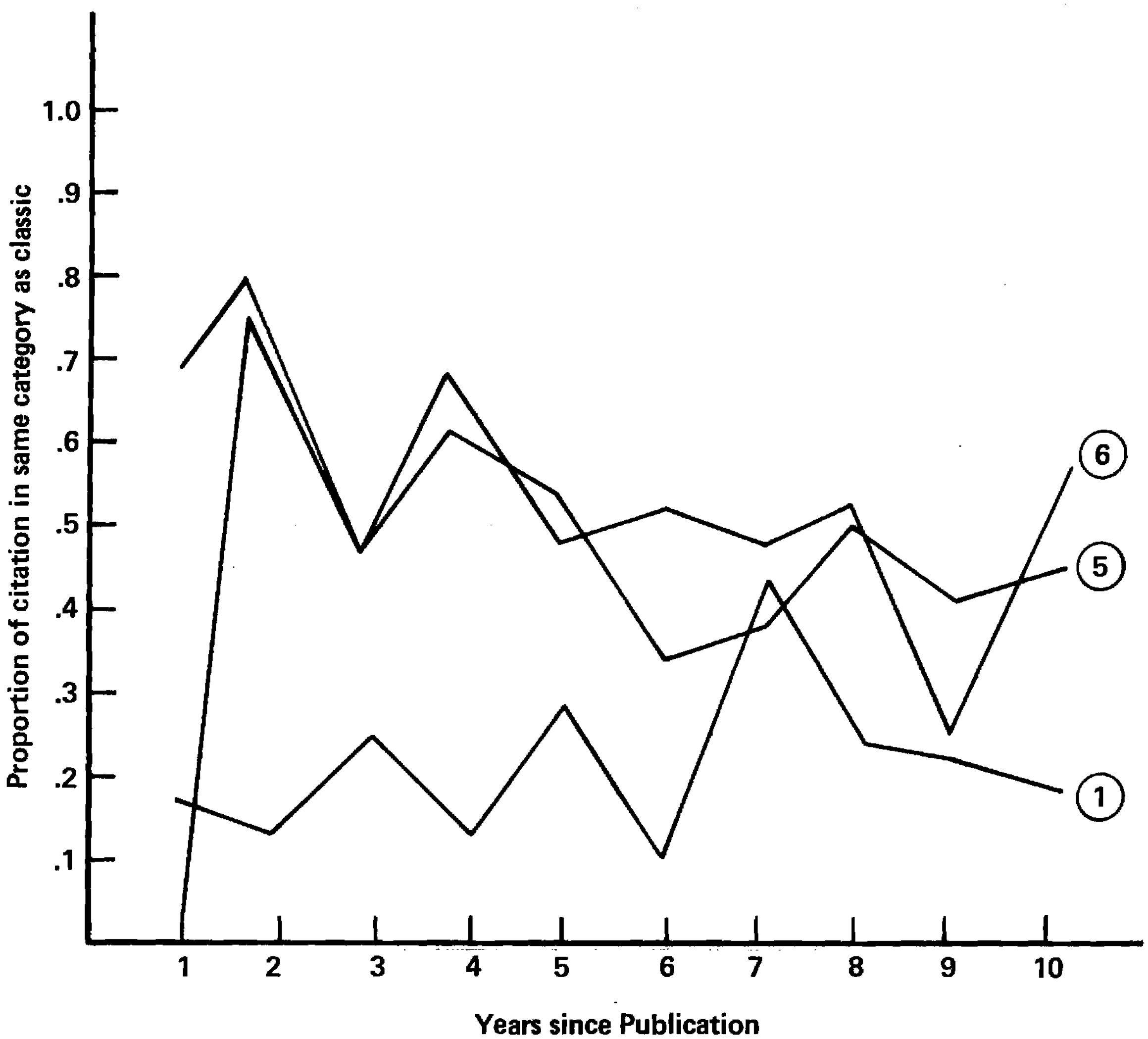
MAP RELATING NUMBER OF CITING CATEGORIES AND CATEGORICAL CONCENTRATION FOR ELEVEN CITATION CLASSICS



KEY:	PC & ES	2, 9, 10
	LS	1, 5, 6
	ET & AS	4, 11
	AB & ES	3, 7
	S & BS	8

FIGURE 2

TEN-YEAR CITATION HISTORIES FOR THREE LIFE SCIENCES CLASSICS*



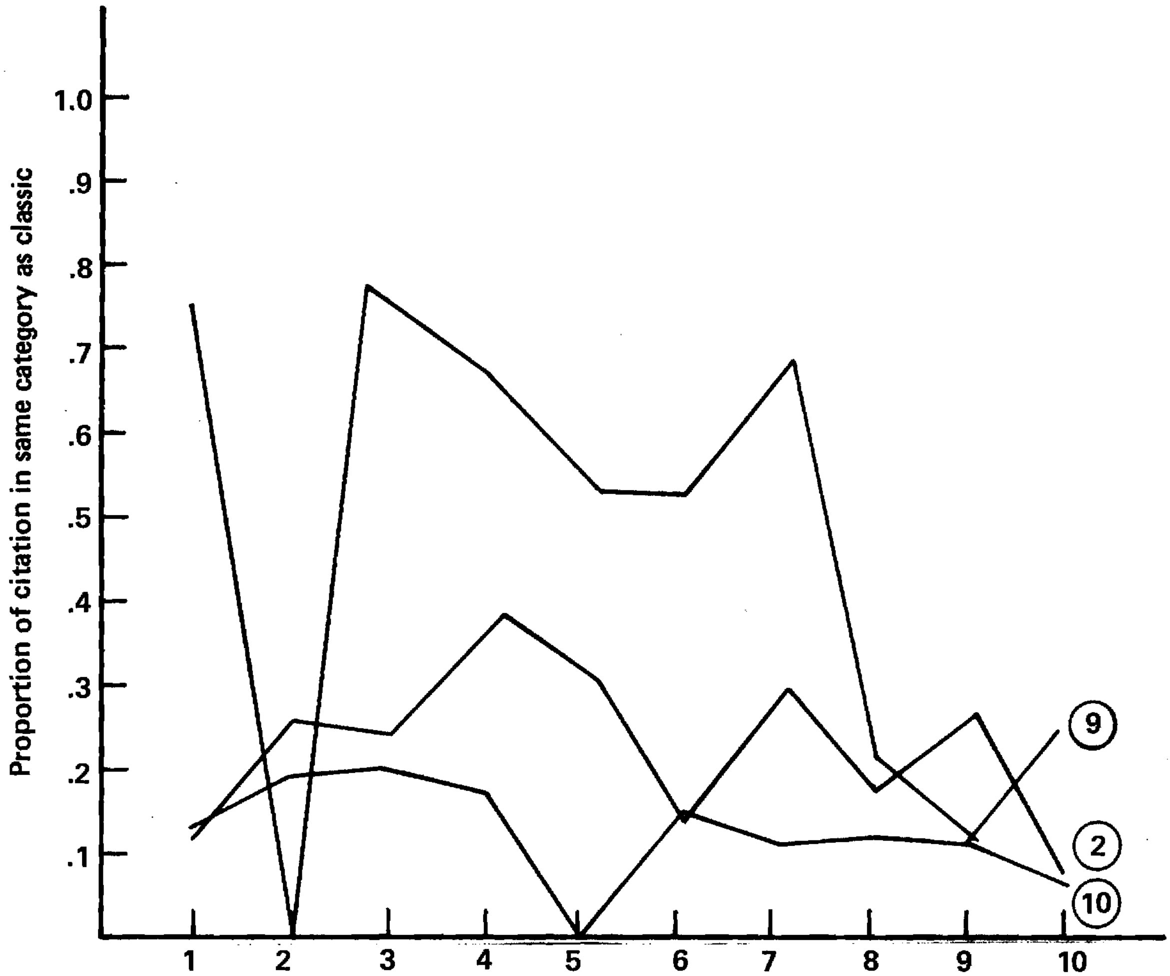
* (1) = 157 cit, 1963 (sample)

(5) = 201 cit, 1972

(6) = 250 cit, 1967 (sample)

FIGURE 3

TEN-YEAR CITATION HISTORIES FOR THREE PHYSICAL, CHEMICAL, & EARTH SCIENCES CLASSICS*



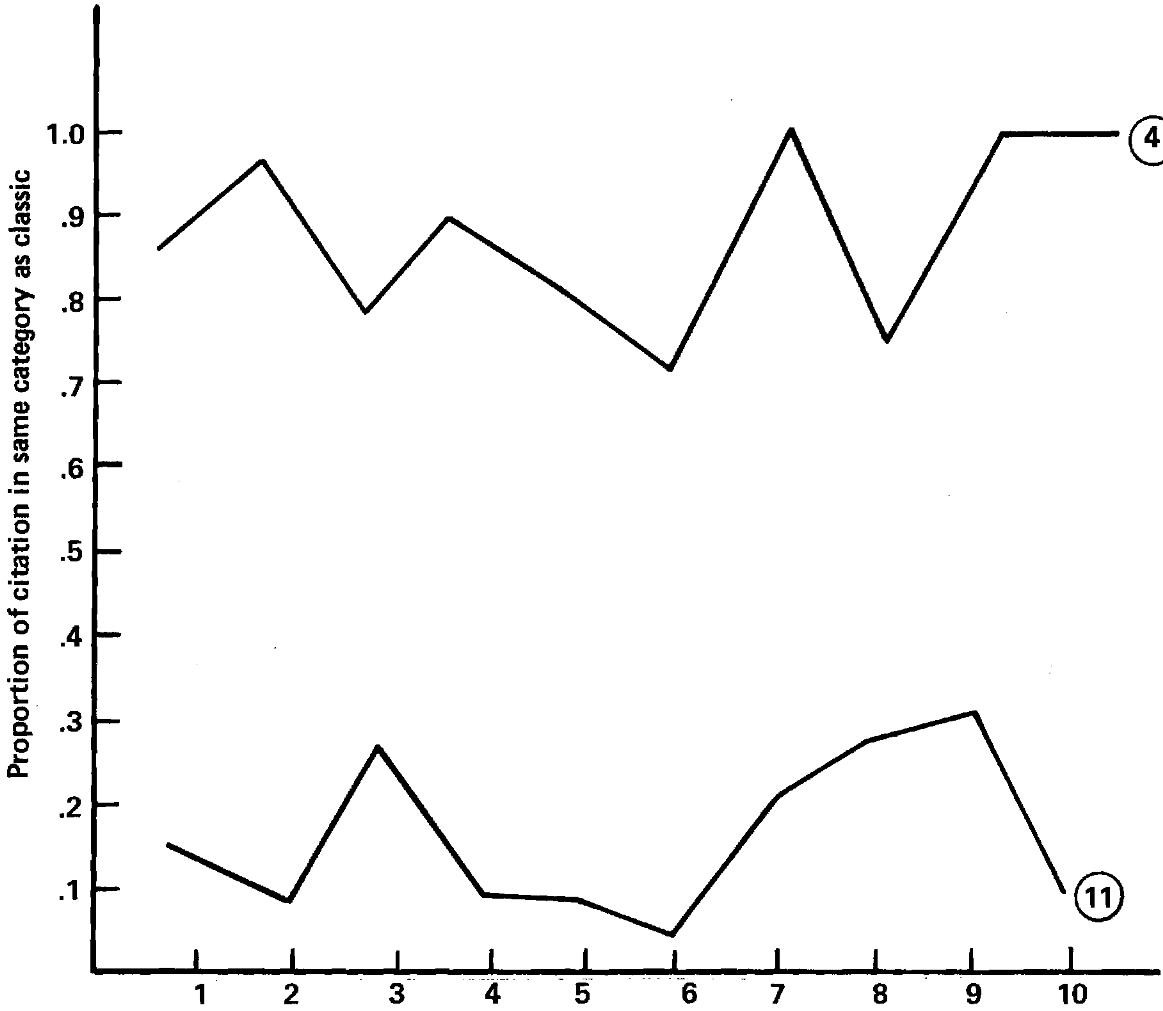
* (2) = 258 cit, 1969

(9) = 203 cit, 1963

(10) = 219 cit, 1960

FIGURE 4

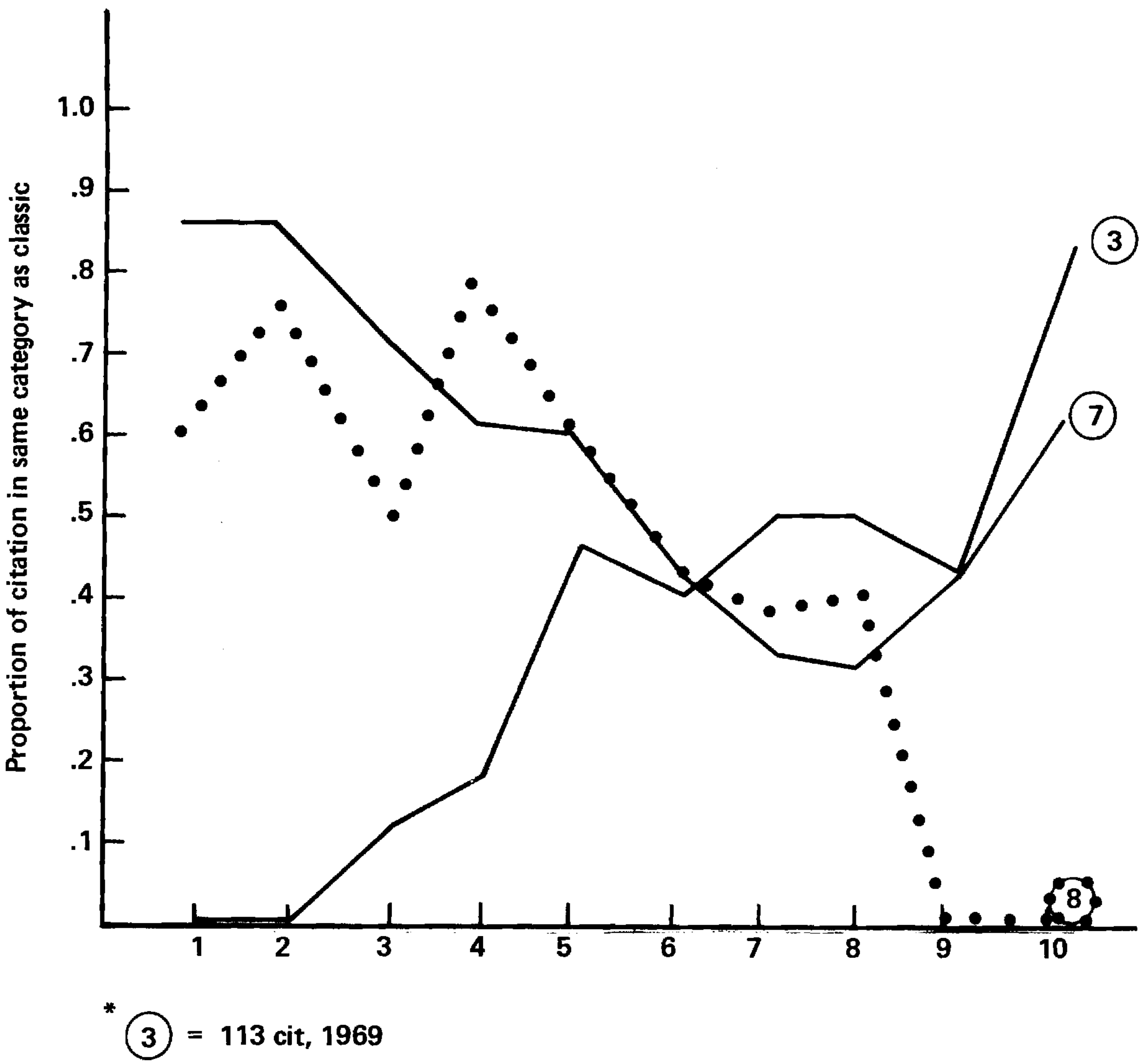
TEN-YEAR CITATION HISTORIES FOR TWO ENGINEERING, TECHNOLOGY & APPLIED SCIENCES CLASSICS*



* (4) = 79 cit, 1969
(11) = 258 cit, 1967

FIGURE 5

TEN-YEAR CITATION HISTORIES FOR TWO AGRICULTURE, BIOLOGY & ENVIRONMENTAL SCIENCES CLASSICS AND ONE SOCIAL AND BEHAVIORAL SCIENCES CLASSIC *



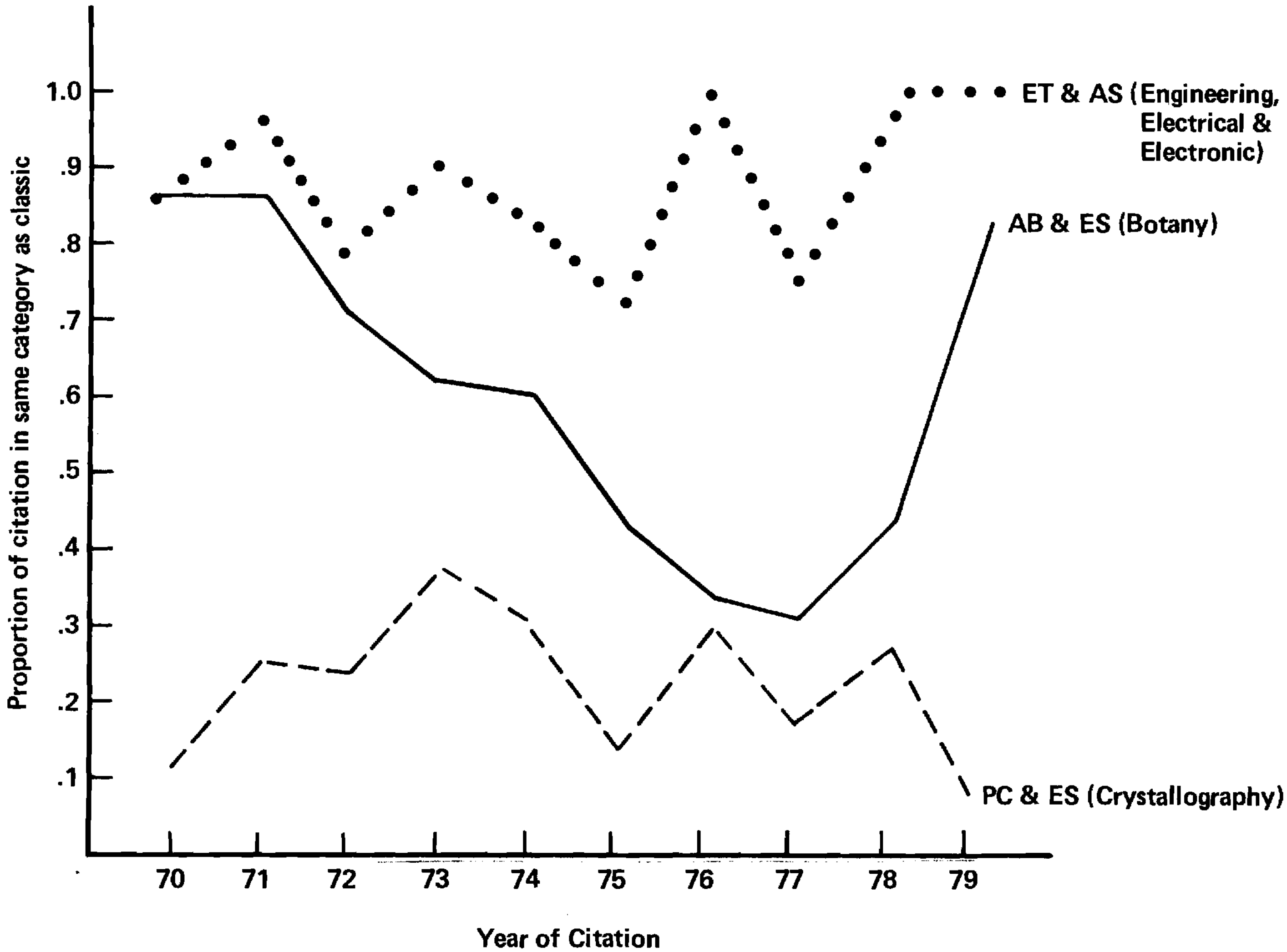
* (3) = 113 cit, 1969

(7) = 67 cit, 1961

(8) = 77 cit, 1963

FIGURE 6

CITATION HISTORIES FOR THREE CITATION CLASSICS PUBLISHED IN 1969



Taken together, these data raise a host of questions about usage which ten-year citation histories cannot address. To wit, who is citing these classics and how are they being used? Furthermore, is there a different usage curve for IDR papers? Is a substantial secondary subject category an "early warning" of a paper's eventual IDR application? These are questions that require the kinds of data and analysis which this experiment was designed to supply. Our preliminary findings provide that justification. The content of the CC citation classics now merits a close look, especially if the criterion of high citation is invoked to distinguish "special" papers from the mass of literature which scientists are, in theory, obliged to use. In Part II of this report, we employ a sample of the broader literature to construct and validate indicators of IDR, not just the diffusion of ideas to new audiences.

II. Results of the Journal Approach

A. Conceptualization

The journal approach assumes that serial publications are organic entities which reflect the research papers submitted to them and deemed worthy of publication. The criteria of "worth" may follow conscious editorial policy, directing a field as it gravitates toward certain problems and methods, and away from others. This suggests that certain journals may be more inherently IDR (or, for that matter, theoretical, experimental, quantitative, etc.) than others. Whether journal content captures the intellectual diversity of specialties, disciplines, and broad fields is another matter altogether. Surely the fit is better in some areas than in others. The prefatory point to be made here is that the construction of journal indicators of IDR inevitably "types" serials by their measured content at time t. If journals are truly organic, their content is evolving. Several questions thus emerge: Can we distinguish disciplinary from IDR journals? Can we characterize broad fields or research areas as being more or less IDR? And can we validate a set of journal indicators that anticipates the lags, fits, and starts in intellectual content which research areas, be they seen as specialties or disciplines, experience?

The purpose of the journal approach is to develop a set of indicators based on public data sources, and therefore usable by others, and to validate them with a data set created and manipulated expressly for this project. The public data source we employed is ISI's <u>Journal Citation Report</u> (JCR). JCR is composed of five "packages" or sections; the three relevant to our approach are the Journal Ranking Package (containing journals ranked by impact factor and reported within subject categories), the Citing Journal Package, and the Cited Journal Package (each displaying citation frequency relationships between pairs of journals). In the Citing Journal Package one finds which journals a particular journal has cited and the distribution by year of the cited material. In the Cited Journal Package one finds which journals have cited a particular journal and the distribution by year. Citation counts in the 1979 JCR are arrayed annually for 1971-79 and aggregated for 1970 and earlier. In addition to "totals," an "all other" entry summarizes reference-citation information for journals citing or cited fewer than six times in 1979, and journal "self-citations" also appear separately.

The Cited Journal Package presents a profile of publication usage--from which areas journals have been cited and across which specialties/disciplines. The Citing Journal Package indicates from which areas authors/publications draw to produce articles. (ISI's description and a sample page from the 1980 JCR are reproduced in Appendix B.)

B. The Independent (Validator) Journal Data Set

Using the JCR subject classification, four "grand" categories of research were defined: Engineering, Life Sciences, Physical Sciences, and Social Sciences. Discussion among a panel of raters (two of the project PIs plus a graduate student in Industrial Engineering) (Dager Gonzales, 1982), led to the following journal selection procedure:

a. select specific subcategories that represent the four grand categories;

b. select some subcategories that appear mainly theoretical in nature and some that appear applied;

c. select some categories/subcategories that appear to be relatively interdisciplinary and some that fall within traditional disciplines.

The resulting specification of journal areas, or sampling frame (denoted by the numbers 1-10), is presented in Table 3.

Two journals were selected from each of the ten areas. The criteria were threefold:

a. select the journal per area with the highest impact factor (recall that this is a measure of the frequency with which the "average cited article in a journal has been cited in a particular year," in our case 1979);

b. select the journal per area with the median impact factor, if at least 0.3; otherwise, take the journal just at or above 0.3;

Table 3
Definition of Journal Areas
for Validation Data Set

grand category	category	subcategory
Engineering	1. Electrical Engineering	
	2. Operations Research	
Life Sciences	Medicine	3. Anatomy
		4. Toxicology
	Biology	5. Ecology
Physical Sciences	Physics	6. Mathematical Physics
	Chemistry	7. Crystallography
	8. Computer Sciences	
Social Sciences	Psychology	9. Developmental Psychology
	Other Social Sciences	10. Demography

c. require that each journal selected have a reference format that provides article title as well as journal name, volume, etc. (information needed for validation purposes).

If the journal did not satisfy criterion c, in the case of the highest impact factor journal we selected the journal with the next highest, and in the case of the median impact factor, that immediately superior. (Originally, 16 journals satisfied all criteria; other journals were added where necessary.) Table 4 shows the journals selected for each of the areas specified in Table 3.

Among the questions this data set will allow us to address are the following: Do the categories/subcategories that appear to fall within the traditional disciplines represented in our journal sample draw literature primarily from the same disciplines? Do the categories/subcategories that appear to be IDR draw from across disciplines (both within and across grand categories)? Utilizing the JCR Citing Package, we can construct production indicators to respond to such queries. Likewise, are categories that are within traditional disciplines cited within those same categories and grand categories? Are the subcategories/categories that appear to be IDR cited by various disciplinary literatures? The JCR Cited Package allows us to examine the "audience" problem, i.e., usage of the serial literature by disciplinary and IDR audiences. Do the consumption and usage patterns of the these audiences differ?

C. Indicator Validation

The creation of a set of potential indicators implies the need for their validation. Several approaches to the validation of our journal indicators were developed. First, a panel of raters was essential for producing an assessment of (inter)disciplinarity based on various criteria, including content analysis of the paper's abstract, author characteristics provided on the paper's title page, the paper's bibliographic references, and any other attributes of the journal in which the paper was published (a review of this methodology is found in Chubin, 1975). Since individual assessments of such characteristics vary with the assessor's own cognitive style and epistemological preferences (Mitroff and Kilmann, 1978), inter-rater comparisons must be made. A summary of inter-rater coding reliabilities is presented in Appendix C.

From the sample of journals selected, 383 articles were drawn. The articles were the first ones published in 1979, to a maximum of 20, to increase the probability of citation in 1980 or 1981. (Citation is central to the usage validation discussed below.)

Table 4

Journals Selected for Validation,
by Grand Category, Category/Subcategory, and Impact Factor

grand category	category/ subcategory	journal	1980 impact factor (h/m)
Engineering	Operations Research	Management Science	0.69 h
		Mathematical Programming	0.56 m
	Electrical Engineering	IEEE Quantum Electronics	2.90 h
		IEEE Transactions on Reliability	0.41 m
Life Sciences	Ecology	Annual Review of Ecological Systems	3.59 h
		J. of Soil and Water Conservation	0.34 m
	Anatomy	American J. of Anatomy	1.59 m
		Anatomical Record	2.56 h
	Toxicology	CRC Critical Reviews in Toxicology	3.63 h
		Toxicology Letters	0.82 m
Physical Sciences	Mathematical Physics	J. of Mathematical Physics	1.15 h
		Letters in Mathematical Physics	0.76 m
	Crystallography*	Progress in Crystal Growth	1.62 h

	Computer Science	*Computer Physics Communications*	1.21 h
		International J. of Biomedical Computing	0.45 m
Social Sciences	Demography	*Population Studies*	0.82 h
		J. of Biosocial Science	0.58 m
	Developmental Psychology	*J. of Experimental Child Psychology*	0.78 h
		International J. of Aging	0.33 m

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*No journal classified as "Crystallography" satisfied criteria b and c; hence, only one journal was used. *J. of Applied Crystallography* was added, where applicable, in later analyses.

The variables used, then, for production, as opposed to usage, validation were:

1. number of authors of the article; and

2. "rank" of the article based on "title-page" information such as title, abstract/introduction, authors' affiliation, and acknowledged sources of research support.

The rank codes form a scale of 1-5 with 1= purely disciplinary to 4= interdisciplinary in the sense that ideas are brought together from more than one source discipline/category, but within the same grand category, and 5= highly interdisciplinary, i.e., ideas are brought together across grand categories that span some intellectual distance.

A third production variable was coded independently of the two above. This variable was a subject classification of the references found in the article sample. Four reference codes were used.

0 - Reference is not classifiable (e.g., foreign language or no title given).

1 - Reference is in the same specialty as the citing article. Specialty is interpreted narrowly (i.e., more than one keyword in the title, abstract, or introduction in common). For instance, suppose the citing article reported research on electron microscopy of epithelial cells in rat kidney; a reference to a study of epithelial cells in monkey kidney would be classified "1." A sample of references in each of the 10 categories was rated independently by two PIs. After discussion and "calibration" by category, one proceeded to code the remaining references in that category.

2 - Reference is in a specialty that is close to, but different from, the citing article in question. For example, a reference within anatomy that does not emphasize two of the keywords, e.g., electron microscopy, epithelial cells, rat, kidney, in the previous illustration, would be coded as 2.

3 - Reference is in a specialty far removed from the article. Appendix D defines codes 1-3 using the subcategory, category, and grand category schema introduced earlier.

The article (qua validator) information is presented in

Table 5 for the 14 journals which allowed coding of the variables described. Notice that this table contains only production information found in the sample of 383 articles. The most striking datum is that the mean proportion of references in code 3 is 0.00. This pales in comparison with the sums for codes 1 and 2, respectively. Further analysis using this validator collapsed codes 2 and 3. This is an admission that virtually no references came from disciplinarily remote sources, i.e., from across grand categories.

This finding undermines the prospect of using grand category cross-referencing to indicate IDR. A very different model of IDR is suggested, namely, that highly specialized research problems bring to bear relevant knowledge from related disciplines. "Interdisciplinary" life scientists don't much draw on social scientists or engineers. They may draw on several disparate technologies and several disciplines, but only "as they pertain." A neuroscientist studying chemical effects on the functioning of cells in the hypothalamus would likely not even notice the "interdisciplinarity" of drawing on information gained by anatomists doing histology, psychologists recording single cells, and physiologists monitoring chemical concentrations of neural transmitters.

With the evidence of Table 5 as the basis for hindsight, the codes 1-3 designating relative proximity to specialty would doubtless miss much IDR. In other words, work of the anatomist, psychologist, and physiologist apt to be cited pertains "unequivocally" to the research specialty. Over the long term, such meshing of interests could fuse to create new disciplines. "Neuroscience" may reflect such a process now underway (Rossini et al., 1981). This raises questions about how one should measure the fusing process, or what Studer and Chubin (1980) call "confluence." For the present exercise, it suggests that we attempt a different reference categorization scheme.

To discern other patterns in these baseline numbers, however, we constructed Table 6. In Part A of this table, three dimensions of rank are shown. Recall that rank is a key (panel) judgment measure of disciplinary-interdisciplinary content of article (aggregated to journal level). We find that the Life Sciences journals exhibit the greatest range in mean rank and Social Sciences the least. The only Physical Sciences journal usable for production coding, International J. of Biomedical Computing, was rated the highest on IDR rank (mean= 3.0). In general, our intuition as to the IDR journals is borne out. In Part B of Table 6, however, the only clear difference exists in the Life Sciences. The two journals a priori considered disciplinary received mean ranks of less than 2.0 while the three suspected of IDR content all exceeded 2.0. The Engineering journals follow no pattern whatsoever, and the ranks of the three Social Sciences initially perceived as IDR all fall below 2.0.

TABLE 5. PRODUCTION CHARACTERISTICS OF ARTICLES IN VALIDATION DATA SET

JOURNAL	GRAND CAT	ART	AUTHORS		RANK		REFS CODED* (in Proportions)				TOTAL REF N	SAMPLE REF N
	D or I		$\bar{x}$	SD	$\bar{x}$	SD	0	1	2	3		
AM J ANAT 1	LD	20	2.30	.92	1.30	.57	.04	.36	.59	.01	732	384
ANAT REC 2	LD	20	1.95	.76	1.25	.44	.05	.37	.57	0	868	384
CRC TOX 3	LI	9	2.11	.60	2.11	.60	.09	.40	.51	0	1870	177
ANN R ECOL 5	LI	14	1.57	.85	2.79	.70	.04	.47	.49	0	1641	263
J SOIL WATER 6	LI	20	2.00	1.30	2.70	1.08	.03	.64	.33	0	227	227
IEEE RELIAB 10	EI	20	1.60	.75	1.85	.67	.07	.60	.33	0	159	159
IEEE Q EL 11	ED	20	2.35	.88	2.20	.52	.07	.68	.25	0	412	328
INT J AGING 13	SI	20	1.65	.88	1.95	.69	.03	.55	.40	.02	384	261
INT J BIOMED 14	PI	20	2.55	1.54	3.00	.97	.20	.45	.35	0	155	155
MATH PROG 15	ED	20	1.80	.77	1.25	.55	.05	.61	.34	0	286	276
MGT SCI 16	EI	19	1.68	.67	2.21	.71	.02	.50	.48	0	242	242
J BIOSOC SCI 17	SI	20	1.65	.88	1.60	.50	.02	.57	.41	.01	388	205
POP STUD 18	SI	20	1.40	.82	1.75	.72	.07	.44	.49	0	348	235
J DEV PSY 19	SD	20	1.65	.81	1.30	.47	0	.47	.52	.01	493	349
	TOTAL	262	1.87	.89	1.95	.66	.06	.51	.43	.00	8205	3645

*See Appendix D and text for explanation

TABLE 6. PATTERNS OF DISCIPLINARY(D)-INTERDISCIPLINARY(I) JOURNAL RANK

A. CATEGORIES OF JOURNALS		RANGE	NUMBER OF JOURNALS
Broad Field:	Life	1.25-2.79	5
	Engineering	1.25-2.20	4
	Social	1.30-1.95	4
	Physical	3.00	1
Initial Classification:	D	1.25-2.20	5
	ID	1.60-3.00	9
Rank:	>2.00	1.25-1.95	8
	<2.00	2.11-3.00	6

B. SUMMARY DISTRIBUTION BY CLASSIFICATION, MEAN RANK, AND BROAD FIELD OF JOURNAL

	D	I
	>2.0/<2.0	>2.0/<2.0
Life	-/2	3/-
Engineering	1/1	1/1
Social	-/1	-/3
Physical		1/-

Turning to usage, the baseline article information is summarized in Table 7. Because the SCI and SSCI Citation Indexes are the data sources here, information was obtained on all 19 journals (not the 14 to which we were limited for production due to formats that omitted information). The 383 articles were searched by first author's surname plus initials for citations received in 1981. These citing articles were then classified, as in the production mode, into codes 0-3 and aggregated by journal. Self-citations were similarly counted and classified. (The "Tot Cit" column includes 1980 plus 1981 citations.)

Although the proportion of journal self-citations seems to vary, a one-way analysis of variance revealed no statistically significant differences. We do note that disciplinary journals exhibit a larger number of self-citations than IDR journals, but their distribution in codes 1 and 2 parallels the IDR journal distribution. And once again, the proportion of citations in codes 3 is miniscule, necessitating (as in production) the consolidation of code 2 and 3 data.

A preliminary look at the relationship between production and usage measures is now possible. The most important of these would appear to be, from Table 6, the number of references classified as 2 and 3 divided by all references (REF23), and mean rank (RANK), and from Table 7, the number of citations judged to be in categories 2 and 3 relative to the subject matter of the article it cited (CIT23).

The results show that RANK is negatively, but weakly, correlated with REF23 (-.28) and with CIT23 (-.18). REF23 and CIT23 are correlated .28. Overall, approximately 2/3 of the references given in the article sample went to papers in the same subcategory (code 1), while the other 1/3 went to papers judged to be within a broader specialty related to the research in question. Usage, however, appears even more restricted: 3/4 of the small sample of citations in 1981 were to authors doing research in the identical specialty. The production measure appears the more promising focus for validation efforts in the present study because the data base is so much larger thanthat for the utilization measures.

D. The Indicator Data

A data file with JCR information on our sample of journals for 1979 was augmented by a printout provided by ISI detailing the journals aggregated in the "all other" line in the Citing and Cited Packages. This line in the published JCR contains the number of journals whose 1979 reference and citation counts, relative to any journal citing or cited by it at least once, total less than six. It was our suspicion that the journals in this residual category would exhibit a reference and/or citation distribution that differs significantly by category of

TABLE 7. USAGE CHARACTERISTICS OF ARTICLES IN VALIDATION DATA SET

JOURNAL	GRAND CAT D or I	CITATIONS CODED* U0	U1	U2	U3	JOURNAL SELF CITATIONS* S0	S1	S2	S3	TOT SELF	TOT CIT	TOT 81
AM J ANAT 1	LD	.08	.21	.71	0	0	.63	.38	0	7	35	31
ANAT REC 2	LD	0	.40	.60	0	0	.80	.20	0	6	43	37
CRC TOX 3	LI	.44	3.33	0	0	.11	.11	0	0	2	34	31
TOX LETT 4	LI	.14	.49	.23	.14	.20	.60	.20	0	6	15	14
ANN R ECOL 5	LI	0	.28	.72	0	0	1.00	0	0	1	23	23
J SOIL WATER 6	LI	0	.48	.52	0	0	0	1.00	0	2	14	10
COMP P. COMM 7	PD	0	0	.14	.46	.40	.20	.50	.30	6	15	15
J MATH PHY 8	PD	0	0	.57	.39	.03	0	.40	.60	2	20	10
P. CRY GRO 9	LI	0	.50	.50	0	0	.65	.35	0	1	31	26
IEEE RELIAB 10	EI	0	.61	.39	0	0	.67	.33	0	1	9	7
IEEE Q ELEC 11	ED	.06	.74	.20	0	0	.96	.04	0	13	60	41
LETT MATH P. 12	PD	0	.38	.63	0	.25	.50	.25	0	4	12	7
INT J AGING 13	SI	0	.50	.50	0	0	.50	.50	0	7	0	5
INT J BIOMED 14	PI	0	.50	.50	0	0	.50	.50	0	2	4	4
MATH PROG 15	ED	0	.54	.46	0	0	.75	.25	0	0	12	10
MGT SCI 16	EI	0	.36	.64	0	0	0	1	0	0	8	7
J BIOSOC SCI 17	SI	0	.25	.75	0	0	1	0	0	2	9	8
POP STUD 18	SI	0	.60	.20	.20	0	1	0	0	3	6	6
J DEV PSY 19	SD	0	.27	.73	0	0	.25	.75	0	7	24	21
TOTAL	$\bar{x}$/SD	.04/.20	.43/.81	.64/.10	.02/.08	.01/.04	.15/.40	.08/.26	.00/.02	72	371	313
	TOTAL	.02	.40	.54	.04	.02	.63	.32	.02			

* See Appendix D and text

production/usage distribution (using the 1-5 scale defined in Appendix D) from the major citing/cited journals. Tables 8 and 9 contain the mean values by category for these putative production and usage indicators. (A complete explanation of the algorithm for computing these journal indicators appears in Appendix E.)

Tables 8 and 9 tell us, respectively, that the mean proportion of references and citations not only differs in the distributions by category, but also that one-half of the references for all 1979 articles in our sample were to journals found in the "all other" line. The corresponding mean citation proportion is only .28. We observe further that the mean proportions in categories 4 and 5 are low relative to 1-3. Most references and citations are not to journals outside the grand category of the article's subject. In both production and usage, however, there is less concentration and more "dispersal" across categories among the "all other" journal entries than among those citing/cited six or more times. Note especially the much higher proportions in category 4--outside the grand category of the source journal.

Due to our sampling of JCR citations for classification purposes, the usage measures are weak; their combination to form indicators, e.g., by aggregating categories of citation, proved rather fruitless. Conceptually, the proportion of citations falling outside the subject category of a journal makes sense; refining that proportion by working with JCR's "all other" line is a recommendation for further exploration. For now, we can examine this conceptual measure of dispersal (e.g., REFDISP in Table 8) more profitably with respect to references.

One reference-based indicator, PROD35, seems best suited for further development. It is a ratio of references in categories 3-5 to references in all categories (1-5). It is formed by adding reference counts greater than or equal to six to weighted references (to compensate for sampling) in the "all other" line.Thus, this indicator is a measure of dispersal in the references used in article production. When coupled with our chief validator, RANK, we find a Pearson's correlation of .57. This is somewhat higher, too, than the correlation between a simpler dispersal measure of "mean proportion of all other" references (i.e., of all references, the proportion appearing in journals with fewer than six citations from the source journal) and RANK (r= .47). PROD35 is also appealing because it employs a more stringent definition of disciplinary category, and therefore, of cross-disciplinary referencing.

Operationally, cross-disciplinarity is a step closer to multidisciplinarity, and ultimately, to IDR. Finally, the validators REF23 and CIT23 are negatively correlated with PROD35 (r= -.18 and -.19, respectively). These findings are consistent if we note that the specialization codes reflected in REF23 and CIT23 don't tap cross-disciplinary referencing, as discussed

TABLE 8. VALUES FOR PRODUCTION INDICATORS, BY CATEGORY

PROPORTION OF CITATIONS WITH COUNTS GREATER THAN SIX, BY CATEGORY			PROPORTION OF CITATIONS WITH COUNTS LESS THAN SIX, BY CATEGORY		
CATEGORY	MEAN	SD	CATEGORY	MEAN	SD
1	.287	.200	1	.112	.158
2	.299	.296	2	.317	.307
3	.329	.262	3	.391	.255
4	.039	.051	4	.155	.189
5	.046	.050	5	.026	.043

Proportion of Numbers of Reference Counts for the All Other Line (Total Less Than Six)/Total Sum of Categories 1 Through 5

	Mean	SD
REFDISP =	.506	.154

NOTE: 1 = Within Subcategory
2 = Within Category (Outside Subcategory)
3 = Within Grand Category (Outside Category)
4 = Outside Grand Category
5 = Multidisciplinary
(see Appendix E)

TABLE 9 VALUES FOR USAGE INDICATORS, BY CATEGORY

PROPORTION OF CITATION COUNTS GREATER THAN OR EQUAL TO SIX, BY CATEGORY			PROPORTION OF CITATION COUNTS LESS THAN OR EQUAL TO SIX, BY CATEGORY		
CATEGORY	MEAN	SD	CATEGORY	MEAN	SD
1	.375	.316	1	.151	.175
2	.241	.341	2	.237	.246
3	.262	.284	3	.466	.306
4	.019	.033	4	.099	.116
5	.013	.033	5	.048	.086

Proportion of Citation Counts for the All Other Line (Total Less than Six)/Sum of Categories 1 Through 5

	MEAN	SD
CITDISP =	.284	.148

NOTE: 1 = Within Subcategory
2 = Within Category (Outside Subcategory)
3 = Within Grand Category (Outside Category)
4 = Outside Grand Category
5 = Multidisciplinary
(see Appendix E)

above. Our interpretation is that PROD35 should be carried forward to the next phase of analysis, where other validation could be sought.

E. Another Approach to the Validation of Indicators

The analysis thus far has produced validation of PROD35, and its weaker version, REFDISP, based largely on judgments of references and citations as within the same subject category (over the range "sub" to "grand") or "outside grand." Such judgments were made by examining the titles of articles referenced in our 19-journal validation sample. As such, our judgments were inferences about article content. An alternative approach is to assume a homogeneity of content within journals and return to the JCR subject classification.

To do this requires consolidation of the JCR categories so that similar research topics and specialties appear within the same category. In other words, we can increase homogeneity of content, for classification purposes, by recoding the 80 JCR categories applied heretofore. This reduction in categories precludes inflated estimates of cross-category referencing due simply to the existence of many categories. The 1980 JCR, for example, distinguishes 8 (sub)categories under Physics (and 150 subject categories in all). This is no doubt useful for retrieving a specific Physics literature, but redundant, and certainly cumbersome, for our purpose. By "deflating" the number of relevant categories--from 80 to 43, as it turns out--we can make distinctions in the production and utilization of the serial literature that can aid in validating our candidate indicators of IDR. Appendix F contains the recoded JCR subject categories used in the remainder of our analysis.

The procedure we employed was as follows. For every article in our 19-journal sample, the first 10 bibliographic references were coded into one of the 43 subject categories corresponding to the referenced journal. For various reasons these data were incomplete. Three journals had fewer than 20 articles in the sampled 1979 issue (two of these publish nothing but review articles). All but one journal had missing references, i.e., fewer than 200 coded. This was due (a) to serials that were notclassified by the JCR, but more important, (b) to non-serials that appeared regularly in the reference lists of certain journals (e.g., J. Soil and Water Conservation), and (c) to a lack of references altogether (e.g., in IEEE Reliability the average number for our 20 articles was 6).

So once again, there are deficiencies in a validation data set beyond our control, i.e., that emanate from the public data source and hamper the detection of IDR. There are substantive clues as well: It is quite possible that IDR is reported disproportionately in project reports, unpublished papers, and monographs, and not in the serial literature, particularly the widely-read and highly-cited literature. If this is so, then our validation will be a conservative estimate of the presence and extent of IDR in our indicators.

Table 10 presents the distribution of references by subject category for the 19 journals. Because category is the key unit of analysis here, note the percentage of references that fall outside the one and two "heaviest" categories, respectively. The columns on the right of the table report means and SD's of references per category. These measures differ significantly: while the mean denotes the average reference spread for the journal as a whole, the SD denotes variability from article to article within the journal. This "test" of the homogeneity assumption allows us to separate the high IDR reference content of one article in a sample of twenty from the lower, but more consistent, IDR content perhaps found in the "typical" article published in the same journal. For this reason alone, the number (or proportion or mean) of references outside the <u>two</u> heaviest categories is probably a better single measure of interdisciplinarity in the production of research than a measure that excludes only the modal subject category. The fourth column in Table 10 seems to bear this out inasmuch as the a priori high IDR journals <u>Toxicology Letters</u> and <u>Annual Review of Ecological Systems</u> reveal the greatest reference spread (105 and 83, respectively). Yet the largest SD's (fifth column) belong to <u>J. Biosocial Science</u> (3.23) and the other toxicology journal, <u>CRC Critical Reviews</u> (2.65, with the highest mean number of categories outside the two heaviest, 3.44).

Let us pause momentarily to reflect on our conceptualization. The mean and SD are independent measures of journal disciplinarity-interdisciplinarity. A journal high on both measures would project an overall IDR journal profile and any of the articles published therein would be expected to mirror this profile. A journal with a high SD, but not mean, could be thought of as multidisciplinary; individual authors/teams draw on diverse sources, but such articles are an oddity in this journal. The low mean-SD journal would be the pure discipline type; references are drawn from a restricted subject literature. The low SD-high mean journal would be empirically improbable; conceptually, it might indicate a fledgling specialty formed by the confluence of, in the present operationalization, two or more categories of literature. In information science lingo, when the "scatter" of a specialty literature behaves like a "core," we should wonder if perhaps something interdisciplinary is going on. A pattern of scatter dominating core, we would argue, implies that IDR is in the making. The empirically improbable set, therefore, could represent an "early warning" signal. But what do the data show?

If we call the mean "JOUT2" and the SD "AOUT2" (computed on the raw n's, of course), we can plot their relationship for each of our 19 journals. They are arrayed in the scattergram labeled

Table 10

DISTRIBUTION OF REFERENCES BY SUBJECT CATEGORY,*
FOR 1980 ARTICLE SAMPLE IN 19 JOURNALS

	journal	n of cats	% outside heaviest	% outside 2 heaviest	refs outside 2 cats n / mean / SD	n(mean)cat out 2 cat
1	American J of Anat	12	50	30	59/ 2.95 / 2.01	37 (1.85)
2	Anat Rec	15	56	33	65/ 3.25 / 2.15	42 (2.10)
3	CRC Crit Rev Toxic	14	83	70	63/ 7.00 / 2.65	31 (3.44)
4	Toxic Letters	22	72	61	105/ 5.25 / 2.15	64 (3.20)
5	Ann Rev Ecol Sys	15	79	59	83/ 5.93 / 2.13	48 (3.43)
6	J of Soil Wtr Consr	5	13	7	5/ 0.25 / 0.55	4 (0.20)
7	Commpute Phys Comm	6	38	14	12/ 0.60 / 1.27	7 (0.35)
8	J of Math Phys	8	23	5	8/ 0.40 / 0.75	7 (0.35)
9	Prog Cryst Grow	9	54	32	61/ 3.21 / 1.90	36 (1.90)
0	IEEE Relib	9	50	13	12/ 0.60 / 0.94	9 (0.45)
1	IEEE J of Quan Elec	7	51	25	46/ 2.30 / 1.62	24 (1.20)
2	Letters Math Phys	2	25	0	0/ 0.00 / 0.00	0 (0.00)
3	Int J of Aging	9	62	31	35/ 1.75 / 2.38	19 (0.95)
14	Int J of Biomedic Comp	17	68	53	46/ 2.30 / 2.30	29 (1.45)
15	Math Program	8	58	20	26/ 1.30 / 2.16	15 (0.75)
16	Mgmt Sci	11	46	33	42/ 2.10 / 2.32	25 (1.25)
17	Biosocial Sci	14	71	49	63/ 3.15 / 3.23	29 (1.45)
18	Popul Stud	10	52	27	20/ 1.00 / 1.62	13 (0.65)
19	J of Exp Child Psy	9	20	14	26/ 1.30 / 1.95	16 (0.80)

*based on recoded JCR, category n= 43 (see Appendix F)

Figure 7. The journals neither cluster perfectly by subject nor is there consistent homogeneity of journal content. A pattern does emerge, however: The hypothesized independence of the two measures is not found; JOUT2 and AOUT2 are correlated .89. The two toxicology journals and the one ecology journal conform to the aforementioned definition of IDR; the journals "off the diagonal," e.g., J. Biosocial Science, exemplify the "multidisciplinary" journal; most of the journals cluster predictably at the "disciplinary" (bottom left quadrant) origin of the scattergram.

On the usage side, the relationship of impact factor to the "OUT2" measures would tell us how journals higher in IDR content fare in the open literature. One hypothesis is that high impact factor journals are cited by a wider audience and therefore will have a "flatter" reference distribution. Conversely, and just as plausibly, a large citing audience in one specialty would overwhelm an intellectually diverse one. Our evidence indicates that IMP80, impact factor of a journal in 1980, is correlated .41 ($p=.05$) with JOUT2 and .59 ($p=.01$) with AOUT2. Thus, the first hypothesis is sustained to the extent that impact factor is positively correlated with referencing outside the two main subject categories of an article, and for all articles, appearing in a particular journal. Note that the measure of the "odd," and presumably IDR, article bears a stronger relation to impact factor than the overall journal IDR measure, JOUT2. Therein may reside a message concerning the visibility of articles that depart from the profile of the journal in which it is published.

This discussion of JOUT2 and AOUT2 has focused on their relationship as validators. To explore their relationship to the two indicators and the other validators introduced earlier, we constructed the correlation matrix shown in Table 11. Note that JOUT2 is correlated higher with PROD35 and RANK than is AOUT2; JOUT2 would appear to be the preferable measure. REFDISP, our other candidate indicator shows low correlations with the OUT2 measures (indeed, -.12 with AOUT2). The bottom row shows the most bizarre, and inexplicable, entry in the table. IMP80 correlates -.44 with REFDISP. The signs of the coefficients relating each indicator to a validator had heretofore been the same, with REFDISP displaying the more modest correlation. This changes here, but we don't know why. The negative relation contradicts the strong and positive OUT2 correlations with REFDISP, i.e., the lower the impact factor of the journal, the greater its reference dispersal. This reinforces the ambiguity of the relation between production and usage; surely the dynamics of referencing differ from those of citing--and IDR is implicated in these processes.

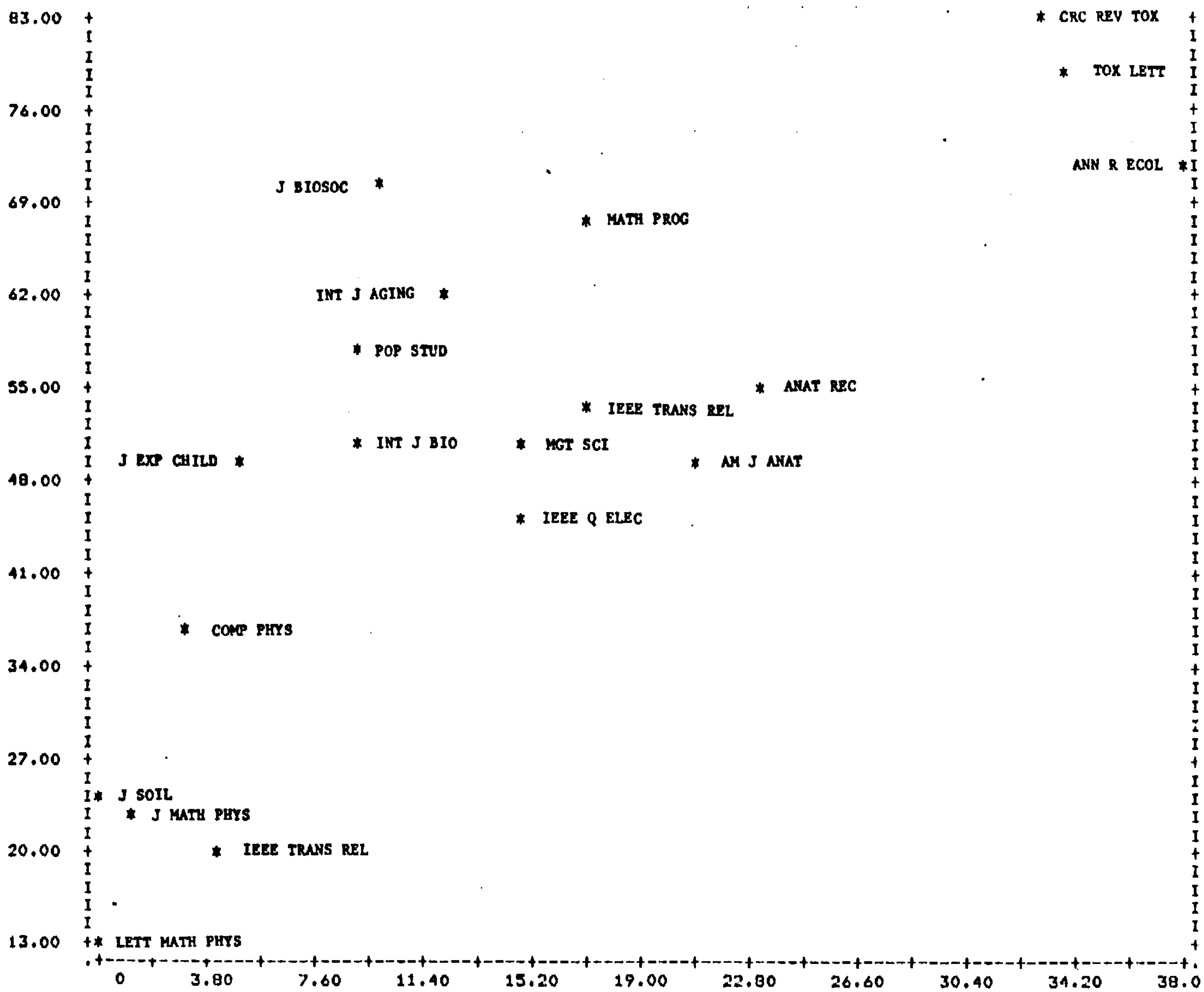


Figure 7

SCATTERGRAM OF NINETEEN JOURNALS
(AOUT2 x JOUT2)

Table 11

Correlation Matrix of Two Indicators (I) and Five Validators

	PROD35(I)	REFDISP(I)	RANK	JOUT2	AOUT2	REF23	IMP80
PROD35	1.00						
REFDISP	.05	1.00					
RANK	.48*	.41*	1.00				
JOUT2	.67**	.17	.35+	1.00			
AOUT2	.55**	-.12	.25	.89**	1.00		
REF23	-.18	-.34+	-.17	.00	.04	1.00	
IMP80	.11	-.44*	.03	.41*	.59**	.03	1.00

+ p=.10
* p=.05
** p=.01

F. An Application of the IDR Indicators

Instead of recapitulating and summing up at this time, we seek to apply our putative indicator to a new data set. Such a "pilot" application will help determine how well the indicators discriminate interdisciplinary research at the journal and article levels.

To address this "ultimate" question empirically, we project a year or two ahead as SRS staff is beginning to plan for Science Indicators 1984. A section on "Indicators of Interdisciplinary Research" is contemplated. The algorithm from this project is in hand. It requires (a) a disaggregated version of the JCR Citing and Cited Packages (which ISI happily supplies), (b) the alphabetical listing of SCI/SSCI journals by JCR subject category, and (c) a "coder" who, conversant with the various hard-copy sources before him/her, classifies and then tallies the references appearing in a given journal's articles for a specific year or other period of time. (In practice, this coder would probably be a computer program, prepared by ISI or another company, to process the journal citations vis-a-vis the ISI categories.) It is not the references per se that are tallied, but the journal subject category as the "origin" journal. A simple ratio of "in/out"--discounting, if we choose, unclassifiable references such as non-serials--yields a journal-level measure of reference patterns. Further analysis of the "outs" can probe the spread or intellectual distance between citing and cited categories. Journals within a category can thus be ordered as more or less open to literature outside their JCR-attributed subject. The cross-category citations provide a very reasonable measure of cross-disciplinary (not to be equated with interdisciplinary) work. To the extent that the ISI categories more closely approximate research areas than do "disciplines," they would be superior.

Examination of various derivative measures might be of interest for Science Indicators. For instance:

*the proportion of cross-category citation for scientific literature over time;

*cross-national comparisons of cross-category citation activity levels;

*the proportion of cross-broad field (e.g., consolidating categories into larger units such as physical, life, and social sciences, engineering, and other) citation for U.S. scientific literature over time;

*comparison among categories, and journals, showing which are most open to cross-category research, and how this is evolving over time;

*identification of "hot" techniques or substantive areas in terms of rapidly spreading citation of journals that "represent" (are associated with) those areas.

Specific scholarly investigations could probe even finer and more diverse issues if they could access the ISI data bases, for instance:

*to track the cross-category citation patterns of seminal articles, key authors, individuals trained in a particular lab, proponents of a certain theory or technique, or graduates of a particular department or program; and

*to predict the emergence of new research areas from dynamic cross-category citation clustering.

Computation of our preferred indicator, PROD35, requires access to ISI's JCR citation data, including the sparse journal citations lumped into an "all other" category in the hard-copy JCR. A manageable proxy for our indicator PROD35 is a proportion of citations, computed on a journal-by-journal basis, that expresses the number of citations given or received that fall outside the journal's JCR subject category. Two expressions, or estimates, of the "proportion outside a journal's JCR category" seem worthwhile. And the formulas differ in the interpretation and treatment of journals aggregated by JCR in the "all other" category. (Journals not classified by ISI, and therefore not appearing in the JCR, are assumed to be few and not necessarily the publication site of IDR. We make no such assumption for non-serial ISR work and recognize our underestimation of it by using this particular data source.)

If we assume that the "all other" journals which give and receive so few citations (relative to the journal in question) belong to a different subject category, then we can subtract the "all other" n from both the numerator and the denominator of our formula. The result is a "conservative" estimate (Con p) computed as follows:

Con p = (total citations - n in-category - n all others)/
(total citations - n all others).

A simpler alternative is to ignore the "all other" line in the JCR and merely subtract the n in-category from the total and divide through by the total. This "liberal" estimate (Lib p) assumes that the "all others" contain no research within the same subject category as that occupied by the journal in question. Because this assumption is tenable, we report this other p below as well. But because the composition of this cited literature is unknown, this p will overestimate the number of pieces that are indeed outside the journal's subject category. Our previous validation efforts (II.C) showed the "all others" to be a heterogeneous lot--with proportionately fewer in the same subject category as the journal citing them. This application, then, is an approximation of the extent to which out-of-category citation occurs in (a) three different subject areas, and (b) within different journals classified in the same subject area at two points in time.

The three subject categories selected as application sites for computing Con p and Lib p are Toxicology, Demography, and Operations Research/Management Science (OR/MS) (a biological, a social, and an engineering discipline, respectively). Thus, the only broad field not represented is the physical sciences (a decision prompted by the large number of journals that appear under Physics and Chemistry headings in the JCR alphabetical listing and rendering hand tabulation of in- and out-of-category tedious at best). Two years data were collected, 1982 and the earliest JCR compilation where we were confident that the information for our three subjects was relatively complete. This year was 1976 for Toxicology, and 1977 for Demography and OR/MS.

The raw SSI/SSCI citing and cited journal counts, and the corresponding estimates, are classified in Tables 12-17. Thus, we have a pair of tables for each of the three subject areas. First, we will examine each table, focusing on variations across journals and between citing and cited estimates. Then we will review graphically the levels and changes over time in the Con p and Lib p estimates of literature as they relate to future application of IDR indicators.

Tables 12 and 13 illustrate two findings that obtain for all three subject areas: Lib p is always greater than Con p and the p's for out-of-category citing tend to exceed the p's for being cited, regardless of journal. Toxicology, Demography, and OR/MS all draw on other areas of science to a greater degree than other areas draw on them. This suggests a potentially very useful metric for distinguishing "applied" from "basic" areas. Further investigation to map exactly which areas each draws upon could be informative. In general, citation by category comparisons of the literature appears to be a promising new scientometric vehicle.

The magnitudes of the estimates fluctuate both within and between journals. Within Toxicology (Table 12), the citing values of Con p and Lib p are stable, while the cited values, especially for ARCH TOXICOL, TOXICOLOGY, and CLIN TOXICOL, diverge. In Table 13, the difference between Con p and Lib p in five journals cited in 1982 exceeded .20. For example, CRC CRIT R TOXICOL (a familiar journal from our Citation Classics experiment) shows a Lib p = .84 and a Con p = .61. This denotes that 39% of the literature cited in this journal came from other journals within the Toxicology area. The liberal estimate says that only 16% was so cited. Again, interpretation hinges on the "all others." Just "flagging," as we have done, the journals with the most divergent estimates is a way of identifying

TABLE 12

Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Eight Toxicology Journals, 1976

	Citing					Cited				
Journal	Total in Category	All Other	Total	Lib p Total-in cat / Total	Con p Total-in-All Other / Total-All Other	Total in Category	All Other	Total	Lib p	Con p
Annu Rev Pharmacol	43	958	3213	0.99	0.98	44	548	1165	0.96	0.93
Toxicol Appl. Pharm	404	1760	4773	0.92	0.87	654	614	2543	0.73	0.64
Arch Toxicol	323	1273	3262	0.90	0.84	90	192	372	0.76*	0.50*
Food Cosmet Toxicol	190	948	2173	0.91	0.85	266	239	813	0.67	0.54
Toxicology	208	982	1761	0.88	0.73	113	65	187	0.40*	0.07*
Toxicon	140	486	1050	0.87	0.75	131	188	478	0.73	0.55
Clin Toxicol	32	534	862	0.96	0.90	55	122	191	0.71*	0.20*
Farmakol Toksikol	203	1154	2699	0.93	0.87	199	100	404	0.51	0.35

*Indicates striking difference (±.20) in the proportions of the two estimates.

TABLE 13

Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Nineteen Toxicology Journals, 1982

	Citing					Cited				
Journal	Total in Category	All Other	Total	Lib p Total-in cat / Total	Con p Total-in-All Other / Total-All Other	Total-in Category	All Other	Total	Lib p	Con p
Annu Rev Pharmacol	62	989	3125	0.98	0.97	70	834	1801	0.96	0.93
Rev Biochem Toxicol	--	--	--	--	--	9	34	85	0.89	0.82
CRC Crit R Toxicol	60	930	2708	0.98	0.97	71	255	439	0.84*	0.61*
Toxicol Appl Pharm	885	2628	7495	0.88	0.82	1501	1147	4523	0.67	0.56
Arch Toxicol	155	790	1500	0.90	0.70	174	397	851	0.80	0.62
Food Cosmet Toxicol	364	1311	3161	0.89	0.80	309	322	1104	0.72	0.61
Arch Environ ConTox	134	1008	1715	0.92	0.81	70	164	398	0.82	0.70
Toxicology	336	989	2858	0.88	0.82	182	282	585	0.69*	0.40*
J. Toxicol Env Health	372	1674	4110	0.91	0.85	215	339	778	0.72	0.51
Toxicon	212	651	1566	0.87	0.77	265	261	786	0.66	0.50
Toxicol Lett	266	1078	2560	0.90	0.82	155	164	424	0.63*	0.40*
Ann Occup Hyg	43	355	606	0.93	0.83	49	136	296	0.83	0.69
J. Anal Toxicol	60	433	797	0.93	0.84	71	93	262	0.73	0.58
Ecotox Environ Safe	62	748	1152	0.95	0.85	8	56	134	0.94	0.90
Drug Chem Toxicol	--	--	--	--	--	13	139	255	0.95	0.89
J. Environ Pathol Tox	--	244	541	--	1.00	99	234	448	0.78*	0.54*
Clin Toxicol	138	912	1811	0.92	0.85	97	348	532	0.82*	0.47*
Farmakol Toksikol	253	1743	3653	0.93	0.87	215	98	471	0.54	0.42
Vet Hum Tox	43	624	948	0.96	0.87	16	9	44	0.64	0.54

*Indicates striking difference (±.20) in the proportions of the two estimates.

journals for further scrutiny. Likewise, by comparing the estimates over time, we note that TOXICOLOGY's cited Lib p rose from .40 to .69 and its Con p from .07 to .40. The other two journals cited both in 1976 and 1982 show more modest changes. Surely the growth of Toxicology--in terms of journal expansion--as a research area is clear. Some journals, such as TOXICOL LETT and TOXICOLOGY, are oriented primarily toward Toxicology in terms of who cites them. In contrast, journals such as TOXICOL APPL PHARM, ANN REV PHARMACOL, and FOOD COSMET TOXICOL garner well over 1000 citations, with the vast majority emanating from outside Toxicology.

A graphical representation of the relationship between citing and cited p values for the eight Toxicology journals common to the years 1977 and 1982 appears in Figures 8 and 9, respectively. These scattergrams depict the "location" of each journal (relative to others in this subject category) and the change in the Lib p and Con p estimates. (Note, for instance, the narrower range in the distribution for 1982 in Figure 9.)

The Demography data contained in Tables 14 and 15 provide the basis for tracing the development of a "core" literature over the five-year period, 1977-1982. During this period, journals such as POPUL STUD LONDON increasingly cited other Demography literature (Con p = .42 to .23), while others, such as DEMOGRAFIA (Con p = .53 to .85), cited in a more cosmopolitan fashion. The noteworthy change in "citations to" Demography literature occurs for SOC BIOL which attracted a wider spectrum over time (Lib p = .73 to .92, Con p = .34 to .76). In general, this area cites other literature far more than other literature cites it.

The Operations Research/Management Science profile, as portrayed in Tables 16 and 17, is remarkable for other reasons. The citing p values are strikingly different across journals, but consistently similar for the same journal in 1977 and 1982. If anything, these proportions suggest that OR/MS is indeed an umbrella for a range of techniques and problems. Authors cite this range accordingly (e.g., MANAGE SCI and OPER RES). On the cited side, OR/MS journals attract a specialized audience faithful to the journal in question. The only exception to this pattern is BEHAV SCI. Were one to draw a citation map among these journals, BEHAV SCI would stand alone, seldom cited by the other OR/MS journals and rarely citing them. Such an analysis would be yet another way to extend this category/journal analysis to identify core journals per area. Peripheral journals such as BEHAV SCI would then qualify as particularly interesting candidates for IDR publication. It is noteworthy, however, that by 1982, OR/MS subsumes more SCI than SSCI journals under its subject heading. The mathematical-systems-computer orientation here is unmistakable.

The total and mean citing and cited p values summarized in Table 18 attest to the stability of our estimates, especially for

FIGURE 8

SCATTERGRAM OF CITING AND CITED p VALUES
FOR EIGHT TOXICOLOGY JOURNALS, 1976

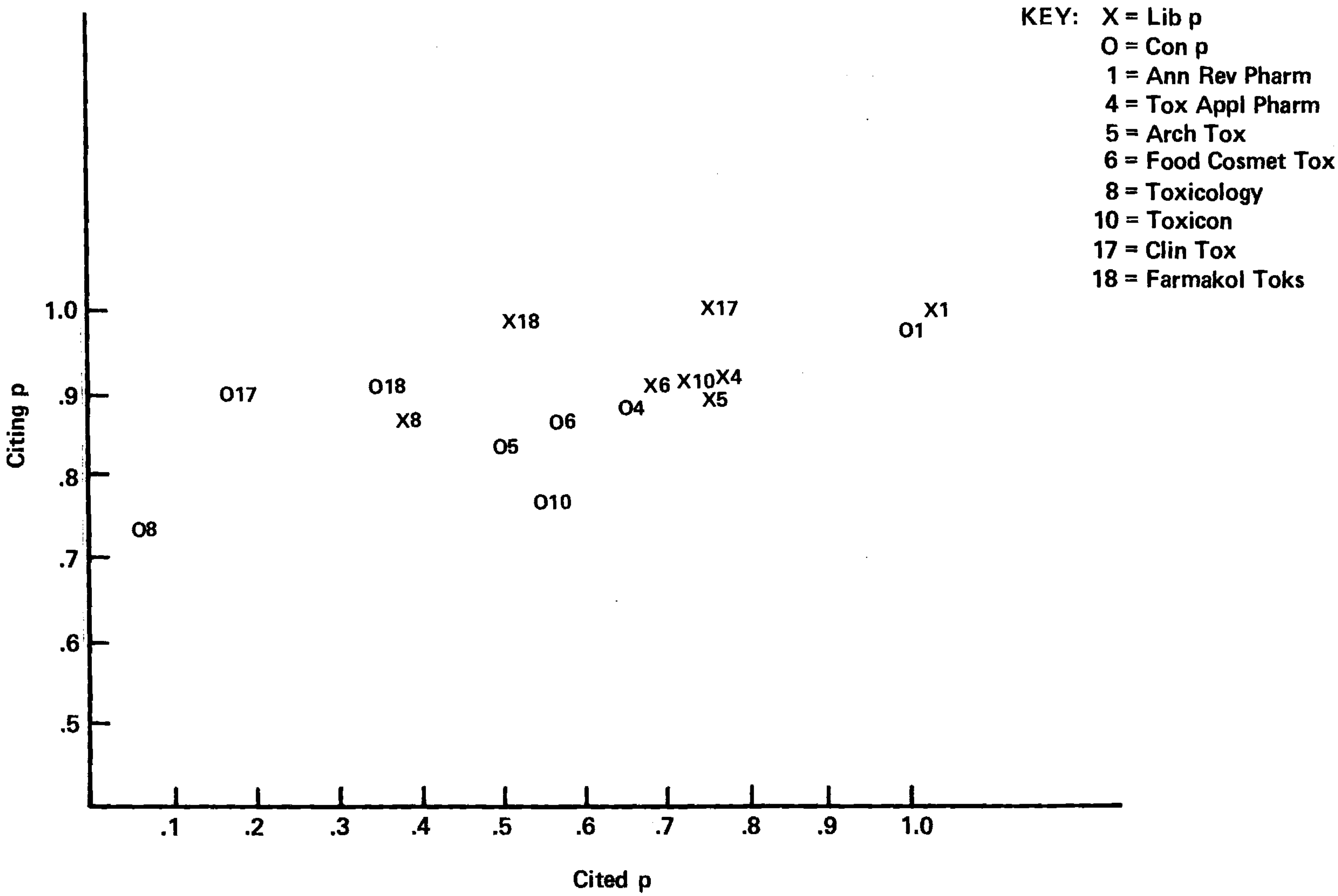


FIGURE 9

SCATTERGRAM OF CITING AND CITED p VALUES
FOR EIGHT TOXICOLOGY JOURNALS, 1982

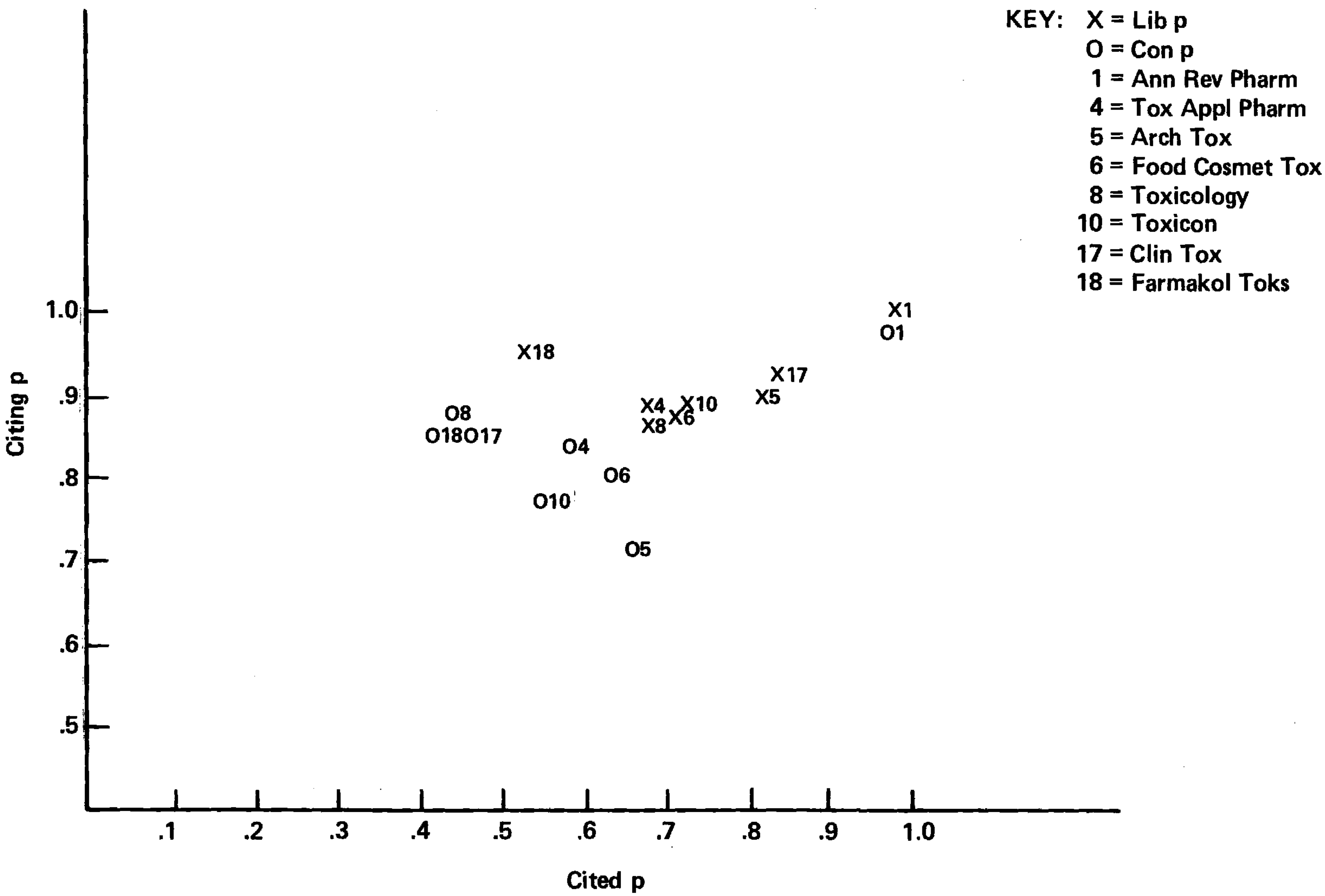


TABLE 14

Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Thirteen Demography Journals, 1977

	Citing					Cited				
Journal	Total in Category	All Other	Total	Lib p Total-in cat / Total	Con p Total-in-All Other / Total-All Other	Total-in Category	All Other	Total	Lib p	Con p
Popu. Bull	26	191	235	0.89*	0.41*	3	5	21	0.86	0.81
Popul. Dev Rev	59	492	595	0.90*	0.43*	35	14	67	0.48	0.34
Demography	125	537	779	0.84*	0.48*	185	165	633	0.71	0.61
Popul Stud London	161	684	960	0.83*	0.42*	217	152	506	0.57	0.39
J. Biosoc Sci	75	462	626	0.88*	0.54*	41	77	158	0.74*	0.49*
Population	131	639	835	0.84*	0.33*	144	77	254	0.43*	0.19*
Stud Family Planning	113	397	604	0.81*	0.45*	125	100	349	0.64	0.50
Int Migr Rev	15	373	414	0.96*	0.63*	13	22	61	0.79	0.67
Soc Biol	82	510	754	0.89*	0.66*	54	118	200	0.73*	0.34*
Int Migr	14	140	168	0.92*	0.50*	9	5	30	0.70	0.64
Popul. Index	2	5	12	0.83	0.71	30	23	62	0.52*	0.14*
Demografia	28	210	270	0.90*	0.53*	29	--	32	0.09	0.09
Genus	15	123	155	0.90*	0.53*	4	--	11	0.64	0.64

*Indicates striking difference (±.20) in the proportions of the two estimates.

TABLE 15

Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Fifteen Demography Journals, 1982

Journal	Citing					Cited				
	Total in Category	All Other	Total	Lib p (Total-in cat / Total)	Con p (Total-in-All Other / Total-All Other)	Total-in Category	All Other	Total	Lib p	Con p
Popul. Bull	22	338	444	0.95	0.79	23	33	80	0.71*	0.51*
Popul. Dev. Rev.	90	501	651	0.86*	0.40*	96	40	171	0.44	0.27
J. Fam Hist	57	993	1259	0.95	0.79	37	19	106	0.65	0.57
Demography	198	612	974	0.80	0.45	200	145	539	0.63	0.49
Popul. Stud London	120	388	543	0.78*	0.23*	212	128	451	0.53	0.34
J. Biosoc Sci	62	529	692	0.91*	0.62*	52	143	249	0.79*	0.51*
Population	72	273	391	0.82*	0.39*	87	68	198	0.56*	0.33*
J. Populat	--	--	--	--	--	10	--	21	0.52	0.52
Stud Family Planning	138	495	806	0.83*	0.56*	94	86	264	0.64	0.47
Int Migr Rev	76	1315	1572	0.95*	0.70*	48	29	148	0.68	0.60
Soc Biol	--	--	--	--	--	17	134	204	0.92	0.76
Int Migr	11	52	84	0.87	0.66	21	--	32	0.34	0.34
Popul Index	3	119	259	0.99	0.98	23	9	46	0.50	0.38
Demografia	8	140	192	0.96	0.85	8	--	10	0.20	0.20
Genus	--	--	--	--	--	1	--	3	0.67	0.67

*Indicates striking difference (±.20) in the proportions of the two estimates.

TABLE 16

Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Seven Operations Research/Management Science Journals, 1977

Journal	Citing: Total in Category	Citing: All Other	Citing: Total	Citing: Lib p (Total-in cat / Total)	Citing: Con p (Total-in-All Other / Total-All Other)	Cited: Total-in Category	Cited: All Other	Cited: Total	Cited: Lib p	Cited: Con p
Behav Sci	50	491	684	0.93	0.74	40	356	607	0.93	0.84
Manage Sci	522	1183	2162	0.76*	0.47*	651	353	1428	0.54	0.39
Interfaces	49	280	341	0.86*	0.20*	22	17	57	0.61	0.45
J. Syst Manage	15	111	149	0.90*	0.61*	12	3	26	0.54	0.48
Omega-Int.J.Manage S	60	614	752	0.92*	0.57*	15	--	19	0.21	0.21
Oper Res	352	730	1266	0.72*	0.34*	616	343	1384	0.56	0.41
Nav Res Log Quart	278	385	782	0.64*	0.30*	175	72	268	0.35*	0.11*

*Indicates striking difference ($\pm$.20) in the proportions of the two estimates.

TABLE 17

Raw JCR Citing and Cited Counts, and Corresponding
Estimates (Lib p and Con p) for Seventeen Operations Research/Management Science Journals, 1982

	Citing					Cited				
Journal	Total in Category	All Other	Total	Lib p: Total-in cat / Total	Con p: Total-in-All Other / Total-All Other	Total-in Category	All Other	Total	Lib p	Con p
Behav Sci	49	494	616	0.92*	0.60*	47	326	646	0.93	0.85
Manage Sci	447	1202	2136	0.79*	0.52*	1104	301	2026	0.46	0.36
Interfaces	114	275	424	0.73*	0.24*	134	28	192	0.30	0.18
Eur J Oper Res	538	1362	2139	0.75*	0.31*	70	16	99	0.29	0.16
J. Syst Manage	25	198	277	0.91*	0.68*	10	--	35	0.71	0.71
Omega-Int J. Manage S	126	789	1060	0.88*	0.54*	3	--	12	0.75	0.75
Oper Res	425	643	1198	0.65*	0.23*	779	224	1495	0.48	0.39
Math Program	169	393	664	0.75*	0.38*	266	161	565	0.53	0.34
Prog Plann	--	248	319	1.00	1.00	3	1	27	0.89	0.88
Int J Syst Sci	117	782	1361	0.91	0.80	86	45	232	0.63	0.54
J Oper Res Soc	262	747	1056	0.75*	0.15*	121	6	142	0.15	0.11
AIIE T	--	--	--	--	--	122	23	171	0.29	0.15
Large Scale Syst	18	277	424	0.96	0.88	2	--	5	0.60	0.60
J Optimiz Theory App	159	573	981	0.84*	0.61*	135	153	388	0.65	0.43
Nav Res Log Quart	344	404	989	0.65*	0.41*	256	108	393	0.35*	0.10*
Ind Res Dev	2	84	147	0.99	0.97	9	10	46	0.80	0.75
Comput Oper Res	173	333	551	0.69*	0.21*	2	--	13	0.85	0.85

*Indicates striking difference (±.20) in the proportions of the two estimates.

Table 18

Total and Mean Citing and Cited p Values for
Three JCR Subject Categories at Two Points in Time

	Citing					Cited				
	Total in Category	All Other	Total	Lib p Total-in cat / Total	Con p Total-in-All Other / Total-All Other	Total-in Category	All Other	Total	Lib p	Con p
A. Demography (13 Jnls)										
1977	846	4763	6407	0.87	0.49	889	758	2384	0.63	0.45
1982	1214	4348	6608	0.82	0.46	882	815	2395	0.63	0.44
B. Toxicology (8 Jnls)										
1976	1543	8095	19793	0.92	0.87	1552	2068	6063	0.74	0.61
1982	2405	10013	25169	0.90	0.84	2773	3689	10653	0.74	0.60
C. OR/MS (7 Jnls)										
1977	1326	3794	6136	0.78	0.43	1531	1144	3789	0.60	0.42
1982	1505	4005	6700	0.78	0.44	2333	987	4799	0.51	0.39

Toxicology between measures and over time. The results for Demography and OR/MS are more equivocal. In each case, the Lib p indicates that closure is beginning to set in, whereas the Con p indicates that citing is becoming more open.

A capsule summary of Tables 12-17 appears in Table 19. It shows that the two operationalizations of our citing indicator yield significantly different estimates of out-of-category citing, where significance is defined as a minimum difference of citing-cited difference in estimation remains virtually constant from 1976/77 to 1982 despite the increase (of 15-100+%) in the number of journals listed under the three subject headings.

An alternative presentation is found in Figures 10 and 11, respectively, where the median proportions based on the Lib p and Con p columns in Tables 12-17, are arrayed by subject area. Figure 10 indicates that the citing pattern in Toxicology is consistent between the two p values. These two values assure us that, among the eight journals identified as reporting Toxicology research at two points in time, authors are citing literature from various subject areas. In Figure 11, the median proportions of citations to journals are uniformly modest, relative to the citing p values in Figure 10, with a move toward closure the norm.

In summary, our pilot application of the PROD35 indicator has succeeded in estimating the proportions of out-of-category literature use for journals in three subject areas at two points in time. Of the PROD35 proxies employed, Lib p is computationally simpler than Con p, and yields consistently higher proportions of out-of-category citation. Con p, in contrast, requires identification of the residual journals aggregated by the JCR in the "all other" line. Both estimates, however, can be interpreted as the size of, or relative extent that, literature classified by SCI/SSCI as outside a particular subject category is citing within/cited by that category. The interpretation equates neither this literature nor the journals in which it appears as being purely IDR. Rather, IDR pieces are assumed to be encompassed by this estimated p. Our empirical inquiry using approximations of the proposed indicator PROD35 suggests that we can feasibly extract and interpret useful information relevant to cross-disciplinary, if not IDR, relationships from the ISI data base.

TABLE 19

Summary of Journal Citing and Cited Proportions
(Estimates* That Differ by .20 for the Same Journal)#
in Three JCR Subject Categories at Two Points in Time

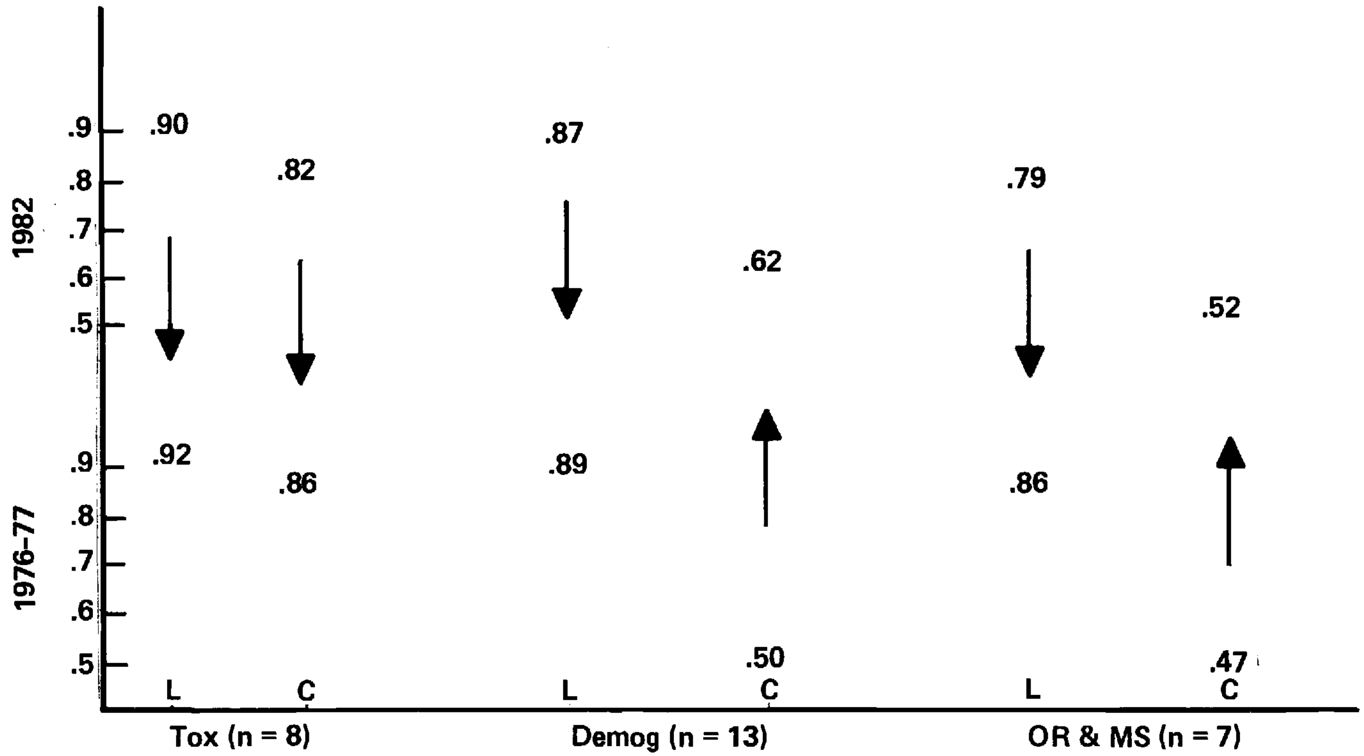
Year:	1976/77			1982		
	citing	cited	jour n	citing	cited	jour n
Area:						
Toxicology	0	3	8	0	5	9
Demography	12	4	13	6	3	15
OR/MS	6	1	7	12	1	17

*Lib p and Con p

#see Tables 12 - 17 and text for full explanation

FIGURE 10

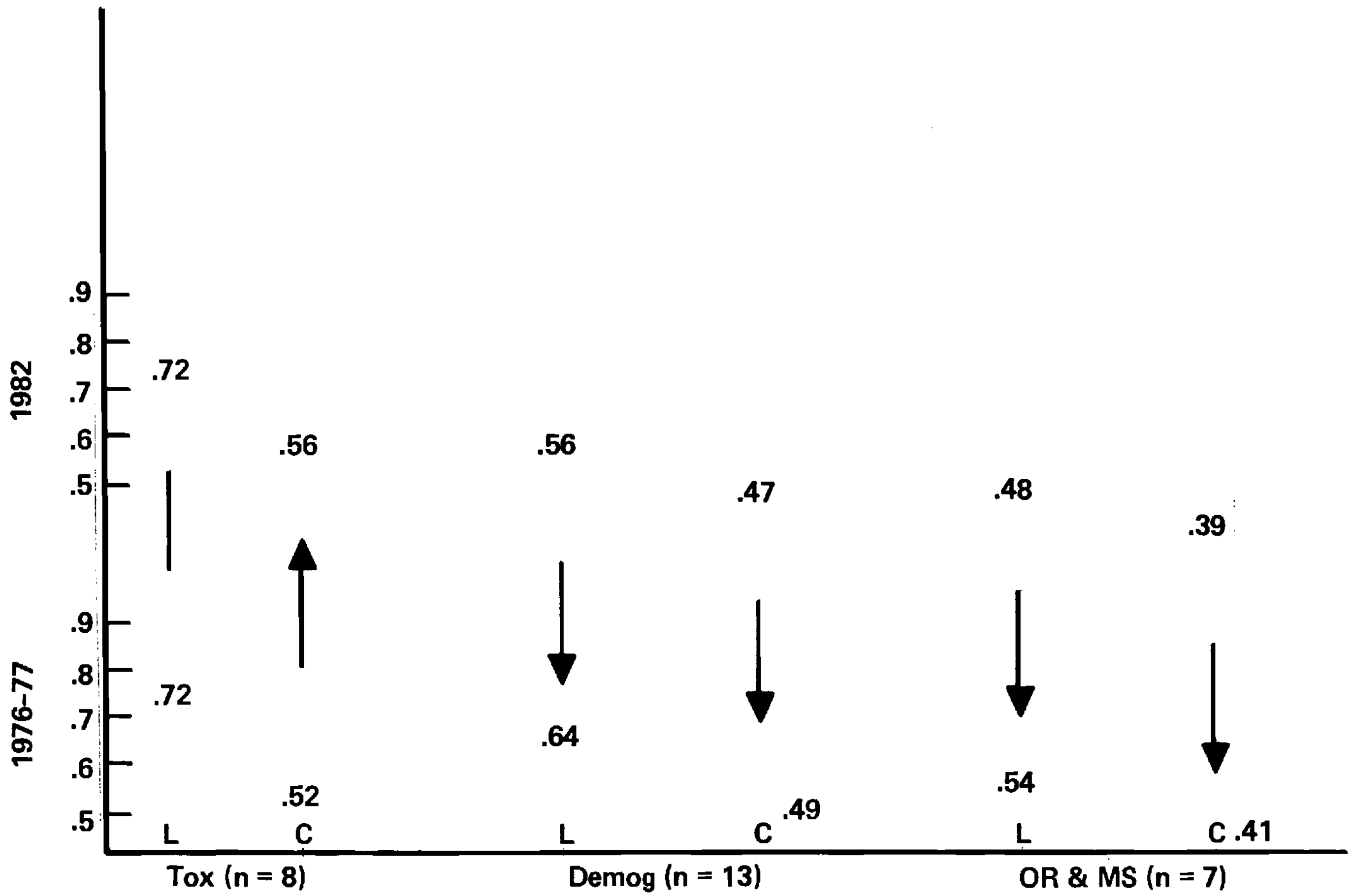
MEDIAN PROPORTION OF CITING BY JOURNALS IN THREE JCR SUBJECT CATEGORIES TO JOURNALS OUTSIDE THOSE SAME CATEGORIES, CONSERVATIVE (C) AND LIBERAL (L) ESTIMATES IN 1976–77 AND 1982*



*arrows indicate direction of change between the two measurements

FIGURE 11

MEDIAN PROPORTION OF CITATIONS TO JOURNALS IN THREE JCR SUBJECT CATEGORIES BY JOURNALS OUTSIDE THOSE SAME CATEGORIES, CONSERVATIVE (C) AND LIBERAL (L) ESTIMATES IN 1976-77 and 1982*



*arrows indicate direction of change between the two measurements

III. CONCLUSIONS AND PROSPECTS

A. Summary of Project Purposes and Approaches

The chief purpose of this project was to distinguish empirically interdisciplinary research from traditional disciplinary research. Upon making this distinction, we would then characterize IDR by describing how it differs from the rest of the massive literature of science. Given the infancy of efforts in this area, the products of this project were anticipated to take various forms, e.g., data-collection procedures, conceptualizations of various units of analysis, operationalizations based on existing public data sources, computational algorithms for validating measures, and perhaps even an indicator or two. We clearly hedged our bets; now we must take account, however, of project payoffs.

To that end, we return to the Progress Report (reproduced in Appendix A) and list the major questions that framed our three approaches to the identification and characterization of IDR.

1. Was the Citation Classic (or additional related publications) used in "unintended" ways or by "untargeted" audiences? (Citation Approach, p. A3)

2. How rare are IDR scientists? Are they found, either currently or at their intellectual origins, in certain disciplines or allied with certain research problems or techniques? Do they seem to be nurtured in particular environments, e.g., academic or nonacademic? Are they more or less productive and cited than their professional age peers? And does their publication suggest conscious intent to produce IDR? (Author Approach, A9)

3. Are entire journals IDR or can they be characterized as such by degree? Is the proportion of IDR papers published in a certain journal stable or fluctuating over time? (Journal Approach, All)

What should be immediately apparent from this blueprint was our decision to omit the Author Approach from the project. Despite the hope that the Porter et al. (1981) "Dissertation" project would provide a ready point of departure for individual author analysis, we found the data base too remote, in form if not substance, from our interests to justify extensive expansion and manipulation. Thus, the individual and the team remained implicit elements in our analysis. But we regard the individual approach as viable and have begun to devise ways of studying both the careers, from the individual perspective, and the local contingencies, from the organizational perspective, of the interdisciplinary researcher (Chubin and Connolly, 1982; Porter et al., 1982).

As for the Citation and Author Approaches, respectively, we trust that Parts I and II have demonstrated both their promise and feasibility. In the next section, we review our findings and their relationship both to the research questions we raised in this report and to the indicator-relevant literature.

B. Review of Findings

Two questions found in Part I warrant restatement here:

a. Does the Citation Classic's information become assimilated into the collective wisdom of the subdiscipline's specialists? (5-6)

b. Who is citing the classics and how are they being used? Is there a different usage curve for IDR papers? (8)

In a way, the Citation Classics kept us at arm's length from the very phenomenon we sought to identify. The definition of "classic" is usage, i.e., high citation relative to other works in the same broad field. But the classic author's retrospective is supposed to supply insight into why the work became a classic, endured, etc. This simply underscores the pivotal role of judgment in the use of literature. If one believes that citations are purposeful, a public acknowledgment of intellectual debt, then one should be drawn to examining the content of citations and not rely solely on absolute (or relative) number of citations. Such content analysis is impossible, however, for all but certain segments of the scientific literature. The Citation Classics constitute one obvious segment, especially since they have emerged historically, i.e., durability over time is their important distinguishing characteristic (Figure 6).

Critics of citation analysis claim either that literature usage is tied to an individual's "implicit theory of citing" (Mulkay, 1974) or that the meaning of citation as a communication link or measure of indebtedness is over-interpreted (Edge, 1979), i.e., what is seen as systematic is arbitrary and capricious. Clearly, the norms of citation do very by field (Price, 1970), and probably, within subfields, specialties, and smaller research units as well. The nagging question is whether such norms are suspended for IDR papers in "atypical" ways? So long as the open literature diffuses information to ever-larger audiences, intended targets and eventual citers may coincide less and less. Further, if the 10-20% of the classics we examined were indeed IDR (as we estimated), then a content analysis of the original papers would be the only way to extract common features that foretell exceptional usage.

One interpretive lesson exemplified first by the Citation Classics and again in Part II is the judgment involved in constructing a category around a research subject. As Chubin

(1983) suggests, there is ambiguity and confusion as to how to conceptualize and delineate scientific "specialties" (variously called "communities," "networks," "invisible colleges," etc.). Once a category has been defined bibliographically, estimation of the proportion of citations that falls within and outside that category is straightforward--insofar as the judgment of inclusivity and exclusivity of the category can be defended. Such judgment will determine the "significance" of the proportions (Table 10).

In Part II, for example, we asked:

a. Can we distinguish disciplinary from IDR journals? Can we characterize broad fields or research areas as being more or less IDR? (10)

b. Do the JCR categories/subcategories that appear to fall within the traditional disciplines represented in our journal sample draw literature primarily from the same disciplines? Do the categories/subcategories that appear to be IDR draw from across disciplines both within and across grand categories)? Do the consumption and usage patterns of disciplinary and IDR audiences differ? (18)

At the journal level, we found that most references (Table 5) are selected narrowly, i.e., from a "band" of literature that surrounds (subcategories and categories) the subject in question. This finding may be limited to so-called basic research as opposed to applied or policy research that appears to be more inherently IDR. Our subjective ratings (RANK) accord with this finding, as do the usage patterns in our 19-journal sample (Table 7). Specialization militates against awareness and/or citation of literature far removed (grand category) from one's immediate focus.

Definition and categorization are intrinsic, of course, to the public data sources we have employed. The subject and journal categories used by the SCI, SSCI, and the JCR were developed to facilitate information retrieval, not to classify that information as more or less IDR. Thus, we adapted and modified these sources at appropriate junctures. Combined with SCI-based measures such as "impact factor," our validators served as a guide to locating intense sites of research activity (Table 11). Again, locating such sites does not begin to explain why the intensity is occurring and whether IDR is contributing to it.

To pursue such explanation, we attempted to disaggregate our measures of IDR. Our most fundamental unit of analysis was the article. But we could examine article content only superficially (Figure 7), and found some variability across articles within a journal. For the 19 journals representing our four broad fields, the variability fades. Journals "advertise" a subject matter and "invite" certain approaches and methodologies; authors submit research according to the perceived identity and receptivity of a journal (Gordon, 1983). If IDR is a normal mode of operation in a specialty, then its results will be reported like all other research with few hints as to the collaborative means or ends of production. Such "unintentional" IDR may be beyond retrieval since scientists are trained to expurgate details of human process and intervention from their reports (Knorr-Cetina, 1981; Latour and Woolgar, 1979). On the other hand, the team that makes its interdisciplinarity explicit may reduce its likelihood of publication so that the research is more apt to appear in unpublished documents and monographs than in the serial literature.

This last observation raises the question, "How well do IDR products fare in competitive peer review--either at the proposal level or at the manuscript stage (Porter et al., 1982)? If teams are not self-conscious about their disciplinary composition or division of labor, everything from their problem formulation to their presentation of data and compilation of references may violate the expectations of program managers, reviewers, and editors (not to mention analysts of IDR). Such a complete lack of fit is unlikely, yet so little is known about the IDR team, its work process, and its products, that impediments to both the phenomena and their detection cannot be considered trivial.

Finally, in our pilot application of the PROD35 proxy indicators, we found evidence of differences in citing and cited proportion estimates of out-of-category literature use for three JCR subject categories. Mean Lib p and Con p are stable for all three (Table 18), but less consistent for the median cited p's in Toxicology in 1976 and 1982. These same indicators differ for citing p in Demography and Operations Research/Management Science in 1977 and 1982 (Table 19). In short, we have a valid indicator which should be applied and interpreted differently depending on the JCR category, specialty, or even journal of interest. The good news here is that a simple algorithm and formula can be used on available data to yield estimates, by ISI subject category, of relative citation originating from outside that particular category.

C. A Research Prospectus

Any research project that fulfills its declared purpose also illuminates gaps, puzzles, and assorted conundrums "for further study." In our case, the prospects for future study are abundant, so we will focus our thoughts on the most provocative and/or appealing.

One gap that must be narrowed is that separating conceptual from operational measures. Units of analysis, for example, may include subject categories, journals, articles, or authors. In measuring the presence or extent of IDR in these units, we usually have two operationalizations in mind--process and product.

Too often, we measure the latter and infer the former. The reason is all too clear: there is a tradeoff between accessibility and relevance to IDR. (We would hazard that they are inversely related.) Our proclivity is to measure at the microscopic level; however appropriate, that may be impossible if one is committed to the utilization of public data sources. What, then, is the compromise? Do we search for new data sources or invent new modes of analyzing what is available?

Some intelligent dialogue on this problem has occurred among those enamored of "qualitative" science indicators (ST&HV, 1982). They have addressed the conceptual-operational gap--to their credit--but have not eroded it at all. And they won't until those enamored of "quantitative" indicators join the action.

If IDR is the stuff of "cutting edges," "research fronts," and even "premature" ideas, then its detection and recognition of its early manifestation in the literature are critical policy tasks. From our experience, in this project and elsewhere, we view IDR as not a subject matter per se, but a mode of problem definition, analysis, and solution. It is a pattern of interaction which, in the absence of direct observation, must be inferred. Basing those inferences on the serial literature (or concomitantly, on patent statistics) alone may miss or obscure the manifestation of IDR. Yet our working hypothesis is that interdisciplinarity is more likely to occur in research on certain problems or at certain times. The literature can provide correlates if not parameters, clues if not full-blown measures. The puzzle is to sort and fit these clues together so that the presence of IDR can be estimated, and then, with the aid of other data, explained.

The approach we favor is a multifaceted one where several data bases can be merged to form a context in which IDR, among other research phenomena, can be seen. One such literature-based project now in the planning stage concerns the evolution of biomedical clusters as impacted by the review-and-funding apparatus of the National Institutes of Health (Lowe and Rogers, 1983). A 40-year history of the growth in biomedical knowledge will be constructed using Small's (1973) co-citation methodology. Amidst the maze of study sections and funding patterns exist the intra- and inter-institutional collaborations that qualify as IDR. So although IDR is not the focus of this project, we could learn much about its germination and expression in the context of biomedical research programs and problem-solving.

A more modest albeit valuable program of inquiries centers on publication strategies and the negotiation processes that journals inevitably maintain (Armstrong, 1981). From such micro-level studies, especially those which achieve access to journal referee files and the like, should emerge hints about authors' motivations as well as the publication norms enforced by journals--and the comparative advantage or disadvantage accorded by IDR.

A final research prospect is the most intrusive: Instead of speculating about publication and citation norms, researchers must gain access, e.g., via survey or interview, to the various scientific audiences whose behavior is, after all, the raw data for the SCIs and JCRs. In the absence of information regarding literature usage, we continue to impose a uniform, somewhat mythical standard upon scientists not unlike philosophers' portrayal of them a generation or more ago (Toulmin, 1977). Rationality is not an absolute; it is employed in various ways and at various times. The contingencies of rationality apply bibliographically, too: Why do scientists cite little or much, old or new sources, are persistent questions (Porter, 1977). As input data, they need to be answered, at least in part, en route to developing valid output indicators of scientific growth.

It is our hope that the construction of indicators of interdisciplinary research proceeds apace of the science indicators enterprise. The extraordinary character of IDR affords the analyst an important perspective that can only enhance the efforts of the qualitative, the quantitative, and the policy-inclined. But as Brooks (1982:22) emphasizes:

> The expertise required to identify and formulate sociotechnical goals, and to relate research objectives to social objectives, is different from the expertise required to assess the opportunities and prospects for advances in a scientific discipline or a technological development.

It is therefore the special role of NSF/SRS and *Science Indicators* to sustain the dialogue among specialists and advance knowledge of IDR processes and products through novel collaborative efforts.

REFERENCES

Armstrong, J.S.
1982 "Research on scientific journals: Implications for editors and authors." Journal of Forecasting 1: 83-104.

Brooks, H.
1982 "Science indicators and science priorities." Science Technology & Human Values No. 38 (Winter): 14-31.

Chubin, D.E.
1975 "The journal as a primary data source in the sociology of science: With some observations from sociology." Social Science Information 14: 157-168.

1983 "Beyond invisible colleges: A bibliographic essay." In D.E. Chubin, Sociology of Sciences: An Annotated Bibliography on Invisible Colleges, 1972-1981. New York: Garland (forthcoming).

Chubin, D.E. and T. Connolly
1982 "Research trails and science policies: Local and extra-local negotiation of scientific work." Pp. 293-311 in N. Elias et al. (eds.), Scientific Establishments and Hierarchies. Sociology of the Sciences, Vol. 6. Boston and Dordrecht: D. Reidel.

Dager Gonzales, Digna Denise
1982 "Indicators of Interdisciplinary Research." M.S. thesis, School of Industrial and Systems Engineering, Georgia Institute of Technology (August).

Edge. D.O.
1979 "Quantitative measures of communication in science: A critical review." History of Science 17: 102-134.

Garfield, E.
1972 "Citation analysis as a tool in journal evaluation." Science 178 (3 November): 471-479.

1977 "Introducing 'Citation Classics': The human side of scientific reports." Current Contents 1 (3 January): 5-6.

1979 "Expansion of 'Citation Classics' - 250 unique commentaries per year." Current Contents 1 (1 January): 5-12.

1981 "'Citation Classics' - Four years of the human side of science." Current Contents 22 (1 June): 5-16.

Gordon, M.
1983 "Journal selection for the submission and resubmission of research papers." Social Studies of Science 13: forthcoming.

Knorr-Cetina, K.D.
1981 The Manufacture of Knowledge: An Essay in the Constructivist and Contextual Nature of Science. Oxford and New York: Pergamon.

Latour, B. and S. Woolgar
1979 Laboratory Life: The Social Construction of Scientific Facts. London and Beverly Hills: Sage.

Lowe, C.U. and E.M. Rogers
1983 "Measuring the Growth and Knowledge in the Biomedical Sciences." Research Proposal submitted to Science Resources Studies, National Science Foundation (January).

Mitroff, I.I. and R.H. Kilmann
1978 Methodological Approaches in the Social Sciences. San Francisco: Jossey-Bass.

Mulkay, M.J.
1974 "Methodology in the sociology of science: Some reflections on the study of radio astronomy." Social Science Information 13: 107-119.

Porter, A.L.
1977 "Citation analysis: Queries and caveats." Social Studies of Science 7: 257-267.

Porter, A.L., D.E. Chubin, M.E. Boeckmann, T. Connolly, and F.A. Rossini
1981 "A Cross-Disciplinary Assessment of the Role of the Doctoral Dissertation in Career Development." Final Report to Science Resources Studies, National Science Foundation (August).

Porter, A.L., F.A. Rossini, D.E. Chubin, and T. Connolly
1982 "Review of the Performance of Interdisciplinary Research." Research Proposal submitted to the Office of Interdisciplinary Research, National Science Foundation.

Price, D. deS.
1970 "Citation measures of hard science, soft science, technology and non-science." Pp. 3-22 in C. Nelson

and D. Pollock (eds.), Communication Among Scientists and Engineers. Lexington, Mass.:D.C. Heath.

Rossini, F.A., A.L. Porter, D.E. Chubin, and T. Connolly
1981 "Cross-disciplinarity in the biomedical sciences: A preliminary analysis of anatomy." Presented at Annual Meeting, American Association for the Advancement of Science, Toronto (January).

Science Technology & Human Values
1982 "On Developing Indicators of Quality in Science and Technology - Parts I and II." Nos. 38 and 39 (Winter and Spring): 4-60, 4-36.

Small, H.G.
1973 "Co-citation in the scientific literature: A new measure of the relationship between two documents." Journal of the American Society for Information Science 24: 265-269.

Small, H. and E. Greenlee
1980 "Citation context analysis of a co-citation cluster: Recombinant-DNA." Scientometrics 2 (July): 277-301.

Studer, K.E. and D.E. Chubin
1980 The Cancer Mission: Social Contexts of Biomedical Research. Beverly Hills: Sage.

Toulmin, S.
1977 "From form to function: Philosophy and history of science in the 1950s and now." Daedalus 106 (Summer): 143-162.

Georgia Tech
March 1982

Drs. Chubin, Porter,
Rossini, Connolly

INDICATORS OF INTERDISCIPLINARY RESEARCH

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Interim Report #1

Overview

The chief purpose of this project is two-fold: (1) to distinguish inter- or multidisciplinary research (hereafter IDR) from single or monodisciplinary research, and (2) to characterize IDR, i.e., describe how it differs from other research. With new "indicators" constituting the ultimate output of the project, we are concentrating on data available from sources in the public domain and from files constructed as part of the NSF-supported (#SRS 78-18959) Porter et al. project, "A Cross-Disciplinary Assessment of the Role of the Doctoral Dissertation in Career Development" (Final Report, August 1981).

We have formulated three approaches to the phenomenon of IDR. Each approach utilizes the same four units of analysis: articles, journals, authors, and citations. We describe below the algorithm that operationalizes each approach. We also summarize the results of one approach and indicate how the project will proceed in the coming months.

The Citation Approach

A. Rationale

Two assumptions underlie this approach. First, IDR can be identified by the intent of a paper's author(s) or by the usage of that paper by a citing audience. Second, citation of a paper or other research publication, for whatever reason, indicates a recognition, however perfunctory, of the paper's visibility or relevance to a problem or issue being addressed

Appendix B

SAMPLE PAGE FROM THE JCR USED IN VALIDATION

The Citing and Cited Journal Packages

The *Citing* and *Cited Journal Packages* show citation-frequency relationships between pairs of journals. In the *Citing Journal Package*, one can find what journals a particular journal has cited, and a distribution by year of the publication dates of the cited material. In the *Cited Journal Package* one can find what journals have cited a particular journal, and a distribution by year of the publications dates of the cited material. Specimens with descriptions from both appear on pages 32A-35A.

Relatively few journals produce most of the references processed at ISI®. Similarly, relatively few journals account for most of the citations made in those references. In either case, a list of 1000 journals will encompass 60% of the items. Beyond lists of 1000 journals, the 'return' in references and citations becomes progressively smaller as the lists are extended, but that return can be valuable for the information it gives about 'narrow' but important specialties and sub-specialties in which journals may be few, publication infrequent, research relatively slow-paced, and so on.

Ratios like the *JCR*™'s impact factor and immediacy index do much to compensate for sheer size in 'comparing' one journal in biochemistry with another, for example, or in 'comparing' a biochemistry journal to a palaeontology journal. But even with the help of such indices, we must extend the lists of citing and cited journals well beyond the select but gigantic core if we are to do justice to as many of the 'narrower' fields and subspecialties and border-marches of science as possible.

The *Citing Journal Package* includes entries for most of the 3,000 journals covered by the *SCI*® in 1980, provided that issues of the journal did appear during the year. The *Cited Journal Package* includes entries for more than 3,700 journals, some of them obviously not covered by the *SCI*. As noted above, journal references contain citations of other items besides journal articles. As far as possible, citations of non-journal material have been deleted in compiling the *JCR*. Cited subentry items in the *Citing Journal Package* and main entries in the *Cited Journal Package* will, therefore, be *journals* in almost all cases.

It would have been uneconomical to give, for every citing journal all the journals it had cited, and for every cited journal, all the journals that had cited it. To do so would have made this volume many times its present size, but would have added to it in either case mainly long strings of singly cited or citing items under every main entry. To avoid the latter, but at the same time to avoid neglect of journal relationships in 'smaller' and 'narrower' fields, the length of subentry lists has been controlled in both the *Citing* and *Cited Journal Package*.

The following algorithm has been adopted to control the length of subentry lists. Subentry lists of cited or citing journals are limited to a maximum of 100 items, or to the number of items that account for 85% of the total references or citations. Where either condition would allow listing of items cited or citing less than 6 times in the year, the items are not printed as subentries but are incorporated in the ALL OTHER subentry, the last subentry under each main entry. Disregarding these conditions, at least six subentries in addition to the ALL OTHER subentry *must* be printed, if the main entry journal can supply them.

Main entries in the *Citing* and *Cited Journal Packages* are arranged alphabetically by journal title abbreviation. As mentioned elsewhere, consistency in abbreviation of journal title words has been subordinated to informativeness. The same word may not be abbreviated in the same way whenever it occurs. The reader can 'decode' most abbreviations that may leave him in doubt by referring to the *Abbreviated-to-Full Titles Of Citing/Cited Journals* list beginning on page 60A.

Citing Journal Package

Specimen

S C I   J O U R N A L   C I T A T I O N   R E P O R T S

CITING JOURNAL PACKAGE

	CITING JOURNAL / CITED JOURNAL	TOTAL	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	REST
		<------ NUMBER OF TIMES THIS YEAR WAS CITED IN 1980 ------>											
.63	J AM SOC HORTIC SCI (CONTINUED)												
.77	BOT GAZ	29	0	0	0	1	0	2	0	0	1	0	25
5.70	SCIENCE	29	0	0	0	2	1	0	0	1	1	1	23
.87	ANN BOT-LONDON	27	0	1	3	1	5	0	1	0	2	4	10
	FLOR REV	26	0	0	2	0	1	1	10	7	3	1	1
.92	CAN J BOT	25	0	1	3	5	1	5	1	0	0	2	7
.55	EUPHYTICA	24	1	0	1	3	2	4	1	4	4	0	4
1.60	J EXP BOT	24	0	2	3	1	1	1	2	6	4	1	3
.40	CAN J PLANT SCI	23	0	1	1	3	1	1	0	5	2	3	6
.34	T ASAE	22	0	0	2	1	3	4	2	2	0	1	7
1.10	J AGR FOOD CHEM	20	0	5	1	1	3	1	0	0	0	0	9
1.06	SOIL SCI SOC AM J	20	0	0	3	0	1	1	0	2	1	0	12
.80	J SCI FOOD AGR	18	0	0	0	1	2	2	2	1	1	2	7
.98	SOIL SCI	18	0	0	0	0	0	0	2	2	0	0	14
.65	AM POTATO J	17	0	1	2	3	0	1	1	1	0	0	8
	J AGR RES	17	0	0	0	0	0	0	0	0	0	0	17
	ACTA HORTIC	16	0	0	5	4	1	3	1	2	0	0	0
2.20	ANAL BIOCHEM	16	0	1	0	2	0	0	0	1	0	0	12
1.29	PHYTOCHEMISTRY	16	0	0	1	2	1	1	1	2	0	1	7
.01	CITRUS IND	15	0	0	1	0	0	6	1	1	0	0	6
	COLO FLOWER GROWERS	15	0	0	0	0	0	0	0	0	0	0	15
.60	J ECON ENTOMOL	15	0	3	2	1	0	2	0	0	0	0	7
.75	AUST J BIOL SCI	14	0	0	0	0	0	0	0	0	0	2	12
.69	J HERED	14	0	0	2	0	0	0	0	1	0	0	11
	PRINCIPLES PROCEDURE	13	0	0	0	0	0	0	0	0	0	0	13
8.77	P NATL ACAD SCI USA	12	1	3	0	0	0	1	0	0	1	0	6
1.11	PLANT CELL PHYSIOL	12	0	3	0	3	0	2	3	0	0	1	0
	PLANT PHYSIOL LANC	12	0	0	0	0	0	0	0	0	1	1	10
.72	ANN APPL BIOL	11	0	0	0	1	2	3	0	2	1	1	1
.36	COMMUN SOIL SCI PLAN	11	0	5	0	3	0	2	0	1	0	0	0
.84	J AGR SCI	11	0	1	1	2	1	1	0	0	0	0	5
.91	J FOOD SCI	11	0	0	1	1	1	1	2	0	0	2	3
2.57	SCI HORTIC-ENGLAND	11	0	0	3	1	3	2	0	0	0	0	2
1.52	ANNU REV PHYTOPATHOL	10	0	1	0	1	0	1	1	2	0	0	4
	CITRUS IND MAG	10	0	0	0	0	0	0	10	0	0	0	0
2.41	GENETICS	10	0	0	0	0	0	0	0	0	0	0	10
.16	J JPN SOC HORTIC SCI	10	0	1	0	1	2	1	0	0	0	0	5
.51	PLANT SOIL	10	0	0	2	1	3	0	2	0	1	0	1
	AM NURSERYMAN	9	0	0	3	0	0	6	0	0	0	0	0
	CONTRIB BOYCE THOMPS	9	0	0	0	0	0	0	0	0	0	0	9
.64	J AIR POLLUT CON ASS	9	0	2	0	1	0	0	1	1	0	0	4
5.71	J BIOL CHEM	9	0	0	0	0	0	0	0	0	0	1	8
1.41	PLANT SCI LETT	8	0	1	1	3	0	2	0	1	0	0	0
1.42	ADV AGRON	7	0	0	0	0	1	0	0	0	0	1	5
3.33	ANAL CHEM	7	0	0	0	0	0	0	0	0	0	0	7
1.57	BOT REV	7	0	0	0	0	0	1	0	0	0	0	6
1.02	CAN J GENET CYTOL	7	0	0	0	0	1	0	0	0	1	0	5
.26	GARTENBAUWISSENSCHAF	7	0	0	1	1	0	1	0	1	0	0	3
.55	HILGARDIA	7	0	0	0	0	0	0	0	0	0	0	7
	P WASH STATE HORT	7	0	0	2	0	0	0	1	0	0	0	4
.56	STAIN TECHNOL	7	0	0	0	0	1	0	0	1	0	0	5
.04	ARKANSAS FARM RES	6	0	0	0	0	0	2	0	0	0	0	4
2.10	AUST J PLANT PHYSIOL	6	0	0	0	3	1	2	0	0	0	0	0
3.19	BIOCHEM J	6	0	0	0	0	0	0	0	0	0	0	6
1.22	BIOMETRICS	6	0	0	0	0	0	0	0	0	0	0	6
	FRUIT VAR HORT DIG	6	0	0	0	0	0	0	0	0	2	1	3
	MICRONUTRIENTS AGRIC	6	0	0	0	0	0	1	0	0	5	0	0
	OFFICIAL METHODS ANA	6	0	0	0	0	0	0	0	0	0	0	6
	P INT SOC CITRICULTU	6	0	0	6	0	0	0	0	0	0	0	0
	STAT METHODS	6	0	0	0	0	0	0	0	0	0	0	6
.50	T BRIT MYCOL SOC	6	0	0	0	0	0	0	0	0	0	0	6
	ALL OTHER (1058)	1438	10	31	84	90	80	82	82	93	65	57	764
1.06	J AM SOC INFORM SCI	786*	26	90	114	123	73	53	43	40	35	28	161
1.06	J AM SOC INFORM SCI	75	2	14	12	16	4	8	4	7	4	2	2
1.31	COMMUN ACM	19	0	0	6	3	1	0	0	0	1	1	7
1.60	ONLINE	15	0	4	5	6	0	0	0	0	0	0	0
	J LIBR AUTOMAT	14	0	2	1	0	0	1	0	3	3	2	2
	AM DOC	10	0	0	0	0	0	0	0	0	0	0	10
	ANNU REV INFORM SCI	10	0	0	3	3	1	1	0	0	1	0	1
.40	IEEE T SOFTWARE ENG	10	0	0	1	6	1	2	0	0	0	0	0
	INFORM PROCESSI	10	0	2	1	3	3	0	0	0	0	0	1
	AM PSYCHOL	8	0	3	2	2	0	0	0	0	0	1	0
	INFORM STORAGE RETR	8	0	0	0	0	0	0	3	2	1	1	1
	LIBR J	8	5	1	0	0	1	0	0	0	0	0	1
5.70	SCIENCE	8	0	1	1	0	0	0	1	1	2	1	1
	B AM SOC INFORM INF	7	0	3	1	3	0	0	0	0	0	0	0
.90	J CHEM INF COMP SCI	6	0	1	0	1	2	2	0	0	0	0	0
1.11	J DOC	6	0	0	0	0	1	0	2	1	0	1	1
	ALL OTHER (438)	572	19	59	81	80	59	39	53	26	23	19	134
.72	J AM STAT ASSOC	2174*	22	127	191	188	149	145	115	120	84	109	926
.72	J AM STAT ASSOC	281	2	15	21	29	25	22	26	16	13	18	94
.83	BIOMETRIKA	159	0	4	4	9	6	11	11	4	3	8	99
	ANN MATH STAT	129	0	0	0	0	1	0	0	1	5	8	114
.76	TECHNOMETRICS	66	0	3	6	4	3	8	8	6	1	3	24
.98	J ROY STAT SOC B MET	64	1	1	3	3	0	1	5	3	7	2	38
.88	ANN STAT	61	2	4	13	14	5	8	4	10	0	0	1
1.22	BIOMETRICS	46	0	2	1	2	4	0	0	2	4	3	28
	ECONOMETRICA	43	1	3	6	4	0	0	1	2	5	4	17
.70	AM STAT	15	1	0	2	0	3	6	0	2	0	0	1
	LINEAR STAT INFER	15	0	0	0	0	0	0	0	10	0	0	5
	ANNALS MATHEMATICAL	14	0	0	0	0	0	0	0	0	0	1	13
	APPL STAT	14	0	0	4	1	0	3	2	2	0	0	2
	COMMUNICATIONS STA A	14	0	1	2	6	5	0	0	0	0	0	0
1.31	COMMUN ACM	12	0	0	5	0	1	0	1	1	1	0	3
	REP LSAC SPONSOR	12	1	0	0	6	1	1	1	2	0	0	0
	AM J SOCIOL	11	0	2	0	0	3	0	0	1	0	1	4
	J BUS	11	0	0	0	0	0	0	1	0	1	0	9
	SANKHYA SER A	11	0	0	0	2	0	2	0	0	0	1	6
	INTRO PROBABILITY TH	10	0	0	0	0	0	0	0	0	0	3	7
	J STAT COMPUT SIM	10	1	3	3	0	1	1	1	0	0	0	0
	P AM STAT ASSOC	10	0	1	3	2	1	2	0	1	0	0	0
	STAT METHODS	10	0	1	0	0	0	0	1	1	0	1	6
	INTRO MULTIVARIATE S	9	0	0	0	0	0	0	0	0	0	0	9
	EXPLORATORY DATA ANA	8	0	0	0	6	0	0	0	0	0	2	0
	J FINANC QUANT ANAL	9	0	0	2	[illegible]	1	1	2	0	1	1	0
.81	J ROY STAT SOC A GEN	8	0	1	1	1	3	0	0	0	1	0	1
	ADV THEORY STAT	7	0	0	0	0	0	0	0	2	0	0	5
	INT ECON REV	7	0	0	0	1	1	0	1	2	0	0	2
.47	INT STAT REV	7	0	0	0	2	0	0	0	0	0	1	4
	J ECONOMETRICS	7	0	0	0	2	2	1	1	1	0	0	0
	J ROY STAT SOC	7	0	0	0	0	0	1	0	0	0	0	6
	REV ECON STAT	7	0	0	1	0	0	0	1	1	1	0	3
	6TH P BERK S MATH ST	7	0	0	0	0	0	0	0	0	7	0	0
	ROBUST ESTIMATES LOC	6	0	0	0	0	0	0	0	0	6	0	0
	STAT DISTRIBU	6	0	0	0	0	0	6	0	0	0	0	0
	STUD BAYESIAN ECO	6	2	0	0	0	0	2	2	0	0	0	0
	ALL OTHER (761)	1056	11	86	114	95	83	68	45	51	26	52	425

Description

Citing journals (journals indexed by *SCI*® during 1980) are listed alphabetically by their abbreviated titles. The first line of the entry for each citing journal gives its impact factor, abbreviated title, and total number of references from articles the journal published in 1980. The total is asterisked. Succeeding columns of the row distribute the reference total by year in which the articles cited in the references were published. The last column includes counts for 1971 and previous years.

Thus, the specimen shows that articles published by the *Journal of the American Statistical Association* in 1980 produced 2,174 unique citations (citations of the same article in a single article's references are counted as one). Twenty-two of the 2,174 references contained citations of articles published in 1980, 127 references cited articles published in 1979, 191 references cited articles published in 1978, etc. The last column in the row shows that 926 of the 2,174 references contained citations of material published in 1970 and earlier years.

Under the total line for each citing journal are listed the journals cited in the references of the citing journal named in the main-entry line. These cited journals are listed, in descending numerical order, by the frequency of their citation in references of the citing journal named in the main-entry total line. The abbreviated title of each of the sub-entry cited journals is preceded by the impact factor of that journal if it has been possible to determine it. The total citation count for each sub-entry cited journal is shown, and then distributed, as described above, by year of publication of the cited items.

Thus, *Journal of the American Statistical Association (J AM STAT ASSOC)* cited itself 281 times in the reference of articles it published in 1980. Of those 281 citations, two were of articles published in 1980, 15 of articles published in 1979, 21 of articles published in 1978, etc. Ninety-four of the 281 citations were articles published in 1970 and earlier years. Similarly, *Journal of the American Statistical Association* cited *Biometrika* 159 times in the references of articles it published in 1980. None of these references contained citations of articles published in *Biometrika* in 1980; four contained citations to articles published in 1979. The chronological distribution shows that over one-half (99/159) of *Journal of the American Statistical Association*'s citations of *Biometrika* was of material published by *Biometrika* in 1970 and earlier years.

The last sub-entry under each citing journal main-entry summarizes data on journals that were cited less than 6 times in the references of articles published in 1980 by the journal named in the main-entry line. (Exceptions to the 'less-than-six' convention are explained elsewhere).

Thus, 'all other' journals cited in the 1980 references of J AM STAT ASSOC numbered 761, and these unnamed journals accounted for 1,056 citations.

This specimen shows that 42% (926/2174) of the articles cited in 1980 references of J AM STAT ASSOC were published in 1970 and earlier years, that its self-citing rate is 12.92% (281/2174), and about one-third (677/2174) of the articles it cited in 1980 were published in 1976 or thereafter.

Description

Cited journals in this package are science journals cited by *SCI®*, *SSCI®* and *A&HCI™* source journals. Not every cited journal is covered by *SCI*. In fact, about 800 cited journals are those not indexed by *SCI* but covered in ISI's current awareness services, *Current Contents®/Clinical Practice. Current Contents/Agriculture, Biology & Environmental Sciences* and *Current Contents/Engineering, Technology & Applied Sciences*. References from these *CC®/CP, CC/AB&ES* and *CC/ET&AS* journals were not processed for the *SCI* and thus citations from them, including self-citations, were not available when *JCR™* was compiled.

Cited journals are listed in alphabetical order of their abbreviated titles. Thus, in the specimen, the entry for *American Journal of Physics* (AM J PHYS) comes before the entry for *American Journal of Physical Anthropology* (AM J PHYS ANTHROPOL). The first line of the entry for each cited journal gives its impact factor, abbreviated title, and total citations received in 1980. The total is asterisked. Succeeding columns of the row distribute the citation total by year in which the cited articles were published. The last column includes counts for 1970 and previous years.

Thus, the specimen shows that *American Journal of Physics (AJP)* was cited 1,048 times in 1980. Twenty-two of the citations were to articles or other items published by *AJP* in 1980, 109 in 1979, 104 in 1978, etc. Of the 1,048 citations, 399 were to articles published by *AJP* in 1970 and earlier years.

Under the total line for each cited journal are listed the journals in whose references citations of the main-entry cited journal appeared. These citing journals are listed, in descending numerical order, by the number of citations each contributed to the citation totals for the cited journal named in the main-entry. The abbreviation for each of the sub-entry citing journals is preceded by the impact factor of that journal, if it has been possible to determine it. The total citation count for each sub-entry citing journal is shown, and then distributed, as described above, by year of publication of cited *AJP* items.

Thus, *American Journal of Physics (AJP)* cited itself 373 times in references of articles it published in 1980. Twenty of these references contained citations of articles published by *AJP* in 1980; 64 of the 1980 references cited 1979 *AJP* articles, and so on. Similarly, *Foundations of Physics* (FOUND PHYS) cited *AJP* 40 times in references of articles it published in 1980. None of these references were to *AJP* articles published in 1980. Two were to articles published in 1979, two cited 1978 articles, etc. Eleven of the *AJP* articles cited by FOUND PHYS were published in 1970 or earlier years.

The last sub-entry under each cited journal main-entry summarizes data on journals whose 1980 references included fewer than six citations of that journal in 1980. (Exceptions to this 'less-than-six' convention are explained elsewhere). Thus, 'all other' journals whose 1980 references contained citations of *AJP* numbered 211. These 211 journals contained in all 366 citations of *AJP* articles in their references. The total for these 'all other' journals is distributed chronologically, as described for named citing journals.

This specimen shows *AJP* has a self-cited rate of nearly 36% (373/1,048); that 38% (399/1,048) of 1980 citations of *AJP* were citations of older material published in 1970 and earlier years, and that 38% (401/1,048) of 1980 citations were to articles published from 1976 on.

The specimen opposite also shows several features users will soon understand at a glance. Notice, for example, the entry for CALPHAD. CALPHAD (*Calphad—computer coupling of phase diagrams and thermochemistry*) began publication in 1977—hence the zeros in the right-hand columns. An array of zeros on the right should alert you to the fact that a journal is relatively new. Zeros in most left-hand columns can mean that the journal has stopped publishing or has changed titles.

Cited Journal Package

Specimen

S C I   J O U R N A L   C I T A T I O N   R E P O R T S

CITED JOURNAL PACKAGE

	CITED JOURNAL / CITING JOURNAL	TOTAL	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	REST
		<------		NUMBER OF		TIMES	THIS	YEAR WAS	CITED IN		1980	------	-->
.30	AM J PHYS	1048*	==22	==109	==104	==103	==63	==72	==36	==41	==52	==47	==399
.30	AM J PHYS	373	20	64	51	41	24	27	12	13	20	7	94
1.62	J PHYS A	46	1	2	6	4	8	5	1	2	1	2	14
.57	FOUND PHYS	40	0	4	3	2	1	5	2	2	4	6	11
.98	J MATH PHYS	20	1	2	2	2	1	1	0	0	0	0	11
2.63	PHYS REV B	16	0	0	0	2	0	1	1	0	0	1	11
2.58	PHYS REV D	16	0	5	1	0	0	0	1	2	1	0	6
.33	IEEE T EDUC	15	0	1	0	0	3	2	1	1	1	1	5
3.17	J CHEM PHYS	13	0	0	1	0	0	3	0	0	0	2	7
1.11	PHYS LETT A	12	0	2	1	1	1	0	0	1	0	0	6
2.58	PHYS REV A	12	0	0	5	2	0	2	0	0	0	0	3
.38	J CHEM EDUC	11	0	0	0	0	2	0	1	2	4	1	1
1.81	J MOL SPECTROSC	11	0	0	0	0	0	0	0	0	0	0	11
.84	LETT NUOVO CIMENTO	11	0	1	0	0	1	2	0	0	0	0	7
1.55	J APPL PHYS	10	0	0	1	2	0	2	0	0	0	0	5
2.89	J PHYS C SOLID STATE	10	0	0	0	2	0	0	0	0	0	0	8
	COMPUT EDUC	9	0	0	1	1	1	3	0	2	0	1	0
1.63	APPL OPTICS	8	0	2	0	0	0	0	0	0	1	0	5
1.19	ISRAEL J CHEM	8	0	1	3	0	2	0	1	0	1	0	0
.98	PHYS STATUS SOLIDI B	8	0	0	1	1	0	0	0	1	0	1	4
.78	NUOVO CIMENTO B	7	0	0	0	1	0	0	0	0	0	2	4
.65	PHILOS SCI	7	0	0	0	0	0	0	0	0	2	0	5
3.01	SURFACE SCI	7	0	0	1	0	0	1	0	0	0	1	4
7.13	PHYS REP	6	0	0	0	1	0	0	0	1	0	0	4
1.53	PROG THEOR PHYS	6	0	1	2	0	0	0	0	0	1	0	2
	ALL OTHER (211)	366	0	24	25	41	19	18	16	14	16	22	171
1.05	AM J PHYS ANTHROPOL	1528*	==25	==102	==151	==136	==96	==83	==82	==108	==92	==54	==599
1.05	AM J PHYS ANTHROPOL	448	11	37	54	45	32	19	26	24	23	17	160
.40	J HUM EVOL	84	0	1	14	7	6	6	5	4	9	3	29
	ANNU REV ANTHROPOL	76	1	7	6	9	10	6	4	3	6	0	24
.67	HUM BIOL	58	0	3	6	9	4	4	3	1	5	3	20
.91	ANN HUM BIOL	46	0	1	6	4	3	2	1	3	3	6	17
	CURR ANTHROPOL	35	2	4	6	4	2	2	1	2	1	2	9
5.70	SCIENCE	34	1	3	0	2	1	0	2	3	3	0	19
.67	AM J ORTHOD	32	0	0	2	3	6	3	2	2	1	0	13
	J ANTHROPOL SOC NIP	31	1	2	3	0	0	3	2	0	1	1	18
.55	FOLIA PRIMATOL	28	0	3	1	4	0	0	2	6	0	0	12
.32	ANGLE ORTHOD	23	0	0	0	2	0	3	0	1	3	0	14
.50	ACTA ANAT	21	0	1	2	1	1	2	0	2	1	0	11
.89	HUM HERED	19	0	4	1	2	0	2	0	0	2	2	6
.35	J MED PRIMATOL	19	0	2	1	3	2	0	0	3	1	0	7
	B MEM SOC ANTHRO PAR	16	0	0	3	1	0	0	0	0	0	1	11
.52	LAB ANIM SCI	14	0	0	5	3	0	0	0	2	0	0	4
1.51	J DENT RES	13	0	2	0	2	0	0	2	0	0	1	6
	MANKIND QUART	13	0	0	0	0	0	0	2	0	0	0	11
.60	ACTA MORPHOL NEER SC	12	0	0	0	0	0	0	0	0	1	0	11
	COLLEGIUM ANTROPOL	12	0	1	0	2	3	0	0	0	2	0	4
1.30	J ANAT	11	0	0	0	0	1	0	2	0	4	0	4
2.35	AM J CLIN NUTR	10	0	0	0	0	0	1	0	0	0	1	8
6.49	NATURE	10	2	1	0	3	1	1	0	0	0	0	2
1.56	TERATOLOGY	10	0	0	0	1	0	0	0	0	2	0	7
3.64	AM J HUM GENET	9	0	1	1	1	0	0	1	1	1	1	2
2.81	AM NAT	9	0	1	2	1	0	1	0	0	0	0	4
	ANTHROPOLOGIE	8	0	0	0	0	1	0	0	1	1	1	4
.29	INDIAN J MED RES	8	0	0	1	0	0	0	0	0	0	0	7
.68	J MAMMAL	8	0	1	2	0	2	0	1	0	0	0	2
	ADV PRIMATOL	7	0	0	0	0	0	2	1	0	2	1	1
2.62	AM ZOOL	7	0	2	2	0	0	1	0	0	1	0	1
1.45	ANIM BEHAV	7	0	0	2	0	0	0	0	2	0	0	3
.68	CLEFT PALATE J	7	0	0	0	0	0	0	0	0	0	0	7
1.06	J MORPHOL	7	1	3	1	0	0	0	0	0	0	0	2
1.60	ANN HUM GENET	6	1	1	1	1	0	2	0	0	0	0	0
.19	AUST DENT J	6	0	1	4	0	0	1	0	0	0	0	0
1.24	BEHAVIOUR	6	0	0	0	1	0	0	0	1	0	0	4
1.10	DEV PSYCHOBIOL	6	0	0	0	0	3	0	1	1	0	0	1
1.82	EXP EYE RES	6	0	1	0	2	0	0	1	2	0	0	0
.72	J MENT DEFIC RES	6	1	1	1	3	0	0	0	0	0	0	0
.57	J PROSTHET DENT	6	0	0	0	1	1	1	0	0	0	0	3
.58	NOUV REV FR HEMATOL	6	0	0	1	0	1	0	0	0	1	0	3
.30	ZOOL ANZ	6	0	2	1	3	0	0	0	0	0	0	0
	ALL OTHER (186)	322	4	16	20	18	16	21	23	44	18	14	128
.50	AM J PHYS MED	208*	==4	==4	==12	==11	==5	==12	==4	==8	==12	==13	==123
1.82	AM J ANAT	10	0	0	0	0	0	1	0	1	1	1	6
.50	AM J PHYS MED	10	3	0	1	1	0	0	0	0	0	1	4
.42	ARCH PHYS MED REHAB	10	0	0	1	1	1	1	0	0	0	2	4
.43	MED BIOL ENG COMPUT	9	0	0	0	1	0	0	2	0	0	0	6
	RES Q EXERCISE SPORT	8	0	0	1	0	0	3	0	0	0	1	3
2.88	PAIN	5	0	1	0	0	2	1	0	0	0	0	1
.77	RADIAT ENVIRON BIOPH	5	0	0	0	0	0	0	0	0	1	0	4
.14	SCAND J REHABIL MED	5	0	0	0	0	0	0	0	2	0	0	3
3.91	AM REV RESPIR DIS	4	0	0	0	0	0	0	0	0	0	3	1
.32	ANN SCI	4	0	0	0	0	0	0	0	0	0	0	4
1.58	ELECTROEN CLIN NEURO	4	0	0	0	0	0	0	0	0	1	0	3
.76	EUR J APPL PHYSIOL O	4	0	0	0	1	0	0	0	0	1	0	2
4.15	J NEUROPHYSIOL	4	0	0	2	0	0	0	1	0	0	0	1
1.19	MED SCI SPORTS	4	0	0	0	0	0	0	0	0	1	0	3
	NEUROBEHAV TOXICOL	4	0	0	0	0	0	0	0	0	0	0	4
	ALL OTHER (88)	118	1	3	7	7	2	6	1	5	7	5	74
.86	CALPHAD	86*	==7	==17	==21	==40	==0	==0	==0	==0	==0	==0	==1
.86	CALPHAD	41	6	8	13	14	0	0	0	0	0	0	0
.81	Z METALLKD	8	1	0	6	1	0	0	0	0	0	0	0
.85	ATOM ENERGY REV	6	0	1	1	4	0	0	0	0	0	0	0
.59	METALL TRANS B	3	0	1	0	1	0	0	0	0	0	0	1
1.79	ACTA METALL	2	0	2	0	0	0	0	0	0	0	0	0
3.17	J CHEM PHYS	2	0	1	0	1	0	0	0	0	0	0	0
1.93	J ELECTROCHEM SOC	2	0	0	1	1	0	0	0	0	0	0	0
.92	J LESS-COMMON MET	2	0	0	0	2	0	0	0	0	0	0	0
.84	METALL TRANS A	2	0	1	0	1	0	0	0	0	0	0	0
2.63	PHYS REV B	2	0	0	0	2	0	0	0	0	0	0	0
10.00	SOLID STATE PHYS	2	0	0	0	2	0	0	0	0	0	0	0
.34	CHEM LISTY	1	0	0	0	1	0	0	0	0	0	0	0
2.10	CHEM PHYS LETT	1	0	0	0	1	0	0	0	0	0	0	0
3.08	GEOCHIM COSMOCHIM AC	1	0	0	0	1	0	0	0	0	0	0	0
.39	HIGH TEMP SCI	1	0	0	0	1	0	0	0	0	0	0	0
	ALL OTHER (10)	10	0	3	0	7	0	0	0	0	0	0	0

AGRICULTURAL SCIENCES

ADV AGRON
ADV FOOD R
ADV PLANT B
ANALYT METH
ASA SPEC P
DEVEL SOIL
ECON MICROB
FOOD SCI T
H VEGET SC
HORTICUL RE
PROG PEST B

BIOCHEMISTRY & BIOPHYSICS

ADV BIOCH E
ADV BIOL M
ADV BIOPHYS
ADV CARB C
ADV COMP PB
ADV CY NU R
ADV ENZYM
ADV INORG B
ADV LIPID R
ADV PROSTAG
ADV PROTEIN
ADV SEX HOR
ADV STER B
ALKALOIDS C
ANN R CLIN
APPL BIOCH
BBA LIB
BEHRING INS
BIO MAGN RE
BIOC BIOP P
BIOCHEM ACT
BIOCHEM DIS
BIOL SEPAR
BIOMEMBRANE
CHEM BIOCHE
CL BIOCHEM
CLIN BIOC A
COLL BIOL M
COMP BIOCH
CURR T BIO
DEV MOL BIO
ELEC MICR P
ENZYMES SER
ESSAYS BIO
FREE RAD B
HANDB LIP R
HORIZ BIOCH
HORM PROT P
IMMUNOCH P
INT R CONN
INT REV BIO
ISOZYMES
MEMBR PROT
MEMBR TR B
METAL ION B
METAL IONS
METH BIOC A
METH CARBOH
METH ENZYM
METH MOL B
METH SURV I
MOL ASP CEL
MOL BIOL B
MOL BIOLOGY
N COMP BIOC
NEW TECH B
PEPTIDES-AN
PHOTOCH P
PROG HORM
PROG LIP R
PROG MOLEC
PROG NUCL A
PROG PEST B
PROG REP IN
PROTEIN SYN
REC ADV C
REC DEV CHE
RECEP COMPR
RECEP R S-B
RECEP RECOG
RECEPT HORM
REV HEMAT
SPR AMINO A
SPR BIOSYNT
SUBCELL B
T BIOELECT
TEC BIOCH B
WILEY S MEM

BIOLOGY

ADV APPL MI
ADV AQ MIC
ADV BEHAV B
ADV BOTAN R
ADV CELL N
ADV INSECT
ADV INVER R
ADV MAR BIO
ADV MICROB
ADV MICROBI
ADV OPT E M
ADV PARASIT
ADV PLANT B
ADV RAD BIO
ADV VIRUS R
ANN RP FERM
APPL BIOL
BEH BIOLOGY
BEHAV MAR A
BIBL ANATOM
BIOC BIOP P
BIOCHEM ACT
BIOL ENV
BIOL KINETO
BIOL MEMBR
BIOL REPTIL
CELL BIOL C
CELL BIOL S
CELL NUCL
CELL SURF R
COMP BIOL M
COMP VIROL
CONTR PRIM
CURR T CELL
CURR T DEV
CURR T MEM
DEVEL MAMMA
DEVELOP AQU
ECON MICROB
ELEC MICROS
ENCYCL PLAN
EVOL BIOL
EXP BOT
FILAM FUNGI
FISH PHYSIO
FORAMINIFER
FRONT BIOL
FRONT MATR
FUNCT ANAT
GBF MG SER
HAND BEHAV
HANDB PHYSL
INT R CONN
INT R CYT S
INT REV CYT
LUNG BIOL H
MAGN RES B
MAR NATUR
MEM TRANS P
MEMBR PROT
MEMBRANES
METH CELL B
METH MEMB B
METH MICROB
METH PSYCH
METH VIROL
MG BIOL
MG THEOR A
MICROBIOL S
MICROSTR SC
NEW TECH B
OCEANOG MAR
PHYSIOL ECO
PLANT CEL S
PROG IND M
PROG PHYTOC
PROG T BIOL
REP MAR INV
RES MG CELL
SER MYCOLOG
SOV SCI R D
SPR FOR COM
T ENZYME F
T MOL STR B
T PHOTOSYN
TEC BIOCH B
ULTRASTR B
WATER DEF

BIOMEDICAL RESEARCH

ACQ PERSP
ADV CARD PH
ADV CELL C
ADV CLIN CY
ADV COMP PB
ADV GENETIC
ADV HUM GEN
ADV IMMUNOL
ADV M S BIO
ADV METAB D
ADV MICROC
ADV MOD ENV
ADV MOD NUT
ADV NUTR R
ADV PATHOB
ADV TUBER R
AGING
AGING-SP M
AM COLL LAB
BAS CLIN IM
BEHAV MED
BEHRING INS
BEITR INFUS
BIBL CARDIO
BIBL NUTR D
BILE ACIDS
BIOCHEM DIS
BIOL REGU D
BIOMED EN C
BIOMED RES
BUT I M R C
CELL MUSC M
CHROM BIOL
CLIN BIOC A
CLIN C MED
CLIN IMMUNB
CLIN MG DBS
CLIN PHYS
COMP ANIM N
COMP BIOL M
COMP ENDOCR
COMP IMMUN
CONT BIOMED
CONT ENDOCR
CONT HEMAT
CONT ISSUES
CONT PROB C
CONT T IMM
CONT T MOL
CONTEM META
CONTR GYNEC
CURR CARD T
CURR CON NU
CURR T EXP
CURR T HEMA
CURR T HIST
CURR T PATH
DEV MOL BIO
DEVEL MED M
ELEC MICR B
ELEC MICROS
ENZYMES SER
ESSAY MED B
EXERC SPORT
FOGAR INT C
FOGARTY INT
FORTSCH GAS
FRONT GASTR
FRONT NEURO
FRONT ORAL
GENET ENG
GENET ENG P
GERONT G EZ
HANDB INFLA
HANDB PHYS
HANDBUCH AL
HARVEY LECT
HEAR RES TH
HEMAT BLOOD
HEPAT RES C
HORM MET R
HORM PROT P
IMMUNOCH P
IMMUNOL ASP
IMMUNOL MET
IMMUNOL PAR
IMMUNOL SER
INT R EXP P
INT R PHYS
INTERO T GE
ISOZYMES
LAC COMP TE
LIVER NORM
LYMP REP F
LYMPHOKINES
METAB ASP C
METH ACH EX
METH IMMUN
MG ALLERGY
MG FETAL PH
NEUROTR REC
NEW PERS CL
NUTR BRAIN
NUTR CLIN N
NUTR HEALTH
NUTR META S
OPHTHAL SER
PATH ANN
PATHOBIOL A
PEDIAT ADOL
PERSP HUMAN
PERSP NEPHR
PHYSIO PATH
PIGM CELL
PROG ALLERG
PROG C FIBR
PROG CLIN I
PROG CLIN P
PROG HEMAT
PROG HEMOS
PROG MED GE
PROG MED VI
PROG NEUROP
PROG SENS
REC ADV C
REC ADV CL
REC ADV CLI
REC ADV HAE
REC ADV NEU
RECEPT HORM
RES TOP PHY
RETICUL SYS
SPR FOR COM
T CARD DIS
T ENVIR PHY
T HORM CHEM
T REV HAEM
ULTRASOUN B
VITAM HORM
WORLD REV N
YEAR ENDOCR

CANCER

ADV CANC R
BREAST CANC
CANC BIOL R
CANC TREAT
CANCER-COMP
CARCINOGEN
CHEM MUTAG
CLIN ONCOLO
COMM RES BR
CONT HEMAT
DEV ON COL
EORTC CAN C
IARC SCI P
IMMUNOL PAR
INT ADV SUR
INTERFERON
METH CANC R
MG E OR CAN
PHYSIOPAT C
POLYC HYDRO
PROG CLIN
PROG EX TUM
S KETTERING

CHEMISTRY

A HOMOG CAT
ACS MON SER
ADV CATAL
ADV CHROMAT
ADV CLIN C
ADV ELEC E
ADV HETERO
ADV INORG C
ADV LIQ CRY
ADV MAGN R
ADV MS CHEM
ADV ORG CHE
ADV ORGMET
ADV PHOTOCH
ADV PHYS O
ADV POLYM S
ADV QUANT C
ADV RAD CH
ALKALOIDS C
ANN RP CH C
ANN RP INOR
BIOL METH
CHEM BIOCHE
CHEM FUNCT
CHEM HETERO
CHEM NONAQ
CHEM PHYS C
CHROMAT SCI
COMP ANAL C
COMP CHEM K
CONT T ANAL
CRIT REP AP
CRYST GR PR
CRYST GROW
ELEC SOC S
ELECTROAN C
ENCY ELECTR
EXCITE STAT
EXP CHEM TH
FLAME RETAR
FLUORINE CH
GEN SYN MET
GROWTH CRYS
HANDB SURF
HIGH PERF L
INORG BIOCH
INORG SYNTH
ION SEL EL
ISOT ORG CH
IUPAC CHEM
J ORG CH LI
METH MICROA
MIDLAND MAC
MOD ANAL CH
MOL INTERAC
MON ASPECTS
ORG BIOL CH
ORG CHEM
ORG PHOTOCH
ORG REACT
ORG REACT M
ORG SYN MET
ORG SYNTH
ORGMET CH S
P CHEM ORGA
PHOTOCH PHO
PHYS CH MAT
PHYS CHEM
PHYS CHEM F
PHYS CHEM S
PHYS METH M
POLYC HYDRO
PROG INORG
PROG MACRO
PROG PHY OR
PROG SURF
REACT INT O
REACT INT S
REACT INTER
REC DEV CHE
RODD'S CHEM
SOV SCI R B
SPR AL REL
SPR ALIC CH
SPR ALKAL
SPR ARO HET
SPR CARB CH
SPR CATALYS
SPR CHEM T
SPR COLL SC
SPR DIELECT
SPR ELEC SP
SPR ELECTR
SPR ELECTRO
SPR GAS KIN
SPR INORG C
SPR INORG R
SPR INORGAN
SPR MASS SP
SPR MOL CH
SPR OR CHEM
SPR ORG COM
SPR ORGANO
SPR PHOTOCH
SPR RADIOCH
SPR SAT HET
SPR SPEC PR
SPR TERP ST
SPR TH CHEM
STEREOCHEM
STRUCT BOND
SURF COL SC
SURF SC S
SURV PROG C
T CARB NMR
T CURR CHEM
T PHOS CHEM
T STEREOCH
T SULF CH
TECH CHEM
THEOR CHEM
TREAT AN 1
TREAT AN 2
TREAT SOL S

COMPUTER APPLICATIONS & INFORMATION SCIENCE

ADV COMPUT
ADV INF SYS
COMP BIOL M
COMP PEOPLE
COMPUTER CH
MATH METH D
MATH PROG S

ECOLOGY & ENVIRONMENTAL SCIENCES

ADV ECOL R
ADV ENV SCI
ADV ENVIR S
ADV MICROBI
BIOL ENV
DEVEL AGR M
ECOSYST WOR
ENVIR SCI
FAO CONSERV
INST ENV SC
LAKE NY STA
PROP MAT
RADIOECOL S
RESIDUE REV
T ENVIR HEA
T ENVIR PHY
VER OST MAB
WATER POLLU
WILEY S ENV
WORLD SURV

ENERGY, FUELS, & NUCLEAR TECHNOLOGY

ADV ENERG S
ADV NUCL S
NUCL SCI T
PROG ENERG
RADIOACT W
STUD NUC AL
THIEMIG TAS

ENGINEERING & TECHNOLOGY

ADV APPL M
ADV BIOCH E
ADV BIOMED
ADV CHEM EN
ADV CORR SC
ADV ELEC E
ADV ENVIR S
ADV HEAT TR
ADV HOLOGR
ADV IMAGE P
ADV OPT E M
ADV TRANS P
AP SOLID ST
APP FIB SCI
APP OPT OPT
APPL BIOCH
CASE STUD E
CHEM ENG S
CHEM PROCES
CLIN ENG S
CONT INSTR
CONTR DYNAM
CRIT REP AP
CURR T MAT
ENG MED
FIBER SC
FLAME RETAR
GA I TECH S
GLASS SCI T
HANDB SEMIC
HMT-SCI APP
HONDA MEM S
INSTR PULP
INT ADV NON
MATER PROC
MATER SCI R
MATER SCI T
MECH FRACT
MED PHYS SE
MULTIPH S C
OPT INF PRO
PHOTOGR TEC
POWD TECH P
PROG OPTICS
PROP MAT
REC ADV NUM
REFR MAT S
RES TECH N
SER THERM F
TREAT MATER
WILEY S NUM

GEOSCIENCES

ADV GEOPHYS
ADV HYDRO
BR MICR PAL
CURR TREN G
DEV EARTH P
DEVEL GEOT
DEVEL PETR
DEVEL SEDIM
DEVELOP PAL
FLUID MECH
FORAMINIFER
GEOL ASSOC
GEOL PALAEO
HAND ASTRON
I BR GEOG S
INT R DEEP
INT AS SED
INT UNION G
JOHN H GEOL
LAKOSC SYST
LOW PAL ROC
MAR NATUR
MOD QUAT RE
NORG GEOL U
OCEAN BAS M
OCEANOG MAR
U KENT OFF

HYGIENE & PUBLIC HEALTH

BR OCCUP HY
OCCUP SAF H
PRINC TECH
STRAH FORS
T ENVIR HEA

MATHEMATICS

ADV MATH S
DEVEL STAT
MATH PROG S
MATH R LEHR
WILEY S PRO

MEDICINE, CLINICAL

ADOLES MED
ADV BEH PED
ADV CLIN CY
ADV INTER M
ADV MAN CL
ADV OPHTHAL
ADV OTO-RH
ADV PEDIAT
ADV PERI NE
ADV PSY MED
ANN R CLIN
ATHEROSCL R
BAS CLIN N
BEITR INFUS
BIBL OPHTH
BIBL RADIOL
BUT I M R C
BUT I M R G
BUT I M R N
BUT I M R O
CHEM BIOCH
CHILD HEAL
CLIN ANDROL
CLIN C MED
CLIN CARD M
CLIN DIAGN
CLIN MG OBS
CLIN OBSTET
CONT HEMAT
CONT NEPHR
CONT PROB C
CONTR GYNEC
CURR CARD T
CURR CARDIO
CURR GASTRO
CURR HEPAT
CURR I DEVE
CURR NEPHRO
CURR PULMON
CURR STAT M
CURR T CRIT
CURR T EYE
CURR T INF
DEV NEPHROL
DEV NUC MED
DEVELOP OIG
ENG MED
EXERC SPORT
FOGARTY INT
FORTSCH GAS
FRANKL I CL
FRONT ORAL
FUND CL INT
GERONT G EZ
HANDB INN M
HEPAT RES C
HUM REPROD
INSTR TEC C
INT BOEH M
INT MED TOD
INTERD T GE
LIT CLIN P
LIVER NORM
LIVER S CR
MAJOR PROB
MED PHYS SE
MED SPORT
METAB ASP C
MG PRACT
MOD PROB OP
NEURO-OPHTH
NEW IMAGE M
NEW PERS CL
NUCL MED A
OBST GYN A
OPHTHAL SER
P CAR REHAB
PADIATR FOR
PEDIAT ADOL
PEDIATRIC
PERSP NEPHR
PERSP PEDIA
PROG CARDIO
PROG CLIN K
PROG GASTRO
PROG LIVER
PROG MED UL
PROG NUCL M
PROG PED HE
PROG PED R
REC ADV CAR
REC ADV CL
REC ADV CLI
REC ADV DER
REC ADV MED
REC ADV OTO
REC ADV RAD
RES CLIN ST
REV PERIN M
ROY SOC MED
SCI PRACT C
SEM INFEC D
STRAH FORS
T ADOL MED
T CARD DIS
WILEY S DIA

MEDICINE, MISCELLANEOUS

ADV VET SCI
ESSAYS CHEM
MAS MG DIAG
MULTI IMAG
ULTRAS MED

MULTIDISCIPLINARY SCIENCES

CHART SYMP
CONT SCI N
COSMET SCI
DEVELOP SER
HARVEY LECT
HIST SCI
METH CHIM
METH PHENOM
T NY A S S2

NEUROSCIENCES

ADV NEUROCH
ADV NEUROS
ADV PERI NE
ADV SLEEP R
BEHAV MED
BUT I M R N
CLIN NEUR
CURR NEUROL
CURR T NEUR
ESSAYS NEUR
FRONT NEURO
HAND BEHAV
HAND CLIN
INT R NEURO
METH NEUROB
METH PHYSL
MG MOD NEUR
MG NEUR SCI
MS NEUR DEV
NEURO-OPHTH
NEUROTOX
NEUROTR REC
PROG NEUROL
PROG NEUROP
PROG PSYCHB
PROG SENS
REC ADV NEU
REC DEV NEU
RES CLIN ST
RES METH N
RES PUBL AS
REV NEUROSC
STUD DEV BE

PHARMACOLOGY

ACTU PHARM
ADV BEH PED
ADV BEHAV P
ADV CLIN P
ADV DRUG R
ADV HUM PSY
ADV MOD TOX
ADV PHARM C
ADV STER B
ANAL PROF D
ANNU REP M
BIOC PHARM
CLIN IMP AD
CLIN NEUR
CURR DEV PS
ESSAYS TOX
HANDB PSYCH
IND PHARMAC
INT ENCY PH
MED CHEM
METH PHARM
MEYLER P DR
MG PHARM PH
MOD PHARM T
MOD PROBL P
NEUROTOX
PAR INVOL D
PHARM BIOCH
PHYS PHARM
POLYM BIOL
PROG DRUG M
PROG DRUG R
PROG HORM B
PROG MED CH
PSYCHOPH SE
QUAL CONTR
REC ADV CLI
REV BIOC TO
SIDE EFFECT
T ANTIB CHE
TARG ORG T
TOX ANNUAL
TRENDS AUTO

PHYSICS

ACOUST VIB
ADV APPL M
ADV ATOM M
ADV CHEM P
ADV EL EL P
ADV ELECTR
ADV HEAT TR
ADV HOLOGR
ADV IMAGE P
ADV INFRA R
ADV MATER D
ADV MECH PH
ADV NUCL P
ANN R NMR S
APP OPT OPT
CARG LECT P
CHEM PHYS S
CREAT DETEC
DEVEL THEOR
ELEC SPECT
ESSAYS PHYS
EXP MAGNETI
HAND ASTRON
HANDB SURF
HMT-SCI APP
INFR MILLIM
INT MG TEXT
LASER INTER
LASERS
METH COMPUT
METH EXP PH
METH SUBNUC
MOSSB EFF M
NMR-BAS P P
NUCL PHYS M
PERGAM MECH
PERSP AUDIO
PHYS ACOUST
PHYS ATOMS
PHYS CHEM S
PHYS SOLID
PHYS THIN F
POLYM PHYS
PRAC SPECTR
PROG LOW T
PROG MATH P
QUANT ELE
REV PLASMA
SEM SEMIMET
SOL ST PHYS
SOL ST SUPP
SOV SCI R A
SOV SCI R C
SOV SCI R E
SPR MOL SPE
SPR MOL STR
SPR NUCL M
SPR STAT ME
SPR TRAC M
SPRIN S ELE
SPRING S OP
ST MOD THER
STUD CONVEC
STUD STAT M
SUBNUCL SER
T APPL PHYS
T CARB NMR
T CURR PHYS
VIBRAT SPEC
WILEY S PLA
WILEY S PUR
WILEY S SOL

PSYCHIATRY

ADV PSY MED
ANN PSYCHOA
CURR PSYCH
EXP CLIN PS
MOD PROBL P
PROG PSYCH
PSYCHOAN ST
PSYCHOPH SE
SER CLIN C

PSYCHOLOGY

ADV BEHAV B
ADV BEHAV P
ADV MENT H
ADV PSYCHOB
ADV SLEEP R
ADV STUDY B
ANN R BEHAV
BEHAV MED
CHILD HEAL
COMM BEHAV
CONTR MED P
CURR DEV PS
DEV PSYCH
HANDB PSY
INT LIB PS
INT REV RE
METH PSYC
PRENT HAL
PROG BEHAV
PROG PSYCH
STUD DEV
WILEY S BE

SURGERY

ADV NEUROS
ADV SURG
BUT I M R
CLIN ANEST
CURR PRAC
INT ADV SU
MOD SURG
MON ANAES
PROG NEURO
PROG ORTHO
PROG SUR
PROG SURG
REC ADV ANA
REC ADV PL
REC ADV SUR
RECONS SURG
SCI PRACT S
SURG ANN
WILEY SER A

APPENDIX C

Inter-rater Coding Reliability

Production

A sample of references appearing in six journals was coded independently by two of the PIs. Of the 448 references coded, total disagreements number 95 (21.2%). However, the extent of these disagreements was noted since three categories of difference were possible: mild (uncertainty in assignment, e.g., 0 or 1, 1 or 2), moderate (one unit difference, e.g., ALP codes 1, DEC codes 2), and severe (two unit difference, e.g., ALP codes 1, DEC codes 3). The distribution of coding difference over these three categories was: mild (47.3%), moderate (53.7%), severe (0%). The coding disagreements for each journal were discussed by the PIs, resolved, and used to guide our judgments when coding the other journals. The typical correction was agreement that one keyword, for example, does not suffice for assigning a code 1.

Usage

Every citation to an article derived from the 19-journal file was coded as categorically identical (1), similar (2), remote (3), or uncodeable (0) with respect to its subject matter. This coding was based on titles only since the source of information was the SCI Source Index. Of the 371 citations, 69.5% were coded into the same category by two individuals, a graduate student and either ALP or DEC. Disagreements were mediated by a third member of the project team, who cast the decisive vote, so to speak. His coding decision locked in the category of the disputed citation. In sum, the reliabilities were good, given the open-ended nature of the coding task.

APPENDIX D

REFERENCE CATEGORIES AND RELATION CODES FOR SAMPLE JOURNALS USED IN PRODUCTION VALIDATION

WS = within same subcategory as the subject journal (code 1)

WC = within same category as the subject journal (2)

WG = within same grand category as the subject journal (3)

U = unclassifiable (e.g., foreign language) (code 0)

1 - AM J ANAT

2 - ANAT REC

WS = Anatomy

WC = Biology Cell; Cytology & Histology
Cardiovascular Systems (heart)
Chemistry
Chemistry Analytical
Dermatology
Engineer Biomedical
Endocrinology
Gastroenterology
Gynecology - Obstetrics
Human Development
Hygiene/Public Health
Morphology
Neurosciences
Otorhinolaryngology
Physical Medicine
Physiology

Urology & Nephrology

Zoology

WG = All the other subcategories in the Life Science Grand category - WS-WC

1 - <u>CRC TOXICOLOGY</u>

2 - <u>TOXICOLOGY LETTERS</u>

WS = Toxicology/Pharmacology

WC = Cancer

Cytology & Histology

Virology

WG - All the other subcategories included in the Life Sciences plus

Chemistry

Chemistry inorganic

Chemistry organic

Chemistry nuclear

Chemistry Physics

Crystallography

Drugs and Addiction

Electrochemistry

Food Sciences & Technology

Statistics

1 - <u>ANN REVIEW OF ECOLOGY</u>

2 - <u>J SOIL WATER</u>

WS = Ecology

WC = Biology, Marine and Freshwater

Environmental Sciences, Water Resources

Hydrology

Soil Sciences

Forestry

WG = All the subcategories included in the Life Sciences grand category + Chemistry inorganic

Chemistry nuclear

WG Only for journal 2 and

Geology

Geography

1 - <u>J MATH PHYSICS</u>

2 - <u>LETTERS IN MATH PHYSICS</u>

WS = Mathematical Physics

WC = All the categories of Physics +

All the categories of Mathematics

WG = All the subcategories included in Physical Sciences Grand category + OR

Nuclear Sciences & Technology

Computer Sciences

Water Resources

1 - <u>COMPUTER PHYSICS COMMUNICATIONS</u>

2 - <u>INT. J. OF BIOMEDICAL COMPUTER</u>

WS = Computer Science

WC for journal 1 = Physics, general

WC for journal 2 = Biomedical Engineer

Operations Research

WG for journal 1 = All the categories of Physics + all the categories of mathematics

WG for journal 2 = All the categories of Medicine +

Microscopy

Marine Biology, Oceanography

Psychology

Information Sciences & Library

Electrochemistry

Ergonomics

Biochemistry

Biometrics

Biophysics

+ all the categories of Chemistry.
+ Electrical Engineering

1 - <u>J APPLIED CRYSTALLOGRAPHY</u>

2 - <u>PROGRESS IN CRYSTAL GROWTH</u>

WS = Crystallography

WC = All the subcategories of Chemistry + Metallurgy and Mining

WG = All the subcategories in the Grand category Physical Sciences +

Biochemistry

Biology Cell

Electrochemistry

Pharmacology

Spectroscopy

Nuclear Science & Technology

Chemical Engineer

Cytology & Histology

Virology

WC

1 - IEEE QUANTUM ELECTRONICS

2 - IEEE TRANSAC RELIABILITY

WS = Electrical Engineering

WC for journal 1 = Atomic Sciences

Physics Solid State

Physics Atomic

Molecular & Chemical

Physics Particles & Fields

WC for journal 2 = Operations Research

Mathematics, Statistics

Physics Condensed Matter

Physics Particles & Fields

WG for journal 1 = All the categories in Engineering Grand Category

+ Biochemistry

Chemistry Analytical

Chemistry Organic

Chemistry Nuclear

Chemistry Physics

Biophysics

Astronomy & Astrophysics

Physics General

Physics Applied

Crystallography

Physics Solid State

Physics Acoustics

Math Physics Applied

Spectroscopy

Statistics

Sonics

WG for journal 2 = All Engineering

All Physics

Sonics

Spectroscopy

Statistics

1 - J EXP. PSYCHOLOGY

2 - INT. J AGING

WS = Developmental Psychology

Human Development

WC = Educational Psychology

Applied Psychology

Psychology

Psychology Clinical

Psychology Experimental

Psychology Social

Education Special

Psychiatry

WG = All other categories in Social Sciences

Hygiene and Public Health

Rehabilitation

Neurosciences

WG for journal 1 Add: Education

1 - <u>POPULATION STUDIES</u>

2 - <u>J BIOSOC SCI</u>

WS = Demography

WC = Statistics

Biometrics

Social Research

WG = All other categories in Social Sciences

1 - <u>MANAG SCI</u>

2 - <u>MATH PROG</u>

WS = OR

WS_1 = Management Sciences

WC_1 = Behavioral Sciences

Business

Applied Psychology

Computer Sciences

Economics

Transportation

Statistics

WC_2= Computer Sciences

Mathematics

Statistics

WG = All Engineering

WG for journal 1 Add: Social Psychology

APPENDIX E

ALGORITHM FOR COMPUTING JOURNAL INDICATORS

Based on the contents of Tables 3 and 4, the following procedure was designed for calculating the indicator using both JCR packages. For the purpose of explanation, the Cited Package will be utilized.

First, assume that: 1) every journal is categorized, and 2) every journal is found in only one category. A random selection of journals was used for each package: For the citing-cited package, every journal with greater than 5 citations is included, plus every other journal with fewer than 6 citations. For the cited-citing package, every journal with 5 citations is included, plus every fifth journal with fewer than 6 citations.

Given a journal x:

1) Place a given journal x in a sub/category by looking up journal x in a SSCI and/or SCI listing.

2) Place journal x in the category by looking at Table 3. (In our case the categories were pre-selected.)

3) Look up journal x in the JCR Cited Package. Recall that we are going to work only with the "total" line throughout the following steps.

4) Add up all the citations to journal(s) y that belong to the same sub/category as journal x.

   WS = journal(s) y/Grand total

   Grand total - Total citations received by journal x in 1979. This grand total is used below.

5) Add up all the citations to journal(s) that belong to the same category as journal x:

WC = journal(s) y/Grand Total

6) Add up all citations to journal(s) y that are outside the category of journal x, but in the same grand category as journal x--(WG).

WG = journal(s) y (WG - WC)/Grand Total

7) Add up residual journal(s) that are found neither in steps 4 nor 5.

8) Self-citation = SC = SC/Grand Total. Self-citation is given as already mentioned.

9) All Other = All Other/Grand Total

Through the analysis of the data for the indicator(s), another level was added--multidisciplinary journals (code 5) that cannot be considered outside the Grand Category as such. The percentage of data for both usage (Cited Package) and production (Citing Package) in the outside category was found to be low. Therefore, in most analyses "OG" (code 4), "WG" (code 3) and multidisciplinary are combined.

The All Other is given as a raw number in JCR. For the detailed indicator, steps 4-7 in the procedure would be used to break out all citation information for journals citing fewer than six times. The detailed information of the All Other line was determined, from a pilot test, to comprise for some journals, as much as 70% of the information.

Appendix F

Recoded JCR Subject Categories*

CATEGORY#	SUBJECTS INCLUDED
acoustics	telecommunications
agriculture	forestry
biochemistry	biophysics
biology	microbiology
chemistry	chemical engineering, electrochemistry, physical chemistry
education	educational psychology
engineering	aerospace engineering, energy, mechanics
hygiene/public health	food science, nursing, nutrition
interdisciplinary social science	area studies, communications, geography, history of science, information science, social medicine, social work
marine biology/ ocean science	atmospheric science, oceanography
mathematics	applied math
medical topicals	andrology, anesthesiology, dentistry, opthamology, psychiatry, radiology
microscopy/ spectroscopy	spectroscopy
physics	astronomy, nuclear science and technology

CATEGORY#	SUBJECTS INCLUDED
psychology	behavioral science
sociology	social issues
zoology	entomology, veterinary medicine

---

* excludes categories retained from the JCR, e.g., astronomy, ecology, statistics, and 23 others

\# expanding the category through recoding sometimes led to renaming it, e.g., medical topicals