

# *Measuring the Interdisciplinarity of a Body of Research*

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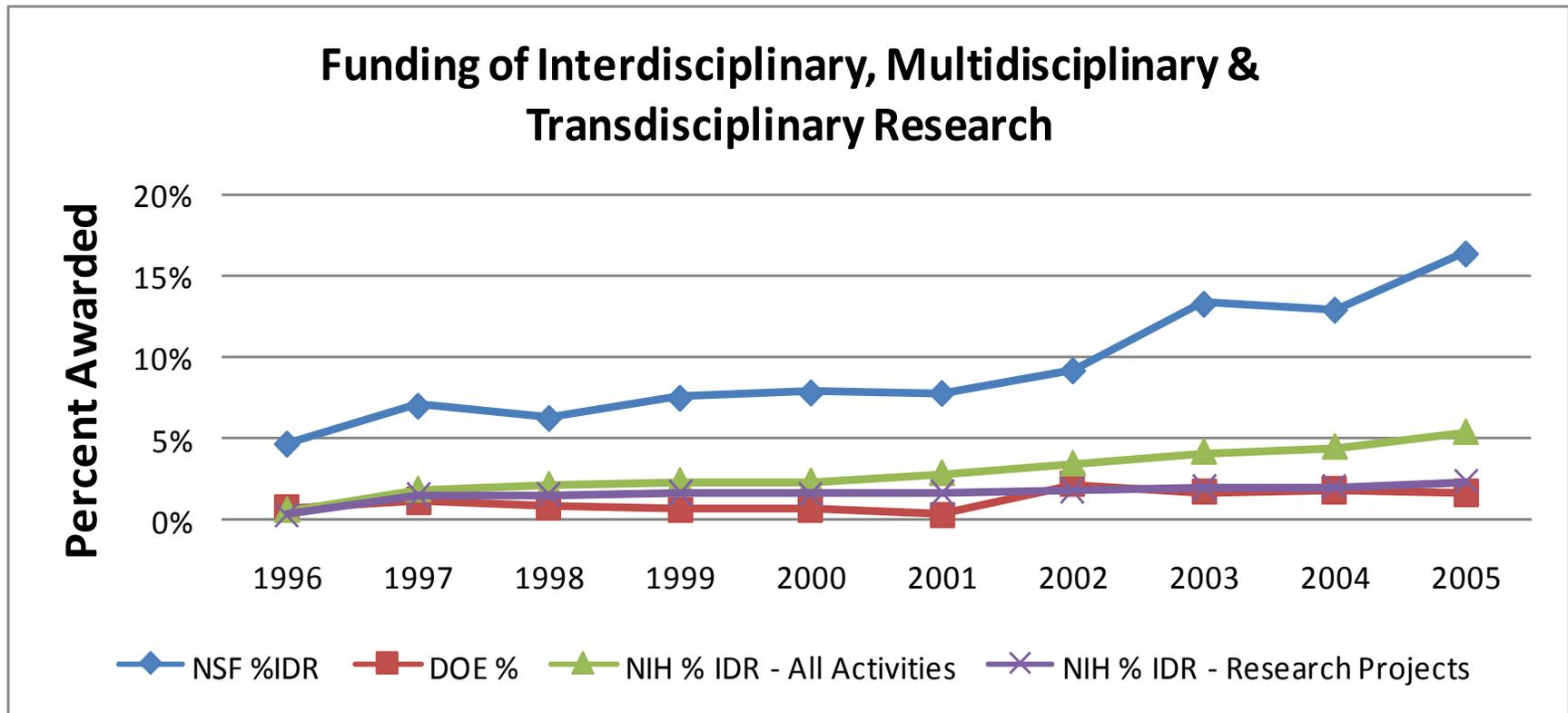
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# Evidence of considerable and growing interest in fostering interdisciplinary research

- ▶ **Research leaders assert that major advances in science are more likely to occur at the interstices of the traditional disciplines** (*Keck Foundation Annual Report, 1999*)
- ▶ **Federal research agencies are increasing their support of interdisciplinary support** (*NSF, DOE, NIH awards databases*)
- ▶ **NIH Roadmap includes initiatives that recognize the importance of interdisciplinary research for future advances in biomedical research** (<http://nihroadmap.nih.gov/>)
- ▶ **NSF's Nanoscale Interdisciplinary Research Teams program requires each funded project to have at least three co-PIs**
- ▶ **National Academies Keck *Futures Initiative*, 15-year, \$40 M project to foster interdisciplinary research**  
([www.keckfutures.org](http://www.keckfutures.org))

# IDR Funding Data from NSF, DOE & NIH

*For the period 1996-2005, support for IDR is increasing strongly*



**So...**

**Identifying where, how and whether interdisciplinary research occurs and could be fostered is critical**

- ▶ **if major advances in S&E are to occur more rapidly than otherwise, and**
- ▶ **If efforts to foster interdisciplinarity in research are to be evaluated accurately.**

**But...**

- ▶ **There is no agreed-upon operational definition of interdisciplinary research, nor are there widely recognized valid and reliable measures of interdisciplinary activity or output.**

## Some nagging questions about defining and measuring “interdisciplinarity:”

- ▶ **Need collaborators be *bona fide* co-researchers for their work to be IDR? For instance, if a statistician on a research team performs statistical analyses in a support role, is this IDR?**
- ▶ **Should IDR be distinguished from multidisciplinary research For instance, if collaborators from different fields in an organized research unit work largely separately on parts of a study, is this IDR?**

- ▶ **Expanding the notion of IDR beyond academia, would one consider collaboration among basic researchers, design engineers, and marketing specialists “IDR”?**
- ▶ **Should IDR include single researchers who integrate multiple fields of knowledge?**
- ▶ **Some argue that collaboration between theoretically inclined and applied researchers in the same field should be considered IDR because of the difficult integration entailed. Differences in conceptual foundations and methods within a “field” may indeed be extreme – consider the challenges in having two psychologists -- a Freudian clinical psychologist working with a neuroscientist -- collaborate.**

**Definition developed by the National Academies Keck *Futures Initiative*:**

**Interdisciplinary research (IDR) is a mode of research by teams or individuals that *integrates***

- **perspectives/concepts/theories and/or**
- **tools/techniques and/or**
- **information/data**

**from two or more bodies of specialized knowledge or research practice. Its purpose is to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single field of research practice.**

**Examples of *bodies of specialized knowledge or research practice* include: low temperature physics, molecular biology, developmental psychology, toxicology, operations research, and fluid mechanics.**

What does integration of knowledge from multiple fields really mean?

*“Conceptual integration can be viewed as a cognitive process or as an outcome of the learning process. As a cognitive process, conceptual integration is a background, perhaps even sub-conscious mental process, which enables one to make meaning from differing concepts that, on the surface, have no readily apparent connection or commonality. Two concepts are integrated into a third concept that contains some properties of both original concepts, but not all of the properties of the two original concepts. Commonalities of the two original concepts provide the basis for an emerging concept that is different from either of the two original concepts. The literature refers to the concepts as mental spaces, and the conceptual integration as the blending of the spaces.”*

“Conceptual Integration in Online Interdisciplinary Study: Current Perspective, Theories, and Implications for Future Research” James L. Morrison, University of Oklahoma

**Most approaches take research outputs (papers, patents) and measure interdisciplinarity in terms of the co-occurrence of discipline-specific items, e.g., keywords, classification headings, authors' affiliations, citations.**

- ▶ **Co-word analysis counts co-occurrence of discipline-specific keywords for papers (chosen by authors or journal editors).**
- ▶ **Co-classification analysis counts co-occurrences of discipline-specific headings (assigned by information managers).**
- ▶ **Co-author analysis counts co-occurrences of the disciplinary affiliations of co-authors (department, degree).**
- ▶ **Citation analysis counts citations between papers of different disciplines as links between these disciplines (assumes that you can assign each cited paper to a single discipline).**

**Another approach, ours, classifies papers on the basis of the interdisciplinarity of the journals in which they are published.**

- ▶ **Currently, Thompson-ISI classifies journals covered by the World of Knowledge into 245 Subject Categories (SC) based on citation patterns and editorial judgments.**
- ▶ **We measure the interdisciplinarity of papers by the disciplinary “span” or range of journals cited in each paper.**

**Integration (I)** measures the *extent of diversity* among a paper's cited Web of Knowledge Subject Categories;

**Specialization (S)** measures the spread of Subject Categories in which the body of research is published.

| Specialization/Integration | Lo             | Hi                                |
|----------------------------|----------------|-----------------------------------|
| Hi                         | Disciplinarian | Single Interdiscipline Specialist |
| Lo                         | Grazer         | Renaissance Integrator            |

Porter, Cohen, Roessner, and Perreault, "Measuring Researcher Interdisciplinarity," *Scientometrics*, Vol. 72, No. 1 (2007) 117–147

## **Integration:**

**This measure examines the spread of references by a given paper to gauge the degree of integration across “bodies of specialized knowledge or research practice” thereby reflected (by the span of Subject Categories cited).**

- 1. Retrieve the given paper’s abstract record from Web of Science. This lists each of its cited references. Most references are to journal articles, and those are the only ones we analyze**
- 2. For the paper itself, and for each of the paper’s references, identify the journal in which it appeared.**

# Integration Continued

- 3. VantagePoint text-mining software is used in these analyses [[www.theVantagePoint.com](http://www.theVantagePoint.com)]. A special import filter extracts journal title from each cited reference field in the abstract record downloaded from Web of Science.**
- 4. Match that journal to its respective Subject Category.**
- 5. Create a matrix of Cited SCs by Cited SCs, for the paper.**
- 6. Calculate Integration (“I”) from this matrix.**

## Integration Formula:

$$I = 1 - \left[ \frac{\left[ \sum (f_i \times f_j \times \cos(SC_i - SC_j)) \right]}{\sum (f_i \times f_j)} \right]$$

where  $i = \text{row}$ ;  $j = \text{column}$ ;  $f = \text{frequency}$

“ $\cos (SC_i - SC_j)$ ” is the cosine measure of association between the two SCs, based on a national co-citation sample from Web of Science. It reflects the relative tendency of two particular SCs to be co-cited. (One can think of cosine as closely related to correlation.)

## Examples from extreme cases:

1. If a paper cites 20 references (all to journals indexed by WOS), and all were associated with journals in the same SC,  $I = 0$ .
2. If a paper cites just 2 references, each one associated with only a single SC but these SCs are never co-cited together, then  $\cos = 0$ , the numerator is 0, and  $I = 1$ .

## Specialization:

**Calculation of  $S$  uses the information on the SCs in which a researcher's publications appear. Note that  $S$  does not use cited SC information at all; hence it is measured independently of  $I$ . The process is:**

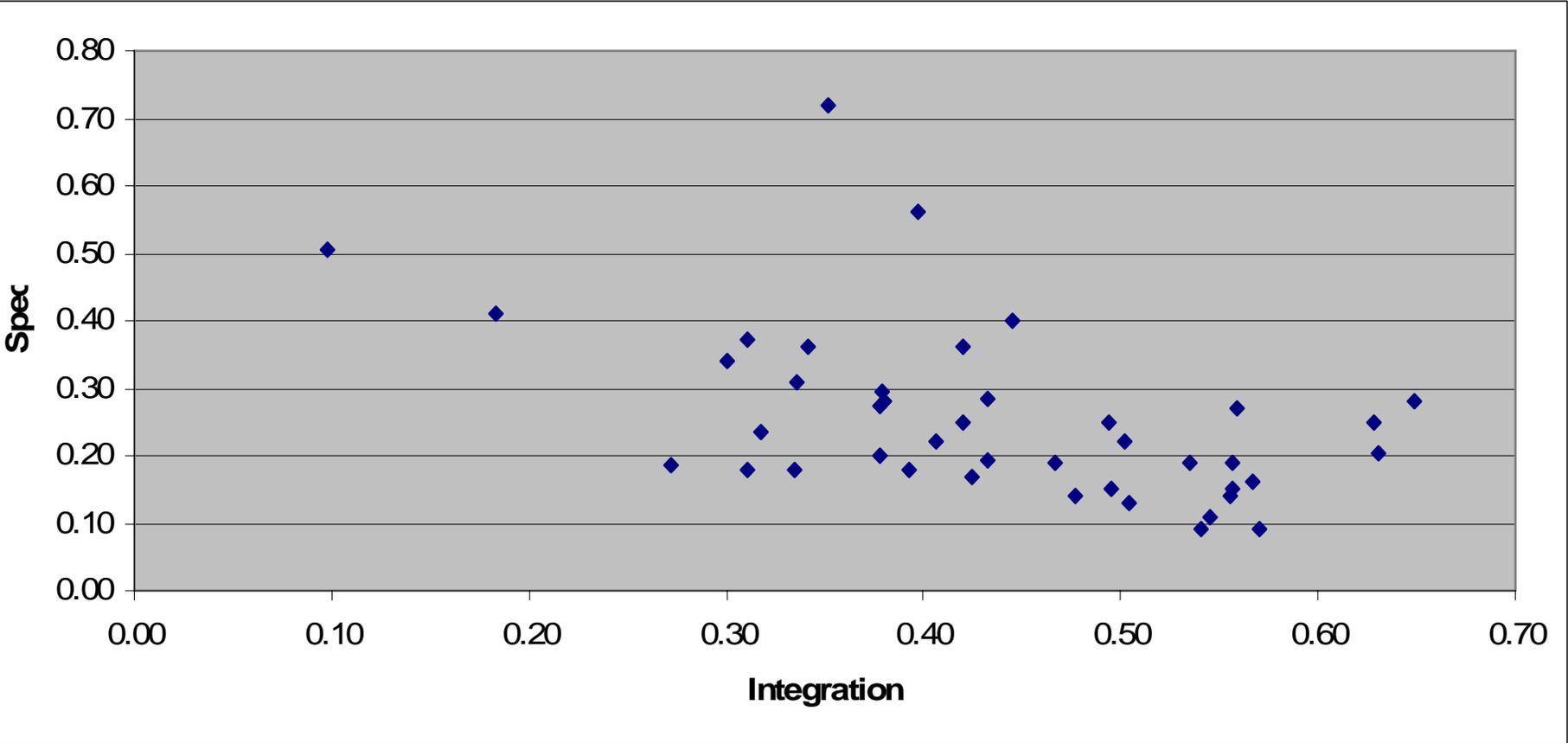
- 1. For the set of journal articles, count the number of publications in each SC.**
- 2. Square the count for each SC; then sum these.**
- 3. Divide that sum by the square of the sum of all the counts.**

## Specialization Formula:

$$S = \left[ \frac{\left[ \sum (f_i \times f_j \times \cos(SC_i - SC_j)) \right]}{\sum (f_i \times f_j)} \right]$$

**Where the Subject Categories (SCs 1--n) are those reflecting the journals in which the set of papers was published.**

# Specialization vs. Integration for the Publication Outputs of 43 Researchers



**Integration Scores for 22 Sample Subject Categories** (based on samples of ~100 papers published in 2005 associated with each indicated SC)

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| <b>Subject Category</b>              | <b>Integration (Mean)</b> | <b>Integration (SD)</b> |
|--------------------------------------|---------------------------|-------------------------|
| Engineering, Biomedical              | 0.69                      | 0.13                    |
| Materials Science, Biomaterials      | 0.68                      | 0.11                    |
| Geriatrics & Gerontology             | 0.68                      | 0.08                    |
|                                      |                           | 0.11                    |
| Clinical Neurology                   | 0.61                      |                         |
| Medicine, Research & Experimental    | 0.61                      | 0.13                    |
| Engineering, Chemical                | 0.61                      | 0.14                    |
|                                      |                           | 0.13                    |
| Biochemistry & Molecular Biology     | 0.53                      |                         |
| Statistics & Probability             | 0.53                      | 0.2                     |
| Engineering, Electrical & Electronic | 0.52                      | 0.19                    |
| <b>Average</b>                       | <b>0.61</b>               | <b>0.13</b>             |
| <b>Standard Deviation</b>            | <b>0.05</b>               | <b>0.03</b>             |

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# Integration, Co-authorship, Author affiliations for Selected Subject Categories

| Subject Category                     | Integration (Mean) | No. of Authors per Paper | Corr. Of I with No. of Authors | Affiliations per Paper | Corr. Of I with No. of Affiliations |
|--------------------------------------|--------------------|--------------------------|--------------------------------|------------------------|-------------------------------------|
| Engineering, Biomedical              | 0.69               | 4.5                      | -0.08                          | 2.5                    | -0.06                               |
| Materials Science, Biomaterials      | 0.68               | 4.2                      | 0.01                           | 2.4                    | 0.1                                 |
| Geriatrics & Gerontology             | 0.68               | 5.0                      | 0.12                           | 3.3                    | 0.11                                |
| Clinical Neurology                   | 0.61               | 4.7                      | 0.17                           | 3                      | 0.1                                 |
| Medicine, Research & Experimental    | 0.61               | 5.7                      | 0.2                            | 3.3                    | 0.29                                |
| Engineering, Chemical                | 0.61               | 3.2                      | 0.07                           | 1.8                    | 0.3                                 |
| Biochemistry & Molecular Biology     | 0.53               | 5.5                      | -0.02                          | 2.7                    | 0.04                                |
| Statistics & Probability             | 0.53               | 2.6                      | 0.32                           | 2.3                    | 0.26                                |
| Engineering, Electrical & Electronic | 0.52               | 3.3                      | 0.12                           | 1.9                    | 0.3                                 |
| <b>Average</b>                       | <b>0.61</b>        | <b>4.45</b>              | <b>0.07</b>                    | <b>2.5</b>             | <b>0.11</b>                         |

# Conclusions

**We're very pleased with the behavior of the I and S measures:**

- ▶ **they have strong face validity**
- ▶ **they stand up well to scrutiny by researchers themselves**
- ▶ **they behave predictably when applied to various groups of researchers**
- ▶ **analysis of individual papers of outliers stand up under detailed examination.**

**We are applying these measures to the outputs of participants in NAKFI programs (conferences and seed grants), before and after participation, and compare their scores with those of carefully selected comparison groups.**

**We thank the National Academies and the NAKFI Program for their support and encouragement in our efforts to operationalize the definition of interdisciplinary research.**