

## PROJECT ADMINISTRATION DATA SHEET



ORIGINAL



REVISION NO. \_\_\_\_\_

Project No. Q43-623DATE: 7-30-81Project Director: D. E. Chubin

School/Dept

Social SciencesSponsor: National Science Foundation  
Washington, D.C. 20550Type Agreement: Grant No. SRS-8105666Award Period: From 7-1-81 To 12-31-82 (Performance) 3-31-83 (Reports)Sponsor Amount: \$ 74,385 6/30/83

Contracted through:

Cost Sharing: \$ 3,700 (Q43-325)

GTRI/ST

Title: Indicators of Interdisciplinary Research

## ADMINISTRATIVE DATA

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Reports: See Deliverable Schedule

Security Classification:

N/ADefense Priority Rating: N/A

## RESTRICTIONS

See Attached

NSF

Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of \$500 or 125% of approved proposal budget category.

Equipment: Title vests with

N/A - None Proposed

## COMMENTS:

Watch for Change later in patents Clause,  
per page 2 of Grant award.

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SPONSORED PROJECT TERMINATION SHEETDate 8/29/83

Project Title: Indicators of Interdisciplinary Research

Project No: G-43-623

Project Director: Daryl Chubin

Sponsor: National Science Foundation

Effective Termination Date: 6/30/83Clearance of Accounting Charges: 6/30/83

Grant/Contract Closeout Actions Remaining:

- ☐ Final Invoice and Closing Documents
- ☒ Final Fiscal Report (FCTR)
- ☒ Final Report of Inventions (Patent Questionnaire attached for Dr. Chubin)
- ☐ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other \_\_\_\_\_

NOTE: Subproject E-24-659/Porter also being terminated)

Assigned to: Social Sciences (School/~~Laboratory~~)COPIES TO:

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## INDICATORS OF INTERDISCIPLINARY RESEARCH

(NSF Grant No. SRS-8105666)

### 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

by a citing author. This author may be embedded in a particular research community, affiliated with a certain team of collaborators, or altogether isolated. We allow therefore that this citing author may have a range of ~~motivations for citing any paper, irrespective of its content.~~

Our citation approach simply aggregates the citations; the motivations for them remain unknown. Nevertheless, we would argue that an appropriate set of publications for exploring the presence and extent of IDR would be ISI's "citation classics." These are, by definition, extraordinary by the large number of citations they have received relative to others published in the same broad field. Since 1977, ISI has published a weekly classic in Current Contents (CC). In 1981, a separate classic appeared weekly in five broad scientific fields defined by CC: Physical, Chemical and Earth Sciences (PC&ES), Engineering, Technology and Applied Sciences (ET&AS), Life Sciences (LS), Social and Behavioral Sciences (S&BS), and Agriculture, Biology and Environmental Sciences (AB&ES).<sup>\*</sup> If the ~~(usually first) author consents to writing a short retrospective on the~~ highly cited publication, it becomes a "citation classic." Thus, an ~~author's refusal denies the publication "classic" status.~~ Those which do ~~appear in CC, however, are prefaced with a note that, according to the~~ SCI, the "paper [or book] has been cited" n times since its year of publication. The author then details subsequent work, reflects on the reasons for the publication's high citation rate, and in Garfield's (CC, 1 June 1981, p.5) words, presents "the human side of science . . . : what prompted the research, the contributions of coauthors, and obstacles that were encountered in both research and publication."

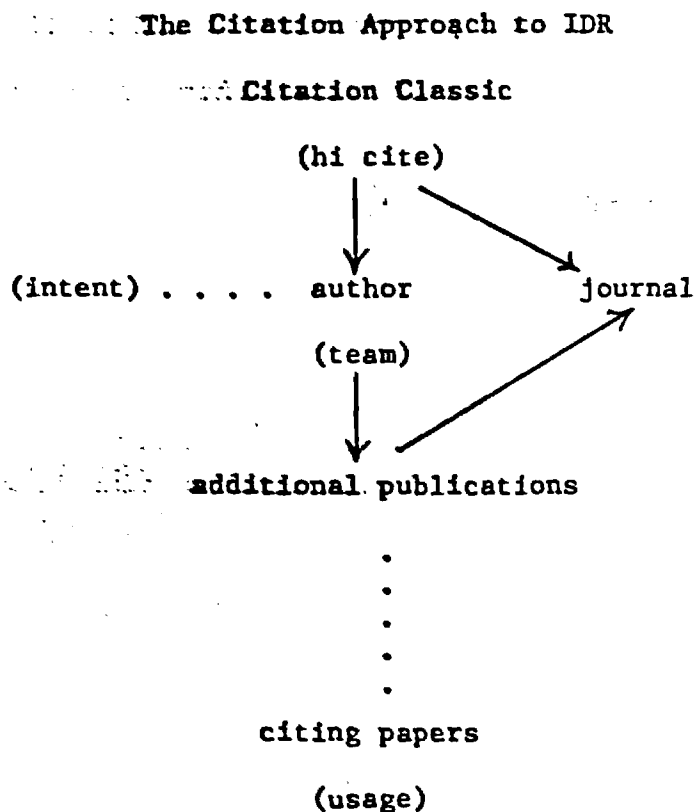
What we have, in short, is a peculiar population of publications which afford an opportunity to explore the incidence of IDR. As the algorithm

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<sup>\*</sup>We omitted CC Clinical Practice.

in Figure 1 shows, this approach may provide information on the author(s)'s

Figure 1



intent. By tracing the citations back to the journals in which they appeared and to the citing papers themselves, we could develop a sense of usage, i.e., why and how was the classic cited. Were the citing papers of a disciplinary or IDR variety? Was the classic (or additional related publications) used in "unintended" ways or by "untargeted" audiences? Such inferences can indeed follow from the data generated by the algorithm. These data contextualize the classic by reconstructing its origin in the author(s)'s research program as well as those of the citers. If fully exploited, the algorithm begins to reveal the process implicit in research products. What portion of both product and process is IDR is the immediate question.

## B. Analysis and Results

Restricting ourselves to 1981 classics,\* we randomly sampled each of the five CC so that the four project investigators could analyze independently the content of the classics. Table 1 shows the stratified random sample of classics assigned to investigators A-D. Approximately equal n's

Table 1

Stratified Random Sample (n's)  
of Citation Classics Assigned  
to Investigators A-D

| <u>CC source</u><br><u>of classic</u><br><u>investigator</u> | PC&ES | ET&AS | LS* | SEBS | AB&ES | Total |
|--|-------|-------|-----|------|-------|-------|
| A  | 12    | 12    | 23  | 11   | 13    | 71    |
| B  | 12    | 12    | 24  | 12   | 12    | 72    |
| C  | 12    | 11    | 24  | 12   | 12    | 71    |
| D  | 13    | 12    | 25  | 11   | 10    | 71    |
| Total  | 49    | 47    | 96  | 46   | 47    | 285   |

\*two classics per week are published in this CC

were sought. The form of the analysis, however, was to be determined by each investigator. This was agreed to be in keeping with the exploratory nature of the algorithm.

Predictably, the form for reporting the results also differs. Given that no a priori definition of IDR was employed, the results are at best heuristic and open to different interpretations. Let us summarize and offer some examples.

Table 2 summarizes the analysis of investigator A. Whereas the mean age of the citation classics hardly varies by broad field, their citation

\*We thank ISI's Director of Communications, Susan M. Deutsch for supplying us with copies of all "classics" we could not secure at Georgia Tech.

Table 2  
Age, Citation and IDR Characteristics  
of Investigator A's Sample

|       | Age      |          |             | Cite     |             | Cite/Year | IDR(u)            |                    |
|-------|----------|----------|-------------|----------|-------------|-----------|-------------------|--------------------|
|       | <u>n</u> | <u>X</u> | <u>S.D.</u> | <u>X</u> | <u>S.D.</u> | <u>X</u>  | <u>Production</u> | <u>Utilization</u> |
| PC&ES | 12       | 16       | 4           | 530      | 359         | 32.5      | --                | 5                  |
| ET&AS | 12       | 15       | 3           | 189      | 132         | 12.3      | 1                 | 3                  |
| LS    | 23       | 16       | 4           | 1496     | 3487        | 94.7      | 4                 | 4                  |
| S&BS  | 11       | 13       | 3           | 230      | 131         | 18.6      | 1                 | 1                  |
| AB&ES | 13       | 16       | 4           | 188      | 96          | 11.6      | 1                 | 2                  |

rates clearly do. Of greatest interest to us, however, are the last two columns on the right. There, Investigator A has distinguished 7 classics as IDR in their production (intent) and 15 in their utilization (usage). These 15 (21% of the sample) also represent the total number of classics judged as IDR. The 10% judged as IDR in intent typically involve collaborations in the life sciences, e.g., anatomy and biophysics, immunology and cell biology. Usage seems less science-specific, e.g., research on molecular orbitals involving chemistry and physics, on insulin structure combining chemistry and crystallography, and on sociobiological implications for ecology. Overall, A detects a small incidence of IDR among the classics.

Table 3  
Citation, IDR, and Process Information  
for Classics in Investigator B's Sample

|       | IDR Rating (1-5) |          | IDR Rated 5 (Hi) |          | IDR Rated 1 (Lo) |          | Process Info   |
|-------|------------------|----------|------------------|----------|------------------|----------|----------------|
|       | <u>n</u>         | <u>X</u> | <u>X Cite/Yr</u> | <u>n</u> | <u>X Cite/Yr</u> | <u>n</u> | <u>X (1-5)</u> |
| PC&ES | 12               | 1.9      | --               | --       | 17               | 6        | 3.6            |
| ET&AS | 12               | 3.1      | 13               | 3        | 8                | 1        | 4.4            |
| LS    | 24               | 3.1      | 37               | 1        | 57               | 6        | 4.3            |
| S&BS  | 12               | 2.1      | 11               | 1        | 18               | 5        | 3.0            |
| AB&ES | 12               | 2.4      | 10               | 3        | 12               | 2        | 3.6            |

Investigator B's approach was to rate each classic in his sample of 72 on a 1-5 scale of (lo-hi) IDR. Table 3 reports some of his findings. First, only 1 in 9 of his sample are convincingly IDR with the life sciences and engineering/applied sciences featuring the highest mean level of IDR content. Yet, for 4 of the 5 broad fields, the classics rated the lowest (1) in IDR have a higher mean citation rate than those rated the highest (5) in IDR. Second, in suggesting that IDR may be cited less than disciplinary research, B also notes that the authors of the highest IDR rated classics were located in non-academic labs (as opposed to academic departments). From the "process" information in Table 3 we know that the authors of classics, especially in LS and ET&AS, provided several insights into the production of IDR. A typical incentive for IDR collaboration is the ability of one area (scientist) to elucidate a need, and another to apply his or her disciplinary skills in fulfilling it. Often a specific technique is involved, to wit: the application of a formal structure in nuclear physics to quantum chemistry or the adaptation of a physical method to biological objects (today known as the discipline of biophysics). B cautions, and rightly so, that the evolution of sciences has created some inherently IDR areas such as ecology, systems engineering, and even biochemistry. Such convergences and consolidation of subject and technique serve to blur the intent-usage distinction. More important, perhaps, results of the citation approach recommend that our examination not end with the (editorial) classics, but extend to analysis of the classic (source) papers themselves.

Investigators C and D, who adopted a more qualitative approach to the classics, endorse the idea of resorting to primary source material for ascertaining dimensions of IDR. Neither was confident that examining classics warranted generalizations about IDR; they proffered two quotes



from classics authors for inclusion in this preliminary report:

Perhaps my review was cited because I tried to present a fundamental and comparative survey of a complex topic which is interesting to many scientists in different ways (AB&ES).

This convergence of scientific interests and several interdisciplinary symposia on the ascending reticular system may explain why the original paper was highly cited (LS).

### C. Prospects

One upshot of the citation approach is that "classics" appear to be fertile sites for testing various notions about how science is done and why certain papers, disciplines, authors, and journals attract the attention that eludes others. Classics, by definition, are extraordinary.

But high citation alone gives few clues as to why a paper is extraordinary.

"Why" becomes even more critical where IDR is involved. Like the citation

of a classic, the suspected IDR paper is an instance of extraordinary, statis-

tically deviant science. What are its origins, how was it supported and

by whom, who were its authors and how did their collaboration occur are

all questions that await probing as we pursue the citation approach. In-

deed, inherent in the algorithm of this approach is a "genetic-analogy"

that invites us to trace source papers both backwards and forwards.\*

Now that we have narrowed the number of citation classics that appear

to have some IDR content to 10-20% of this population, we plan to retrieve

those source papers and profile both their predecessors and their citing

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\* M.S. thesis research on the construction of an IDR journal or article indicator is underway, under the direction of Alan Porter, as a component of this project.

audiences. For we have yet to differentiate multi- from interdisciplinary research, and for that matter, the transfer of a technique or method--and the chronic over-citation of methods papers--from the creation of, say, a new technique derived from distinct disciplinary contributions. Finally, generalizations from classics to the general population of cited papers may, at best, be premature and, at worst, misleading.

## The Author Approach

### A. Rationale

The author approach centers on an algorithm designed to tap the "Dissertation Project" data base. Figure 2 depicts this algorithm. All data featured here, at least

Figure 2  
The Author Approach to IDR

Dissertation Project Authors  
(hi published sample)

(intent) ... number/title of  
journals published in

(usage) ... number/title of  
citing journals,  
(by paper)

demographic/work data:

- a. BS-Ph.D. field change
- b. dissertation subject area
- c. first post-Ph.D. work subject area
- d. first post-Ph.D. professional (self)-identification
- e. ninth-year post-Ph.D. work subject area
- f. ninth-year post-Ph.D. professional (self)-identification

at the outset, are already in hand. Recall that this sample of 645 authors was stratified by field of Ph.D.: physics, biochemistry, zoology, psychology, sociology, and electrical engineering.

### B. Results: Provisional and Anticipated

Some indication of the richness of this base resides in the following:

1. 461 (71.5%) of the authors have multi-authored more than 1 paper contained in our publication file;

2. 198 (30.7%) have published only multi-authored papers;

3. 4288 (77.7%) of the publications in our file are multi-authored.

Clearly, multi-authored papers are the dominant mode in the file.

~~Very few~~ of these are coauthored by scientists in our sample, i.e., the typical collaboration is between a member of our sample and one or more non-members. Furthermore, 252 (39.1%) of our sample are never cited. In general, "cites per person" are only modestly correlated with "percent multiauthored papers" (including .22 in zoology, -.19 in sociology, -.11 in physics, .14 in EE, and near zero in biochemistry and psychology). Our preliminary analysis also indicates that our measure of BS-Ph.D. "field shift" (derived from questionnaire responses to the NSF classification of research specialties) bears little relationship to percent multiauthored publications. Specializations in psychology--social, experimental, and clinical-- and inexplicably in zoology, hold some promise for elaborating this relationship.

The author approach allows for simultaneous analysis of author, journal, and citation characteristics. Measures of variability (number and title) in the latter two units will again prompt examination of primary sources. Linkages with the journal approach (described below) are obvious.

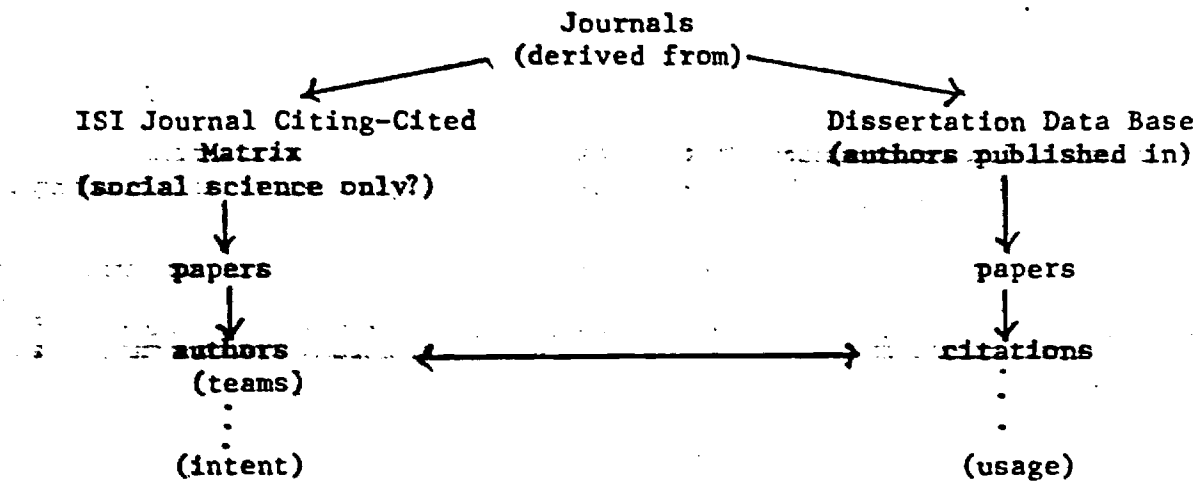
The importance of tracing IDR through authors is the opportunity to separate individual from team properties of the process/product, including the notion that IDR may be embodied in a single researcher. If so, how rare are these scientists? Are they found, either currently or at their intellectual origins, 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? Or conversely, is their work

unintentionally or circumstantially used more frequently in IDR efforts of other researchers? What, above all, are the most conducive circumstances? Superficially, it appears that IDR is more endemic to the life sciences (zoology and biochemistry in our author sample) than other broad fields. This is but one hypothesis that the author approach allows us to address.

### The Journal Approach

This approach is essentially a subset of the operations entailed in the other two, but it can be viewed as a separate algorithm plus data base (see Figure 3). We can readily define a pool of journals in two ways--

Figure 3  
The Journal Approach to IDR



from ISI data and from those published in by members of our Dissertation Project sample. Both sources define a set of journals in which IDR is more or less likely to be reported. Thus we seek to characterize journals by the research papers they publish.

This implies that journals are organic entities which cannot be "typed" for all time as, e.g., clinical or experimental. Rather, they will reflect the work that is submitted to them and deemed worthy of publication. The

criteria of "worth" may follow conscious editorial policy, e.g., JAMA, or "follow the field" as it gravitates toward certain problems and methods and away from others. Again, this suggests that certain specialties, disciplines, and broad fields may be more inherently IDR than others. Our approach here asks, "how do we know?" Are entire journals IDR or can they be characterized as such by degree? And is the proportion of IDR papers published in a certain journal stable or fluctuating over time?

As Figure 3 shows, the journal algorithm results in symmetrical author-citation analysis that attempts to specify the relationship between intent (references from) and usage (citations to authors) as displayed in serials. The journal remains the basic unit of analysis here; though its content is expected to vary over time. The aforementioned M.S. thesis research in progress should help to clarify the field location and extent of such variations.

Conclusions

It is, of course, evident that no conclusions can be drawn from our work to date. Rather, we have developed a blueprint for data collection and analysis of IDR. This analysis, distributed among the project investigators, will lead to a joint consideration of what the data mean and how each approach can be used to construct defensible indicators of IDR.

Our next progress report, projected for May, will be almost exclusively empirical. That is, we plan (a) to present an array of data developed according to each algorithm and (b) to describe both the findings and the difficulties in making inferences from them about IDR. Our provisional conceptualization of IDR as product and process, intent and usage, is now complete.

6-173-1023

**FINAL REPORT**

**INDICATORS OF INTERDISCIPLINARY RESEARCH**

**By**

**Daryl E. Chubin**

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**Prepared for**

**THE NATIONAL SCIENCE FOUNDATION**

**Division of Science Resources Studies**

**GRANT NO. SRS-810566**

**March 1983**

**GEORGIA INSTITUTE OF TECHNOLOGY**

**A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA  
TECHNOLOGY AND SCIENCE POLICY PROGRAM**

**SCHOOL OF SOCIAL SCIENCES**

**Atlanta, Georgia 30332**

1983



FINAL PROJECT REPORT  
NSF FORM 98A

PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING

PART I-PROJECT IDENTIFICATION INFORMATION

|   |  |  |
|---|--|--|
| 1. Institution and Address<br>Georgia Tech Research Institute<br>Administration Building<br>Atlanta, GA 30332 | 2. NSF Program<br>Science Resource Studies | 3. NSF Award Number<br>SRS-810566      |
|   | 4. Award Period<br>From 7/1/81 To 12/31/82 | 5. Cumulative Award Amount<br>\$74,385 |
| 6. Project Title<br>Indicators of Interdisciplinary Research  |  |  |

PART II-SUMMARY OF COMPLETED PROJECT (FOR PUBLIC USE)

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. 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 content as evidenced in reporting how the research was performed or how it was used (cited). The striking finding was that the 11 articles were extremely idiosyncratic with respect to the amount of cross-category citing (using ISI subject categories) and the pattern over time.

Our approach in developing a journal-based indicator was to propose a set of potential indicators drawing on Journal Citation Reports, then to validate these against a selected sample. The sample consisted of 2 journals in each of 10 ISI subject categories spanning Engineering, and the Physical, Life, and Social Sciences. We analyzed 383 articles published in 1979. A basic finding was that there are few "broad" cross-category citations; 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), an allied specialty, or a remote one. Cumulating results for each article to the journal level showed that none had more than 2 percent of the references cited to "remote" research. The most promising IDR production indicator was cross-categorical referencing which was validated both by judgment of article interdisciplinarity and the mean percentage of references cited by our sample articles falling outside the two most heavily cited categories.

We applied this indicator to three subject categories at two points in time and found remarkable stability. We urge further investigation into indicators based on the percentage of cross-categorical citation derived from ISI sources.

PART III-TECHNICAL INFORMATION (FOR PROGRAM MANAGEMENT USES)

| 1. ITEM (Check appropriate blocks)   | NONE | ATTACHED   | PREVIOUSLY FURNISHED | TO BE FURNISHED SEPARATELY TO PROGRAM |                    |
|--|------|--|----------------------|---------------------------------------|--------------------|
|  |      |  |                      | Check (✓)                             | Approx. Date       |
| a. Abstracts of Theses   |      |  |                      | X                                     | March 1983         |
| b. Publication Citations   | X    |  |                      |                                       |                    |
| c. Data on Scientific Collaborators  |      |  | X                    |                                       |                    |
| d. Information on Inventions   | X    |  |                      |                                       |                    |
| e. Technical Description of Project and Results                            |      | X  |                      |                                       |                    |
| f. Other (specify)   |      |  |                      |                                       |                    |
| 2. Principal Investigator/Project Director Name (Typed)<br>Daryl E. Chubin |      | 3. Principal Investigator/Project Director Signature<br><i>Daryl E. Chubin</i> |                      |                                       | 4. Date<br>3/11/83 |

FINAL REPORT

INDICATORS OF INTERDISCIPLINARY RESEARCH

Daryl E. Chubin  
Alan L. Porter  
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Terry Connolly

Technology and Science Policy Program  
School of Social Sciences  
and  
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March 1983

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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 interdisciplinaryity (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

### Table of Contents

|   |      |
|---|------|
| List of Tables . . . . .  | viii |
| List of Figures . . . . .   | x    |
| Introduction . . . . .  | 1    |
| I. Results of the Citation Approach . . . . .                               | 2    |
| A. Mode of Data Collection. . . . .   | 2    |
| B. Data and Analysis. . . . .   | 3    |
| II. Results of the Journal Approach. . . . .                                | 14   |
| A. Conceptualization. . . . .   | 14   |
| B. The Independent (Validator) Journal<br>Data Set . . . . .                | 15   |
| C. Indicator Validation . . . . .   | 17   |
| D. The Indicator Data . . . . .   | 24   |
| E. Another Approach to the Validation of<br>Indicators. . . . .             | 29   |
| F. An Application of the IDR Indicators . . . .                             | 35   |
| III. Conclusions and Prospects. . . . .                                     | 52   |
| A. Summary of Project Purposes and<br>Approaches. . . . .                   | 52   |
| B. Review of Findings . . . . .   | 53   |
| C. A Research Prospectus. . . . .   | 55   |
| References . . . . .  | 58   |
| Appendices  |      |
| A. Indicators of Interdisciplinary Research<br>(Interim Report, March 1982) |      |

- B. Sample Page from the JCR Used in Validation
- C. Inter-rater Coding Reliability
- D. Reference Categories and Codes for the  
Sample Journals Used in Production  
Validation
- E. Algorithm for Computing Journal Indicators
- F. Recoded JCR Subject Categories

## LIST OF TABLES

- |           |   |
|-----------|---|
| Table 1.  | Eleven Citation Classics: Authors, Annual SCI Citations, and CC Source Information                                    |
| Table 2.  | Ten-Year Citation Characteristics for Eleven Citation Classics  |
| Table 3.  | Definition of Journal Areas for Validation Data Set   |
| Table 4.  | Journals Selected for Validation, by Grand Category, Category/Subcategory, and Impact Factor                          |
| Table 5.  | Production Characteristics of Articles in Validation Data Set   |
| Table 6.  | Patterns of Disciplinary (D) - Interdisciplinary (I) Journal Rank   |
| Table 7.  | Usage Characteristics of Articles in Validation Data Set  |
| Table 8.  | Values for Production Indicators, by Category   |
| Table 9.  | Values for Usage Indicators, by Category  |
| Table 10. | Distribution for References by Subject Category, for 1980 Article Sample in Nineteen Journals                         |
| Table 11. | Correlation Matrix of Two Indicators (I) and Five Validators  |
| Table 12. | Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Eight Toxicology Journals, 1976    |
| Table 13. | Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Nineteen Toxicology Journals, 1982 |
| Table 14. | Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Thirteen Demography Journals, 1982 |
| Table 15. | Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Fifteen Demography Journals, 1982  |



- Table 16. Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Seven Operations Research/Management Science Journals, 1977
- Table 17. Raw JCR Citing and Cited Counts, and Corresponding Estimates (Lib p and Con p) for Seventeen Operations Research/Management Science Journals, 1982
- Table 18. Total and Mean Citing and Cited p Values for Three JCR Subject Categories at Two Points in Time
- Table 19. Summary of Journal Citing and Cited Proportions (Median Estimates That Differ by .20 for the Same Journal) in Three JCR Subject Categories at Two Points in Time

## LIST OF FIGURES

- Figure 1. Map Relating Number of Citing Categories and Categorical Concentration for Eleven Citation Classics
- Figure 2. Ten-Year Citation Histories for Three Life Sciences Classics
- Figure 3. Ten-Year Citation Histories for Three Physical, Chemical, & Earth Sciences Classics
- Figure 4. Ten-Year Citation Histories for Two Engineering, Technology, & Applied Sciences Classics
- Figure 5. Ten-Year Citation Histories for Two Agriculture, Biology, & Environmental Sciences Classics and One Social & Behavioral Sciences Classics
- Figure 6. Citation Histories for Three Citation Classics Published in 1969
- Figure 7. Scattergram of Nineteen Journals (AOUT2 x JOUT2)
- 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
- Figure 10. Median Proportion of Citations From Journals in Three JCR subject Categories to Journals Outside Those Three Categories, Conservative (C) and Liberal (L) Estimates in 1976/77 and 1982
- Figure 11. Median Proportion of Citations To Journals in Three JCR Subject Categories to Journals Outside Those Three Categories, Conservative (C) and Liberal (L) Estimates in 1976/77 and 1982

## 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

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

Table 1 (cont.)

|                             |   |    |    |    |    |    |    |    |    |    |                 |
|-----------------------------|---|----|----|----|----|----|----|----|----|----|-----------------|
| Edmiston/63<br>Rev Mod Phys | 5 | 13 | 14 | 21 | 16 | 19 | 16 | 32 | 33 | 31 | PC&ES/21,2 Mar  |
| Kneubuhl/60<br>J Chem Phys  | - | 24 | 21 | 26 | 30 | 1  | 26 | 27 | 25 | 27 | PC&ES/21,19 Jan |
| Barker/67<br>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 within its immediate subject area in years 7-9 of its life.



Table 2  
Ten-Year Citation Characteristics for Eleven Citation Classics

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

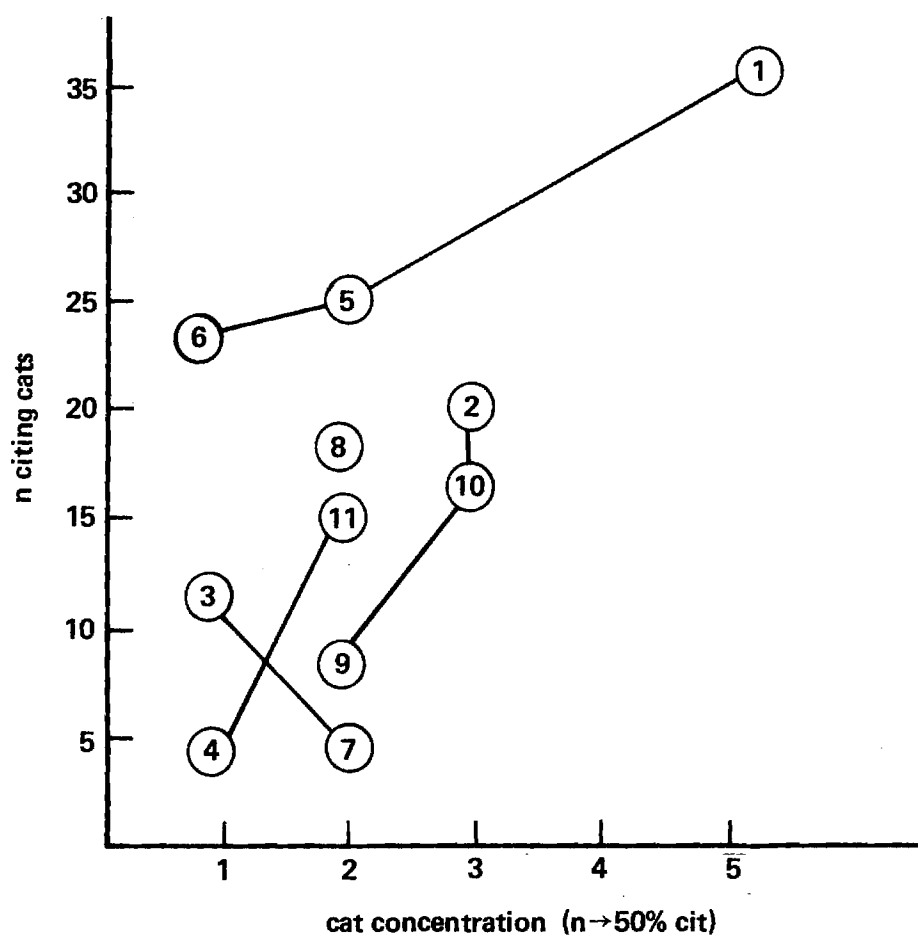
---

\*total or sample

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

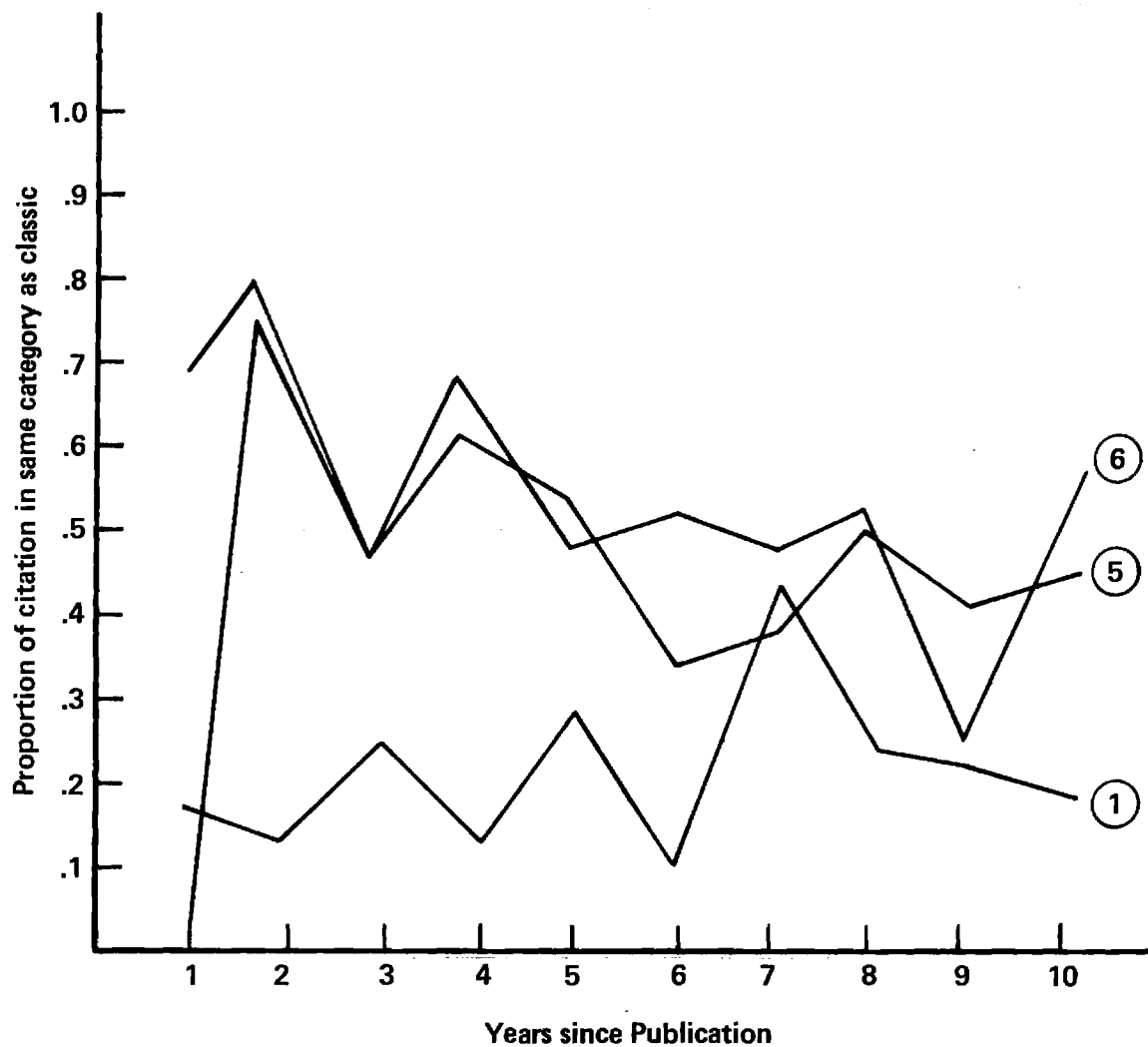
FIGURE 1

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



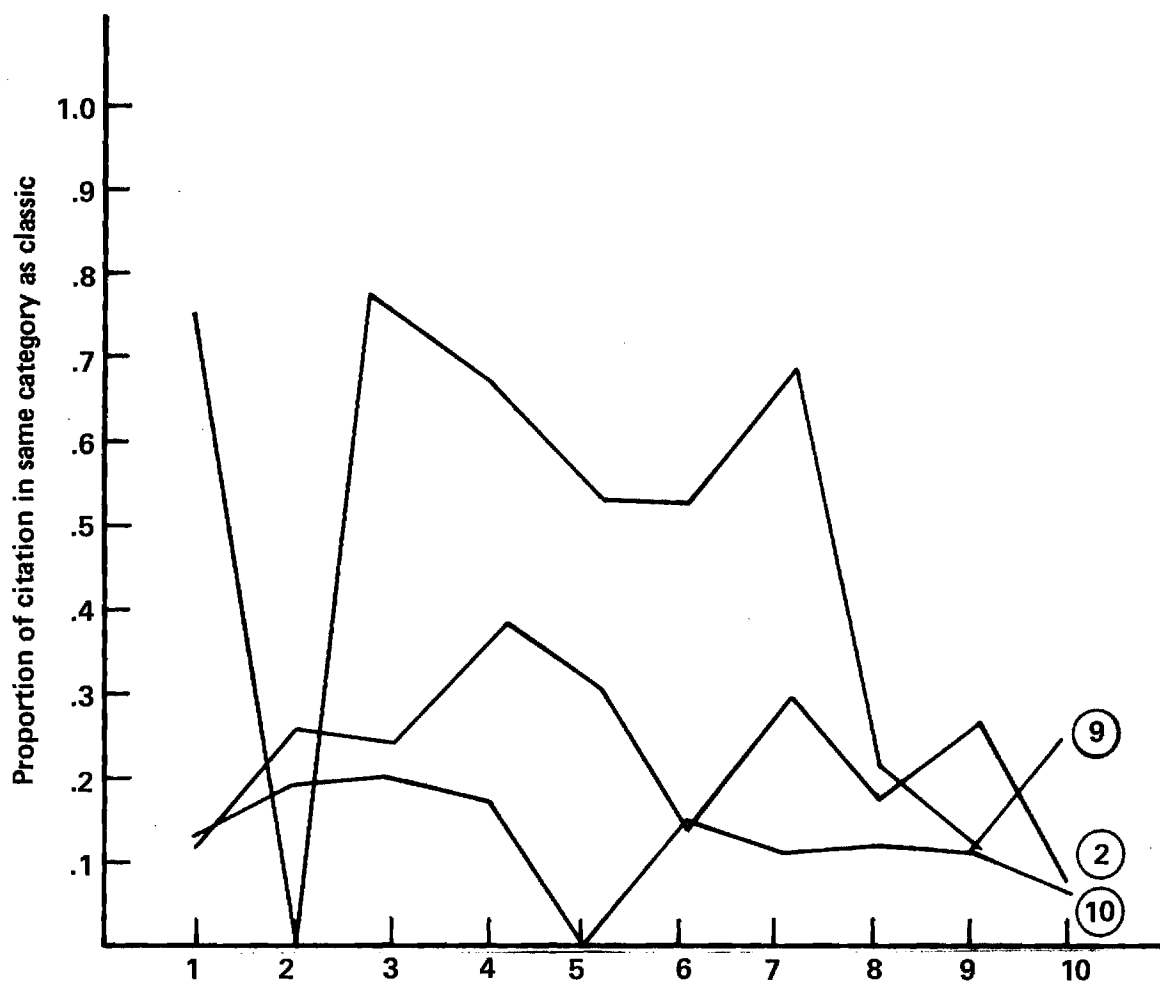
KEY: PC & ES 2, 9, 10  
 LS 1, 5, 6  
 ET & AS 4, 11  
 AB & ES 3, 7  
 S & BS 8

FIGURE 2  
TEN-YEAR CITATION HISTORIES FOR THREE  
LIFE SCIENCES CLASSICS\*



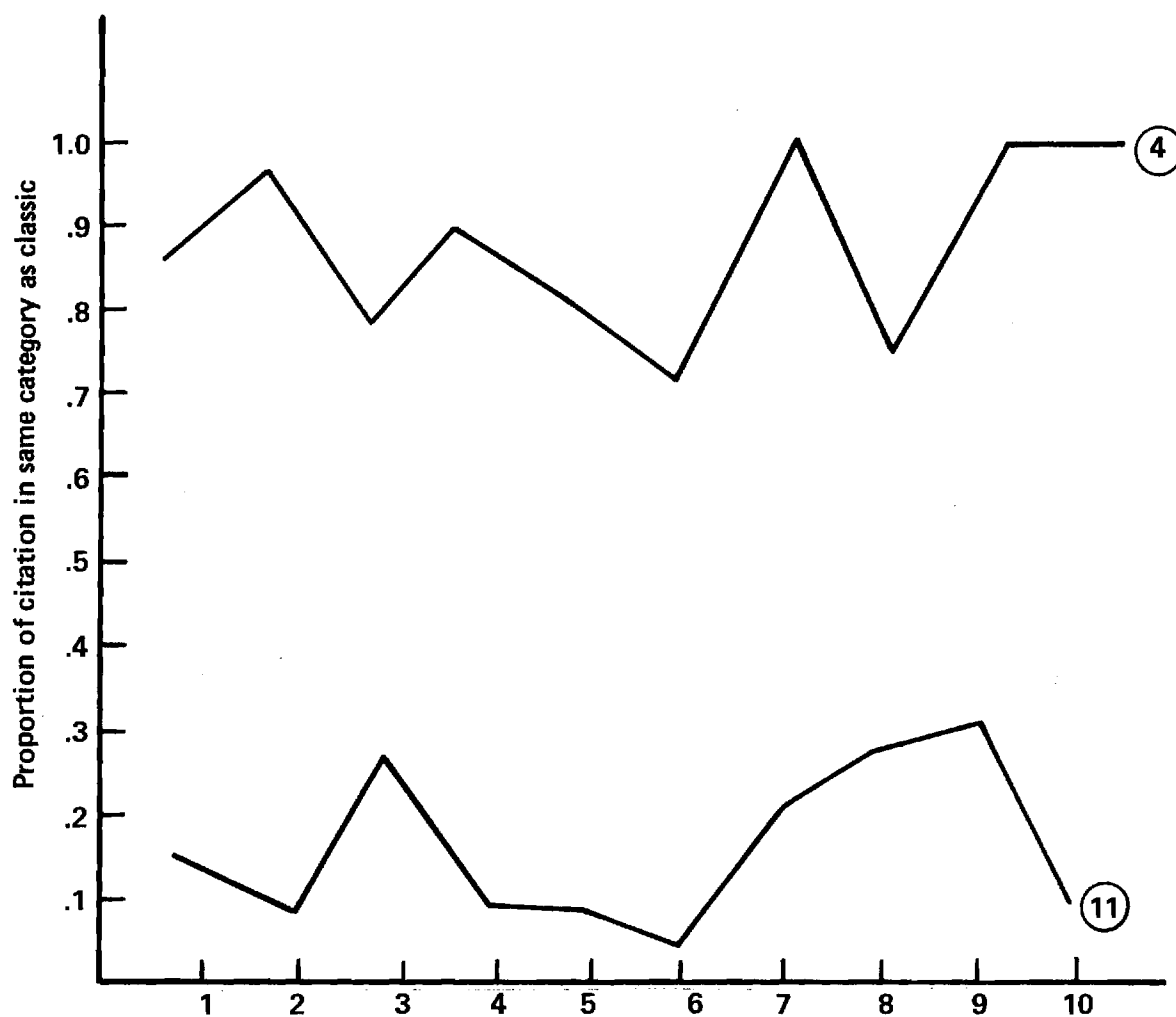
- \*  
① = 157 cit, 1963 (sample)  
⑤ = 201 cit, 1972  
⑥ = 250 cit, 1967 (sample)

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\*

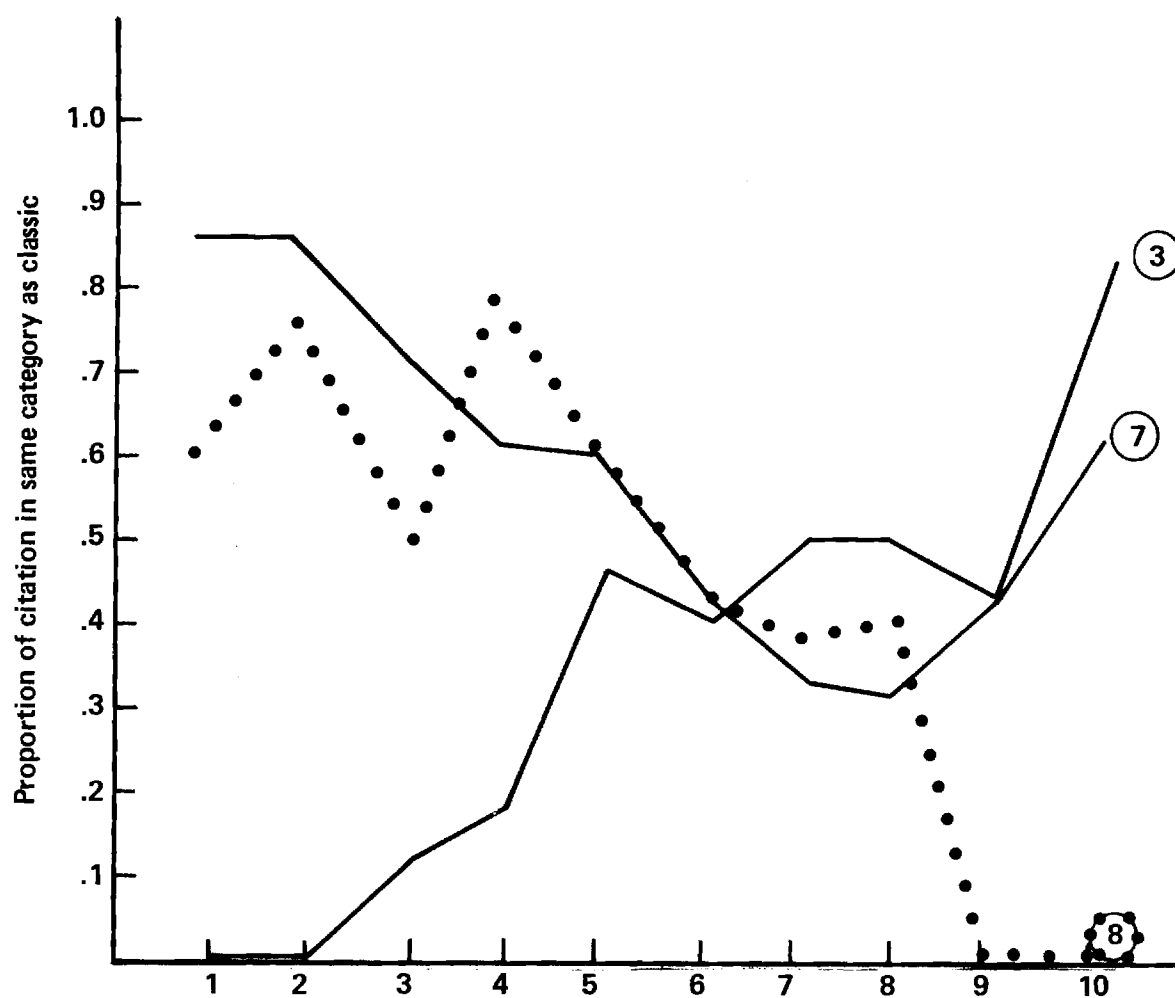


\* (4) = 79 cit, 1969

(11) = 258 cit, 1967

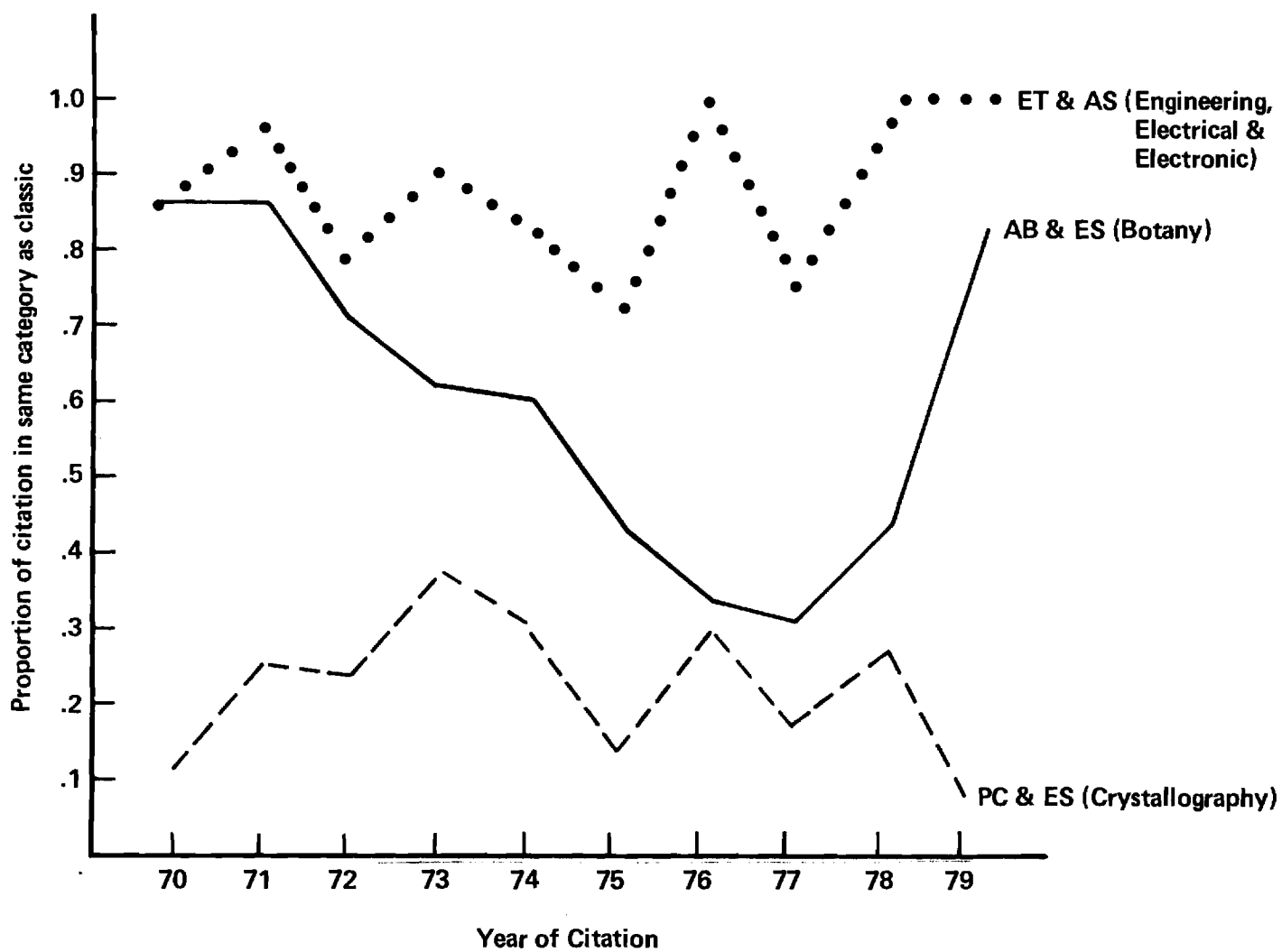
FIGURE 5

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 Journal Citation Report (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

| <u>grand category</u> | <u>category</u>           | <u>subcategory</u>          |
|-----------------------|---------------------------|-----------------------------|
| 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 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

| <u>grand category</u> | <u>category/<br/>subcategory</u> | <u>journal</u>                                      | <u>1980 impact<br/>factor (h/m)</u> |
|-----------------------|----------------------------------|---|-------------------------------------|
| Engineering           | Operations<br>Research           | <u>Management<br/>Science</u>                       | 0.69 h                              |
|                       |                                  | <u>Mathematical<br/>Programming</u>                 | 0.56 m                              |
|                       | Electrical<br>Engineering        | <u>IEEE Quantum<br/>Electronics</u>                 | 2.90 h                              |
|                       |                                  | <u>IEEE Transac-<br/>tions on Re-<br/>liability</u> | 0.41 m                              |
| Life Sciences         | Ecology                          | <u>Annual Review<br/>of Ecological<br/>Systems</u>  | 3.59 h                              |
|                       |                                  | <u>J. of Soil and<br/>Water Conser-<br/>vation</u>  | 0.34 m                              |
|                       | Anatomy                          | <u>American J. of<br/>Anatomy</u>                   | 1.59 m                              |
|                       |                                  | <u>Anatomical<br/>Record</u>                        | 2.56 h                              |
|                       | Toxicology                       | <u>CRC Critical<br/>Reviews in<br/>Toxicology</u>   | 3.63 h                              |
|                       |                                  | <u>Toxicology<br/>Letters</u>                       | 0.82 m                              |
| Physical Sciences     | Mathematical<br>Physics          | <u>J. of Mathemat-<br/>cal Physics</u>              | 1.15 h                              |
|                       |                                  | <u>Letters in<br/>Mathematical<br/>Physics</u>      | 0.76 m                              |
|                       | Crystallography*                 | <u>Progress in<br/>Crystal Growth</u>               | 1.62 h                              |

|                 |                          |   |        |
|-----------------|--------------------------|---|--------|
| Social Sciences | Computer Science         | <u>Computer Physics Communications</u>          | 1.21 h |
|                 |                          | <u>International J. of Biomedical Computing</u> | 0.45 m |
|                 | Demography               | <u>Population Studies</u>                       | 0.82 h |
|                 |                          | <u>J. of Biosocial Science</u>                  | 0.58 m |
|                 | Developmental Psychology | <u>J. of Experimental Child Psychology</u>      | 0.78 h |
|                 |                          | <u>International J. of Aging</u>                | 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. <u>CATEGORIES OF JOURNALS</u>   |             | <u>RANGE</u> | <u>NUMBER OF JOURNALS</u> |
|--|-------------|--------------|---------------------------|
| 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 |             |              |                           |
|  | <u>D</u>    | <u>I</u>     |                           |
|  | >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 than that 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<br>D or I | CITATIONS CODED* |         |         |         | JOURNAL SELF CITATIONS* |         |         |         | TOT SELF | TOT CIT | TOT 81 |
|--------------|----|---------------------|------------------|---------|---------|---------|-------------------------|---------|---------|---------|----------|---------|--------|
|              |    |                     | U0               | U1      | U2      | U3      | S0                      | S1      | S2      | S3      |          |         |        |
| 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<br>WITH COUNTS GREATER THAN<br>SIX, BY CATEGORY |      |      | PROPORTION OF CITATIONS<br>WITH COUNTS LESS THAN<br>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<br>COUNTS GREATER THAN OR<br>EQUAL TO SIX, BY CATEGORY |      |      | PROPORTION OF CITATION<br>COUNTS LESS THAN OR<br>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 not classified 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 two 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 Toxicology Letters and Annual Review of Ecological Systems reveal the greatest reference spread (105 and 83, respectively). Yet the largest SD's (fifth column) belong to J. Biosocial Science (3.23) and the other toxicology journal, CRC Critical Reviews (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<br>heaviest | % outside<br>2 <sup>nd</sup> heaviest | refs outside 2 cats<br>n / mean / SD | n (mean) cat<br>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)                 |
| 4 Int J of Biomedic Comp | 17        | 68                    | 53                                    | 46/ 2.30 / 2.30                      | 29 (1.45)                 |
| 5 Math Program           | 8         | 58                    | 20                                    | 26/ 1.30 / 2.16                      | 15 (0.75)                 |
| 6 Mgmt Sci               | 11        | 46                    | 33                                    | 42/ 2.10 / 2.32                      | 25 (1.25)                 |
| 7 Biosocial Sci          | 14        | 71                    | 49                                    | 63/ 3.15 / 3.23                      | 29 (1.45)                 |
| 8 Popul Stud             | 10        | 52                    | 27                                    | 20/ 1.00 / 1.62                      | 13 (0.65)                 |
| 9 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.

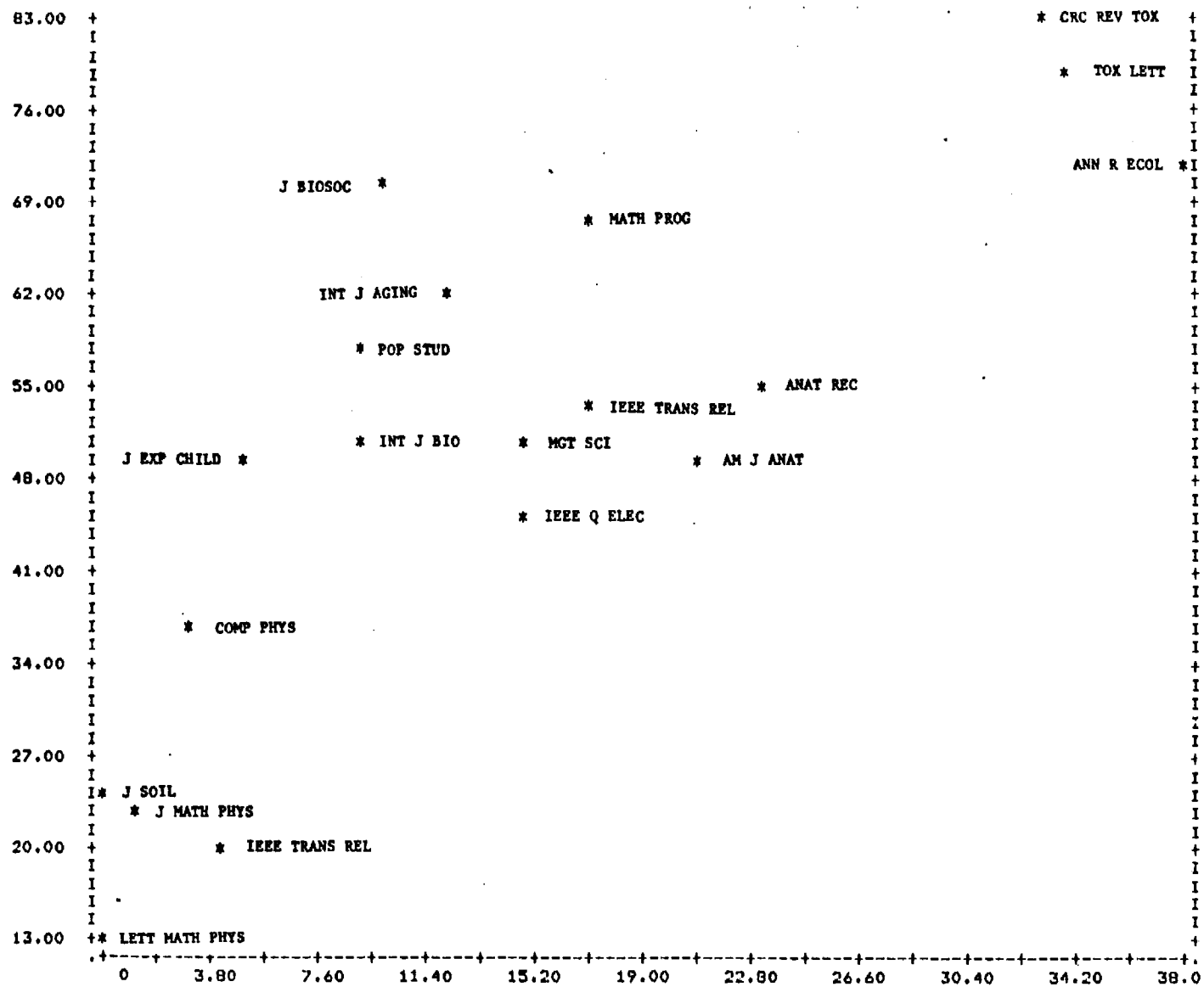


Figure 7

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 <sup>+</sup> | 1.00  |       |       |       |
| AOUT2   | .55**     | -.12              | .25              | .89** | 1.00  |       |       |
| REF23   | -.18      | -.34 <sup>+</sup> | -.17             | .00   | .04   | 1.00  |       |
| IMP80   | .11       | -.44*             | .03              | .41*  | .59** | .03   | 1.00  |

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<sup>+</sup> p=.10  
<sup>\*</sup> p=.05  
<sup>\*\*</sup> 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:

$$\text{Con } p = (\text{total citations} - n \text{ in-category} - n \text{ all others}) / (\text{total citations} - n \text{ all others}).$$

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

| Journal             | Citing               |              |       |                           |   | Cited                |              |       |       |       |
|---------------------|----------------------|--------------|-------|---------------------------|---|----------------------|--------------|-------|-------|-------|
|                     | Total in<br>Category | All<br>Other | Total | Lib p                     | Con p   | Total in<br>Category | All<br>Other | Total | Lib p | Con p |
|                     |                      |              |       | Total-<br>in cat<br>Total | Total-in-<br>All Other<br>Total-<br>All Other |                      |              |       |       |       |
| 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 ( $\pm 0.20$ ) 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

| Journal               | Citing               |              |       |                           |   | Cited                |              |       |       |       |
|-----------------------|----------------------|--------------|-------|---------------------------|---|----------------------|--------------|-------|-------|-------|
|                       | Total in<br>Category | All<br>Other | Total | Lib p                     | Con p   | Total-in<br>Category | All<br>Other | Total | Lib p | Con p |
|                       |                      |              |       | Total-<br>in cat<br>Total | Total-in-<br>All Other<br>Total-<br>All Other |                      |              |       |       |       |
| 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 ( $\pm .20$ ) 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

KEY: X = Lib p  
O = Con p  
1 = Ann Rev Pharm  
4 = Tox Appl Pharm  
5 = Arch Tox  
6 = Food Cosmet Tox  
8 = Toxicology  
10 = Toxicon  
17 = Clin Tox  
18 = Farmakol Toks

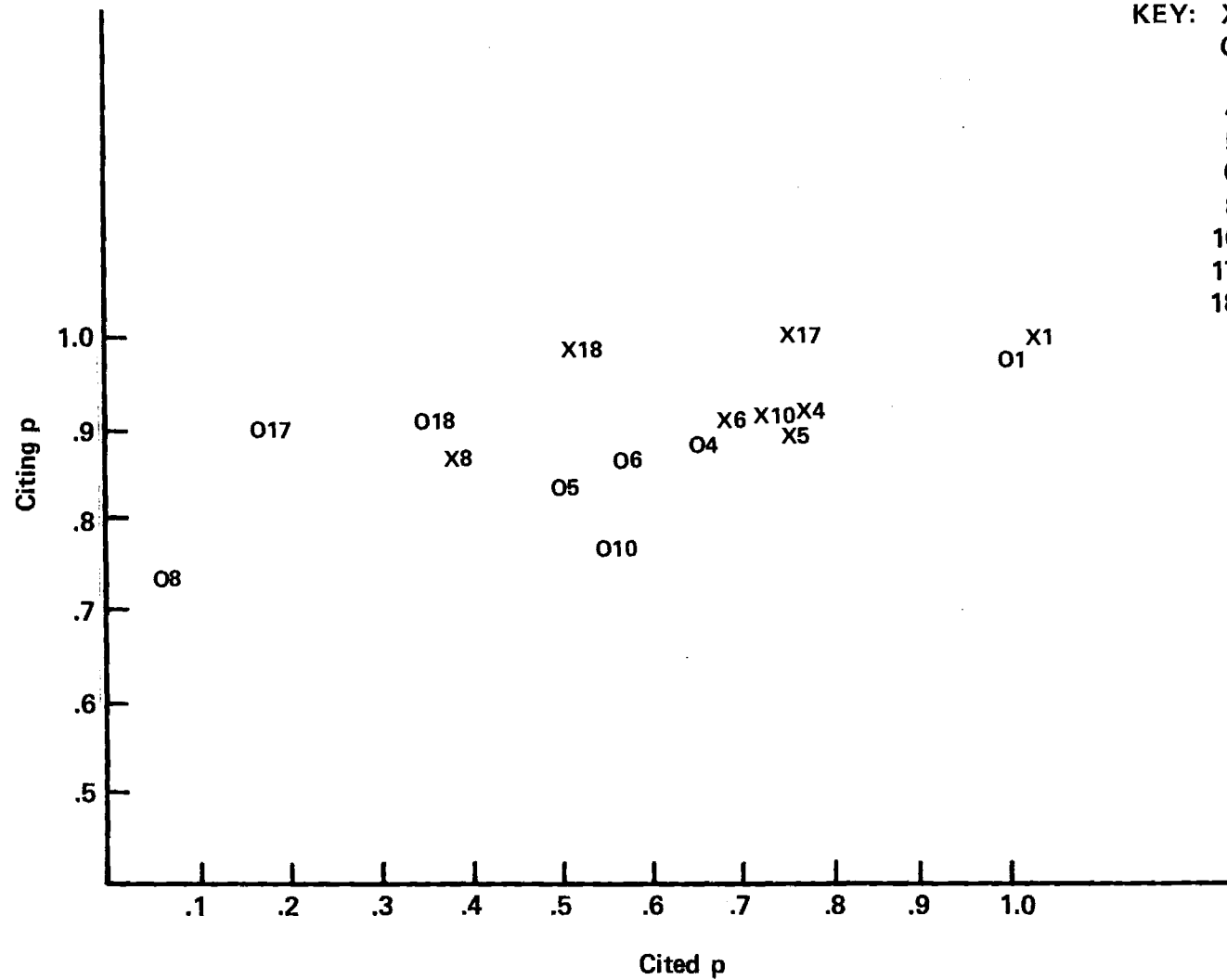


FIGURE 9  
SCATTERGRAM OF CITING AND CITED p VALUES  
FOR EIGHT TOXICOLOGY JOURNALS, 1982

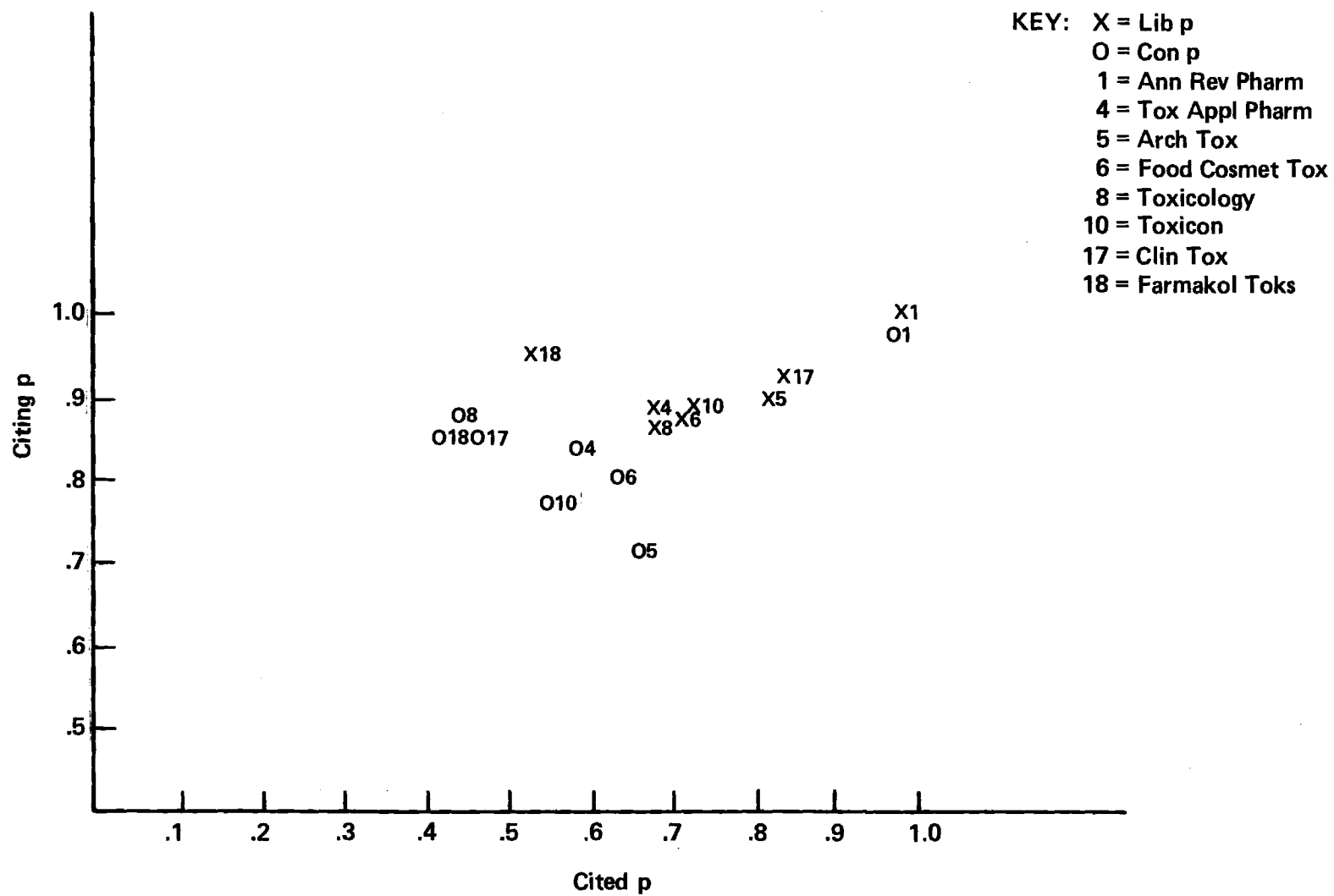


TABLE 14

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

| Journal              | Citing               |              |       |                                    |  | Cited                |              |       |       |       |
|----------------------|----------------------|--------------|-------|------------------------------------|--|----------------------|--------------|-------|-------|-------|
|                      | Total in<br>Category | All<br>Other | Total | Lib p<br>Total-<br>in cat<br>Total | Con p<br>Total-in-<br>All Other<br>Total-<br>All Other | Total-in<br>Category | All<br>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 ( $\pm .20$ ) 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<br>Category | All<br>Other | Total | Lib p<br>Total-<br>in cat<br>Total | Con p<br>Total-in-<br>All Other<br>Total-<br>All Other | Total-in<br>Category | All<br>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 ( $\pm .20$ ) 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               |              |       |                           |   | Cited                |              |       |       |       |
|----------------------|----------------------|--------------|-------|---------------------------|---|----------------------|--------------|-------|-------|-------|
|                      | Total in<br>Category | All<br>Other | Total | Lib p                     | Con p   | Total-in<br>Category | All<br>Other | Total | Lib p | Con p |
|                      |                      |              |       | Total-<br>in cat<br>Total | Total-in-<br>All Other<br>Total-<br>All Other |                      |              |       |       |       |
| 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

| Journal               | Citing               |              |       |                                    |  | Cited                |              |       |       |       |
|-----------------------|----------------------|--------------|-------|------------------------------------|--|----------------------|--------------|-------|-------|-------|
|                       | Total in<br>Category | All<br>Other | Total | Lib p<br>Total-<br>in cat<br>Total | Con p<br>Total-in-<br>All Other<br>Total-<br>All Other | Total-in<br>Category | All<br>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 ( $\pm .20$ ) 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<br>Category | All<br>Other | Total | Lib p                     | Con p   | Total-in-<br>Category | All<br>Other | Total | Lib p | Con p |
|                         |                      |              |       | Total-<br>in cat<br>Total | Total-in-<br>All Other<br>Total-<br>All Other |                       |              |       |       |       |
| 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)<sup>#</sup>  
 in Three JCR Subject Categories at Two Points in Time

| Year:      | 1976/77       |              |                | 1982          |              |                |
|------------|---------------|--------------|----------------|---------------|--------------|----------------|
|            | <u>citing</u> | <u>cited</u> | <u>journal</u> | <u>citing</u> | <u>cited</u> | <u>journal</u> |
| Area:      |               |              |                |               |              |                |
| Toxicology | 0             | 3            | 8              | 0             | 5            | 9              |
| Demography | 12            | 4            | 13             | 6             | 3            | 15             |
| OR/MS      | 6             | 1            | 7              | 12            | 1            | 17             |

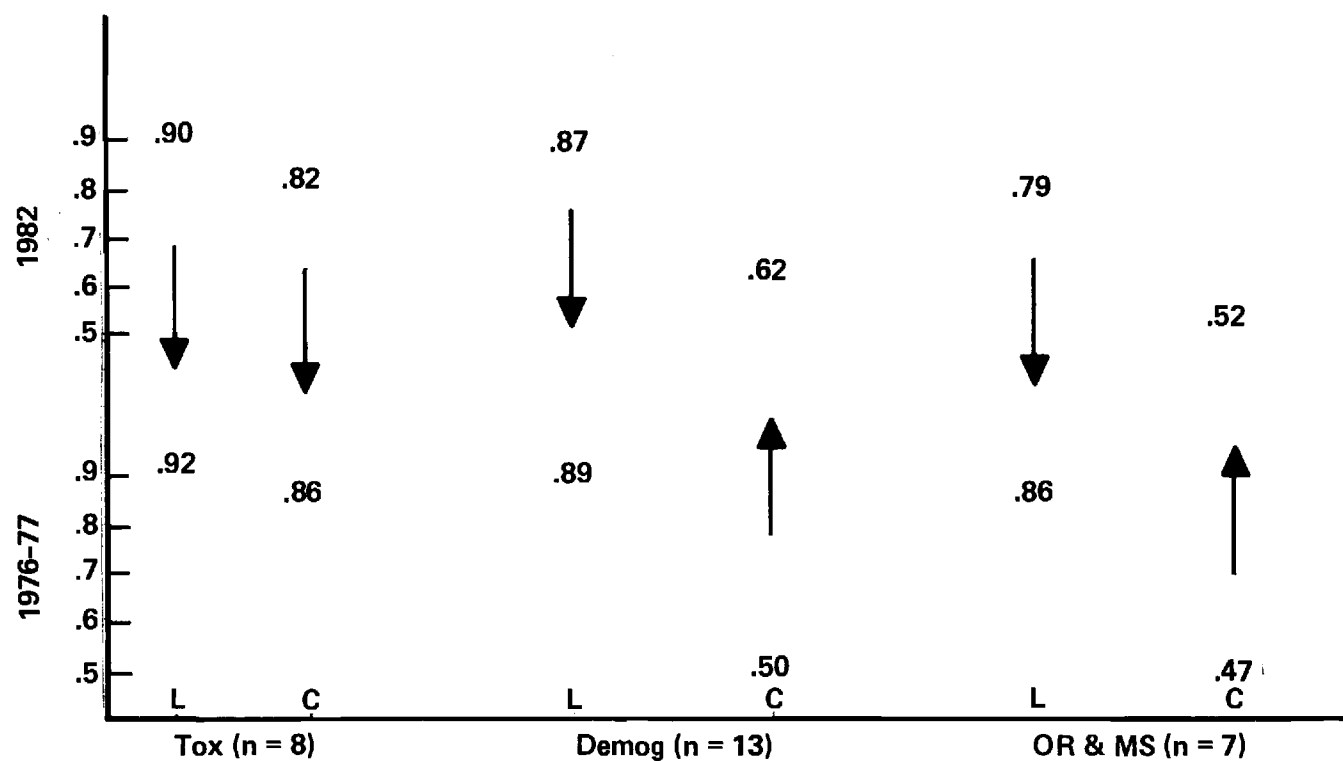
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\*Lib p and Con p

<sup>#</sup> see Tables 12 - 17 and text for full explanation

FIGURE 10

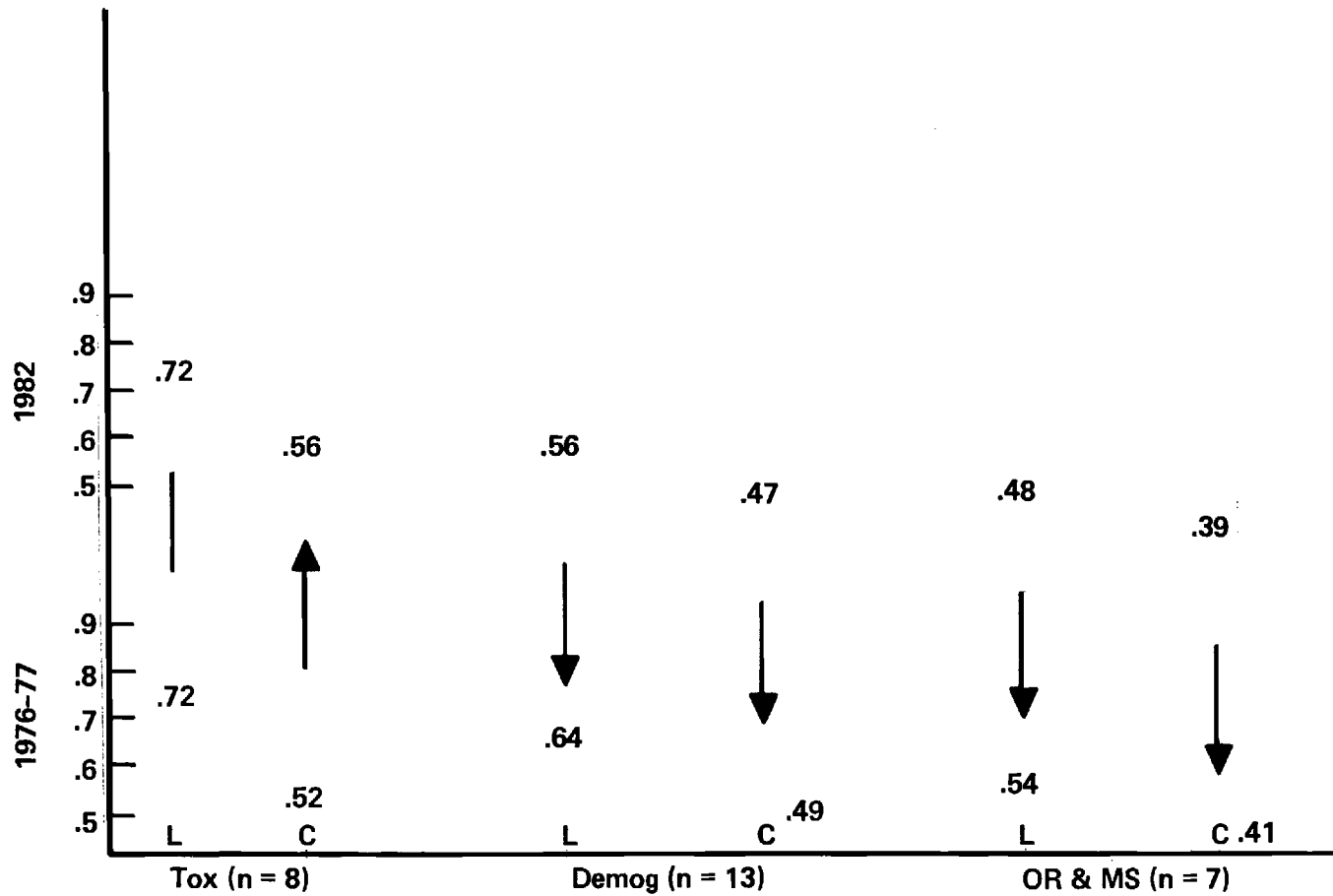
MEDIAN PROPORTION OF CITING BY JOURNALS IN THREE JCR SUBJECT CATEGORIES TO JOURNALS OUTSIDE THOSE SAME CATEGORIES, CONSERVATIVE (C) AND LIBERAL (L) ESTIMATES IN 1976-77 AND 1982 \*



\*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 vary 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.

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## 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

## 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

### SCI JOURNAL CITATION REPORTS

#### CITING JOURNAL PACKAGE

| CITING JOURNAL<br>CITED JOURNAL     |                       | TOTAL |    | NUMBER OF<br>1979 1978 |     | TIMES<br>1977 1976 |     | THIS YEAR WAS CITED IN<br>1976 1975 |     | 1974 | 1973 | 1980-<br>1972 | 1971 | REST |
|-------------------------------------|-----------------------|-------|----|------------------------|-----|--------------------|-----|-------------------------------------|-----|------|------|---------------|------|------|
| .63 J AM SOC HORTIC SCI (CONTINUED) |                       |       |    |                        |     |                    |     |                                     |     |      |      |               |      |      |
| 77                                  | SCI                   | 29    | 0  | 0                      | 0   | 1                  | 0   | 2                                   | 0   | 0    | 0    | 1             | 0    | 23   |
| 5 70                                | ANN BOT-LONDON        | 27    | 0  | 1                      | 3   | 2                  | 0   | 0                                   | 0   | 1    | 0    | 2             | 4    | 20   |
| 92                                  | FLOR REV              | 26    | 0  | 0                      | 2   | 0                  | 1   | 1                                   | 10  | 7    | 3    | 1             | 1    | 17   |
| 93                                  | CAN J BOT             | 25    | 0  | 0                      | 3   | 0                  | 1   | 3                                   | 1   | 4    | 0    | 2             | 2    | 17   |
| 1 60                                | EUPHYTICA             | 24    | 0  | 0                      | 1   | 0                  | 1   | 1                                   | 1   | 1    | 1    | 1             | 1    | 17   |
| 40                                  | J EXP BOT             | 24    | 0  | 2                      | 3   | 1                  | 1   | 1                                   | 2   | 6    | 4    | 3             | 3    | 17   |
| 34                                  | CAN J PLANT SCI       | 23    | 0  | 1                      | 1   | 3                  | 1   | 1                                   | 1   | 0    | 3    | 2             | 3    | 17   |
| 1 10                                | T ASAE                | 22    | 0  | 0                      | 2   | 1                  | 3   | 4                                   | 2   | 2    | 0    | 1             | 1    | 17   |
| 1 06                                | PLAGR FOOD CHEM       | 20    | 0  | 0                      | 3   | 0                  | 1   | 1                                   | 0   | 0    | 0    | 0             | 0    | 17   |
| 80                                  | SOIL SCI SOC AM J     | 18    | 0  | 0                      | 0   | 1                  | 2   | 2                                   | 2   | 1    | 1    | 2             | 2    | 14   |
| 98                                  | J SCI FOOD AGR        | 18    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 18   |
| 65                                  | SOIL SCI              | 17    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 17   |
|                                     | AM POTATO J           | 17    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 17   |
|                                     | J AGR RES             | 17    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 17   |
| 2 20                                | ACTA HORTIC           | 16    | 0  | 0                      | 0   | 3                  | 1   | 3                                   | 1   | 2    | 0    | 0             | 0    | 10   |
| 1 29                                | ANAL BIOCHEM          | 16    | 0  | 0                      | 1   | 2                  | 0   | 0                                   | 0   | 1    | 0    | 0             | 0    | 12   |
| 01                                  | PHYTOCHEMISTRY        | 16    | 0  | 0                      | 1   | 2                  | 0   | 1                                   | 1   | 2    | 2    | 1             | 1    | 12   |
|                                     | CITRUS IND            | 15    | 0  | 0                      | 1   | 1                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 15   |
| 60                                  | COLO FLOWER GROWERS   | 15    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 15   |
| 75                                  | J ECON ENTOMOL        | 15    | 0  | 0                      | 3   | 2                  | 1   | 2                                   | 0   | 0    | 0    | 0             | 0    | 12   |
| 69                                  | AUST BIOL SCI         | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 14   |
|                                     | J HERED               | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 14   |
| 8 77                                | PRINCIPLES PROCEDURE  | 13    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 13   |
| 1 11                                | P NATL ACAD SCI USA   | 12    | 1  | 3                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 10   |
| 72                                  | PLANT CELL PHYSIOL    | 12    | 0  | 0                      | 3   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 12   |
| 36                                  | PLANT PHYSIOL LANC    | 12    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 12   |
| 84                                  | ANN APP BIOL          | 11    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 11   |
| 91                                  | COMMUN SOIL SCI PLAN  | 11    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 11   |
| 1 52                                | J AGR SCI             | 11    | 0  | 1                      | 1   | 2                  | 1   | 1                                   | 1   | 0    | 0    | 0             | 0    | 8    |
| 2 57                                | J FOOD SCI            | 11    | 0  | 0                      | 1   | 1                  | 1   | 1                                   | 1   | 2    | 0    | 0             | 0    | 8    |
| 1 32                                | SCI HORTIC-ENGLAND    | 11    | 0  | 0                      | 0   | 1                  | 1   | 1                                   | 1   | 2    | 0    | 0             | 0    | 8    |
| 2 41                                | ANNU REV PHYTOPATHOL  | 10    | 0  | 1                      | 0   | 1                  | 1   | 1                                   | 1   | 1    | 1    | 1             | 1    | 7    |
| 1 49                                | CITRUS IND MAG        | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 10   |
| 51                                  | GENETICS              | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 10   |
|                                     | PLANT SOIL            | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 10   |
| 64                                  | AM NURSERYMAN         | 9     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 9    |
| 5 71                                | CONTRIB BOYCE THOMPS  | 9     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 9    |
| 1 41                                | CONTRIB BOYCE THOMPS  | 9     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 9    |
| 1 42                                | J BIOL CHEM           | 9     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 9    |
| 3 33                                | PLANT SCI LETT        | 8     | 0  | 1                      | 1   | 3                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 5    |
| 1 02                                | ADV AGRON             | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 26                                  | ANAL CHEM             | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 35                                  | BOY REV               | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 56                                  | CAN J GENET CYTOL     | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 04                                  | GARTENBAUWISSENSCHAFT | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 2 10                                | HILGARDIA             | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 1 32                                | WASH STATE HORT       | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 40                                  | STAIN TECHNOL         | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 7    |
| 90                                  | ARKANSAS FARM RES     | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
| 1 11                                | AUST J PLANT PHYSIOL  | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
| 1 32                                | BIOMETRICS            | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | BIOMETRICS            | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | FRUIT VAR HORT DIG    | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | MICRONUTRIENTS AGRIC  | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | OFFICIAL METHODS ANA  | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | PLANT SOC CITRICULTU  | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    | 6    |
|                                     | STAT METHODS          | 6     | 0  | 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             | 0    | 6    |
|                                     | ALL OTHER (1058)      | 1438  | 10 | 31                     | 84  | 0                  | 80  | 82                                  | 82  | 93   | 89   | 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   | 4                                   | 4   | 0    | 1    | 1             | 7    |      |
| 1 31                                | COMMUN ACM            | 19    | 0  | 0                      | 6   | 3                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 1 60                                | ONLINE                | 14    | 0  | 4                      | 3   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J LIBR AUTOMAT        | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | AM DOC                | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 40                                  | ANNU REV INFORM SCI   | 10    | 0  | 0                      | 3   | 3                  | 1   | 1                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | IEEE SOFTWARE ENG     | 10    | 0  | 0                      | 1   | 1                  | 1   | 2                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | INFORM PROCESSI       | 10    | 0  | 0                      | 1   | 3                  | 3   | 2                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | AM PSYCHOL            | 8     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | INFORM STORAGE RETR   | 8     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | LIBR J                | 8     | 0  | 1                      | 0   | 0                  | 1   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 5 70                                | SCIENCE               | 8     | 0  | 1                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 90                                  | J AM SOC INFORM INF   | 7     | 0  | 3                      | 3   | 3                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 1 11                                | J CHEM INF COMP SCI   | 6     | 0  | 1                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J OOC                 | 6     | 0  | 0                      | 0   | 0                  | 1   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | ALL OTHER (438)       | 572   | 19 | 59                     | 81  | 80                 | 59  | 30                                  | 33  | 26   | 23   | 19            | 134  |      |
| .72 J AM STAT ASSOC                 |                       | 2174  | 22 | 127                    | 191 | 188                | 149 | 145                                 | 115 | 110  | 84   | 109           | 926  |      |
| 72                                  | J AM STAT ASSOC       | 281   | 2  | 13                     | 21  | 29                 | 23  | 22                                  | 26  | 16   | 13   | 15            | 94   |      |
| 83                                  | BIOMETRIKA            | 139   | 0  | 4                      | 4   | 9                  | 11  | 11                                  | 11  | 4    | 3    | 15            | 40   |      |
|                                     | ANN MATH STAT         | 129   | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 76                                  | TECHNOMETRICS         | 64    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 98                                  | J ROY STAT SOC B MET  | 64    | 1  | 3                      | 3   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 88                                  | ANN STAT              | 61    | 2  | 4                      | 13  | 14                 | 3   | 8                                   | 4   | 10   | 0    | 0             | 0    |      |
| 1 22                                | BIOMETRICS            | 46    | 0  | 2                      | 1   | 2                  | 2   | 2                                   | 2   | 2    | 4    | 3             | 28   |      |
|                                     | ECONOMETRICA          | 43    | 1  | 3                      | 6   | 4                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 70                                  | AM STAT               | 15    | 1  | 0                      | 2   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | LINEAR STAT INFER     | 15    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | ANNALS MATHEMATICAL   | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | APPL STAT             | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | COMMUNICATIONS STA A  | 14    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 1 31                                | COMMUN ACM            | 12    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | REP LSAC SPONSOR      | 12    | 1  | 2                      | 0   | 0                  | 1   | 1                                   | 1   | 2    | 0    | 0             | 0    |      |
|                                     | AM J SOCIOL           | 11    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | BUS                   | 11    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | SANKHYA SER A         | 11    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | INTRO PROBABILITY TH  | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J STAT COMPUT SIM     | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | AM STAT ASSOC         | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | STAT METHODS          | 10    | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | INTRO MULTIVARIATE S  | 9     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | EXPLORATORY DATA ANA  | 8     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J FINANC QUANT ANAL   | 8     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 81                                  | J ROY STAT SOC A GEN  | 8     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | ADV THEORY STAT       | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | INT ECON REV          | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
| 47                                  | INT STAT REV          | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J ECONOMETRICS        | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | J ROY STAT SOC        | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | REV ECON STAT         | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | OTH P BERK S MATH ST  | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | ROBUST ESTIMATES LOC  | 7     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | STAT DISTRIBU         | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | STUD BAYESIAN ECO     | 6     | 0  | 0                      | 0   | 0                  | 0   | 0                                   | 0   | 0    | 0    | 0             | 0    |      |
|                                     | ALL OTHER (761)       | 1056  | 11 | 86                     | 114 | 95                 | 83  | 66                                  | 43  | 51   | 26   | 52            | 425  |      |

## Description

Citing journals (journals indexed by *SCI*<sup>®</sup> 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*<sup>®</sup>, *SSCI*<sup>®</sup> and *A&HCI*<sup>™</sup> 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 IST's current awareness services, *Current Contents*<sup>®</sup>/*Clinical Practice*, *Current Contents/Agriculture, Biology & Environmental Sciences* and *Current Contents/Engineering, Technology & Applied Sciences*. References from these *CC*<sup>®</sup>/*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*<sup>™</sup> 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

### SCI JOURNAL CITATION REPORTS

| CITED JOURNAL  |                        | CITED JOURNAL PACKAGE |      |      |      |      |              |                  |      |      |      | 1980-1971 |     | REST |
|----------------|------------------------|-----------------------|------|------|------|------|--------------|------------------|------|------|------|-----------|-----|------|
| CITING JOURNAL |                        | TOTAL                 | 1980 | 1979 | 1978 | 1977 | THIS<br>1976 | YEAR WAS<br>1975 | 1974 | 1973 | 1972 | 1971      |     |      |
| 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              | FOUND PHYS             | 40                    | 0    | 4    | 3    | 2    | 1            | 5                | 2    | 2    | 4    | 6         | 11  |      |
| 2              | J MATH PHYS            | 20                    | 0    | 1    | 2    | 2    | 1            | 1                | 0    | 0    | 0    | 0         | 11  |      |
| 2              | PHYS REV B             | 16                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 11  |      |
| 2              | PHYS REV D             | 16                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 11  |      |
| 3              | IEEE T EDUC            | 15                    | 0    | 1    | 0    | 0    | 3            | 2                | 1    | 1    | 1    | 1         | 5   |      |
| 3              | J CHEM PHYS            | 13                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 7   |      |
| 1              | PHYS LETT A            | 12                    | 0    | 0    | 1    | 1    | 1            | 0                | 0    | 0    | 0    | 0         | 3   |      |
| 2              | PHYS REV A             | 12                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 3   |      |
| 3              | J CHEM EDUC            | 11                    | 0    | 0    | 0    | 0    | 2            | 0                | 1    | 2    | 4    | 0         | 1   |      |
| 1              | J MOL SPECTROSC        | 11                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 11  |      |
| 1              | LETT NUOVO CIMENTO     | 11                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 7   |      |
| 1              | J APPL PHYS            | 10                    | 0    | 0    | 0    | 1    | 2            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 7              | J PHYS C SOLID STATE   | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 2              | COMPUT EDUC            | 9                     | 0    | 0    | 0    | 1    | 1            | 1                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | APPL OPTICS            | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ISRAEL J CHEM          | 8                     | 0    | 0    | 1    | 1    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | PHYS STATUS SOLIDI B   | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 7              | NUOVO CIMENTO B        | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 3              | PHILOS SCI             | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 3              | SURFACE SCI            | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 7              | PHYS REP               | 6                     | 0    | 0    | 0    | 1    | 1            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | PROG THEOR PHYS        | 6                     | 0    | 1    | 2    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ALL OTHER (211)        | 366                   | 0    | 24   | 23   | 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        | 399 |      |
| 1.05           | AM J PHYS ANTHROPOL    | 448                   | 11   | 37   | 54   | 45   | 32           | 19               | 26   | 24   | 23   | 17        | 160 |      |
| 1              | J HUM EVOL             | 84                    | 0    | 1    | 14   | 7    | 6            | 6                | 3    | 4    | 0    | 0         | 29  |      |
| 1              | ANN REV ANTHROPOL      | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | NUM BIOL               | 58                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ANN HUM BIOL           | 46                    | 0    | 1    | 6    | 4    | 3            | 2                | 3    | 3    | 3    | 3         | 17  |      |
| 1              | CURR ANTHROPOL         | 35                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 5              | SCIENCE                | 34                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM J ORTHOD            | 32                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J ANTHROPOL SOC NIP    | 31                    | 1    | 2    | 3    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | FOLIA PRIMATOL         | 28                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 3              | ANGLE ORTHOD           | 23                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ACTA ANAT              | 21                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | HUM HERED              | 19                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J MED PRIMATOL         | 19                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J MEM SOC ANTHRO PAR   | 16                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | LAB ANIM SCI           | 14                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J DENT RES             | 13                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | MAKING QUART           | 13                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ACTA MORPHOL NEER SC   | 12                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | COLLEGIUM ANTHROPOL    | 12                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J ANAT                 | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM J CLIN NUTR         | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | NATURE                 | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | TERATOLOGY             | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM J HUM GENET         | 9                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM NAT                 | 9                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ANTHROPOLOGIE          | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | INDIAN J MED RES       | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J MAMMAL               | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ADV PRIMATOL           | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM ZOOL                | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ANIM BEHAV             | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | CLEFT PALATE J         | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J MORPHOL              | 7                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ANN HUM GENET          | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AUST DENT J            | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | BEHAVIOUR              | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | DEV PSYCHOBIOL         | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | EXP EYE RES            | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J MENT DEFIC RES       | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J PROSTHET DENT        | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | NOUVEAU REV FR HEMATOL | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ZOOL ANZ               | 6                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ALL OTHER (186)        | 322                   | 0    | 1    | 2    | 18   | 19           | 21               | 23   | 4    | 18   | 14        | 128 |      |
| 50             | AM J PHYS MED          | 208                   | 4    | 4    | 12   | 11   | 5            | 12               | 4    | 8    | 12   | 13        | 123 |      |
| 1              | AM J ANAT              | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM J PHYS MED          | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ARCH PHYS MED REHAB    | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | MED BIOL ENG COMPUT    | 9                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | RES Q EXERCISE SPORT   | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 2              | RAIN                   | 8                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | RADIAT ENVIRON BIOPH   | 3                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | SCAND J REHABIL MED    | 3                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | AM REV RESPIR DIS      | 3                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ANN SCI                | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ELECTROEN CLIN NEURO   | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | EUR J APPL PHYSIOL O   | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J NEUROPHYSIOL         | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | MED SCI SPORTS         | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | NEUROBEHAV TOXICOL     | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ALL OTHER (88)         | 118                   | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 86             | CALPHAD                | 86                    | 7    | 17   | 21   | 40   | 0            | 0                | 0    | 0    | 0    | 0         | 1   |      |
| 1              | CALPHAD                | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | Z METALLUR             | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ATOM ENERGY REV        | 4                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | METAL TRANS B          | 3                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ACTA MET               | 3                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J CHEM PHYS            | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J ELECTROCHEM SOC      | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | J LESS-COMMON MET      | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | METAL TRANS A          | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | PHYS REV B             | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | SOLID STATE PHYS       | 2                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | CHEM LISTY             | 1                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | CHEM PHYS LETT         | 1                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | GEOPHYS COSMOCHIM AC   | 1                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | HIGH TEMP SCI          | 1                     | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |
| 1              | ALL OTHER (10)         | 10                    | 0    | 0    | 0    | 0    | 0            | 0                | 0    | 0    | 0    | 0         | 0   |      |



## 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 - CRC TOXICOLOGY

2 - TOXICOLOGY LETTERS

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 - ANN REVIEW OF ECOLOGY

2 - J SOIL WATER

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 - J MATH PHYSICS

2 - LETTERS IN MATH PHYSICS

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 - COMPUTER PHYSICS COMMUNICATIONS

2 - INT. J. OF BIOMEDICAL COMPUTER

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 - J APPLIED CRYSTALLOGRAPHY

2 - PROGRESS IN CRYSTAL GROWTH

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 - POPULATION STUDIES

2 - J BIOSOC SCI

WS = Demography

WC = Statistics

Biometrics

Social Research

WG = All other categories in Social Sciences

1 - MANAG SCI

2 - MATH PROG

WS = OR

WS<sub>1</sub> = Management Sciences

WC<sub>1</sub> = Behavioral Sciences

Business

Applied Psychology

Computer Sciences

Economics

Transportation

Statistics

WC<sub>2</sub> = 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.

$$WS = \text{journal(s) } y / \text{Grand total}$$

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:

$$WC = \text{journal(s) } y / \text{Grand Total}$$

- 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).

$$WG = \text{journal(s) } y (WG - WC) / \text{Grand Total}$$

- 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,<br>electrochemistry,<br>physical chemistry   |
| education                           | educational psychology   |
| engineering                         | aerospace engineering,<br>energy, mechanics  |
| hygiene/public health               | food science, nursing,<br>nutrition  |
| interdisciplinary<br>social science | area studies, communica-<br>tions, geography, his-<br>tory of science, infor-<br>mation science, social<br>medicine, social work |
| marine biology/<br>ocean science    | atmospheric science,<br>oceanography   |
| mathematics                         | applied math   |
| medical topicals                    | andrology, anesthesiol-<br>ogy, dentistry, optha-<br>mology, psychiatry,<br>radiology  |
| microscopy/<br>spectroscopy         | spectroscopy   |
| physics                             | astronomy, nuclear sci-<br>ence and technology   |

| CATEGORY#  | SUBJECTS INCLUDED                  |
|------------|------------------------------------|
| psychology | behavioral science                 |
| sociology  | social issues                      |
| zoology    | entomology, veterinary<br>medicine |

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\*

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

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