

LIFE Evaluation Report: Baseline Bibliometric Analysis

Dr. Jan Youtie
Dirk Libaers

Enterprise Innovation Institute
School of Public Policy
Georgia Institute of Technology
Atlanta, Georgia
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1. Overview

The objective of this aspect of the evaluation of the Learning in Informal and Formal Environments (LIFE) Center is to develop a baseline understanding of the knowledge environment and elements in the fields that comprise the science of learning. This report seeks to explore methods for defining this knowledge domain from which the LIFE center was created.

The characteristics of the pre-LIFE research domain are measured using bibliometric analysis. Bibliometrics is a type of research method often employed in library and information sciences. It utilizes quantitative analysis and statistical techniques to assess patterns of scientific publication within given research domains, fields, and disciplines. In the evaluation of the LIFE center, bibliometric analysis is best used to answer questions about the extent to which a center adds value to a particular domain of knowledge. Bibliometrics can help to understand how center activity (in the form of publications) changes and becomes more developed. Questions about the degree to which a research domain brings together multiple disciplines can also be explored using bibliometric analysis, given that these underlying disciplines are broadly established, distinguishable, and measurable. It can also be used to assess the ability of the center to support knowledge-based human capital development of students (as measured by co-authored publications). Bibliometric analysis is not appropriate for understanding the critical qualitative impacts of the center on human capital development, informal influences on research knowledge, capacity building, or similar issues. Other methodologies such as case studies, curriculum vitae analysis, and social network analysis will be utilized during the evaluation to address these questions more directly.

The information presented in this document reflects the time period 2002 to 2004. This analysis should be conceived of as a baseline profile rather than an evaluation of the LIFE Center. The evaluation can come back to these measures in a subsequent time period (currently scheduled for Year 4) to assess changes in the research domain that have occurred since the creation of the LIFE center. A further set of measures (such as research co-authorships with students) may be incorporated into the Year 4 analysis.

Baseline measures of several aspects of the science of learning domain are examined: (1) knowledge output, (2) size of the domain, (3) extent of research collaborations, and (4) the influence of the research. The data source for this analysis is Thomson Scientific's Web of Science (WOS). One of the major challenges of this analysis is the definition of the pre-LIFE research domain. This report shows that identification of this domain is not straightforward. Through an iterative process, the analysis used keywords taken from existing articles of current LIFE principals.

The resulting pre-LIFE domain is described in full and in terms of the subset of past work of present-day LIFE principals. In the 2002 to 2004 time period, the full domain was comprised of nearly 4,000 scholarly publications. These publications represented 8,600 authors at roughly 1,730 institutions located in 70 countries and 48 US states. In this sizable domain, we saw that current LIFE investigators were highly productive in their

output in the 2002 to 2004 time period, working with 68 co-authors at institutions in seven countries, and producing 26 publications that received more than 300 citations by other works. In the 2002 to 2004 time period, LIFE principals tended to be engaged in collaborative activities and their publications were highly influential in the field.

We did not uncover substantial co-authorships across strands, with what now are other SLCs, or with MSIs. These are items that can be examined in a later phase of the evaluation.

2. Background

The most prevalent conduit for the flow of knowledge is the publication. The idea behind bibliometric analysis is that through counting (rather than reading) research publications, we can observe changes in a field of knowledge. (Narin and Hamilton 1996) Publications can be used to represent the attributes of knowledge generated by a variety of institutional mechanisms including multidisciplinary research centers (MRCs). MRCs have been proposed as policy tools for accelerating the development of knowledge from a burgeoning research topic to formal scientific field. (Youtie, Libaers, and Bozeman, forthcoming). One way this transformation can be observed is by gauging changes in research output (e.g., articles) and human capital participation (e.g., authorships) of investigators associated with the MRCs. Increases in the breadth of the knowledge domain can be captured through quantification of numbers of participating institutions with which MRC authors are affiliated. Emerging MRC-stimulated fields can also be measured in terms of their geographic characteristics; Wagner and Leydesdorff (2005) show that a growing geographic span of researchers is an important element of scientific progress in a new, field. MRC's can facilitate this geographic spread through partnerships with authors and centers at other universities. It has been conversely argued that MRCs can reduce geography through a clustering effect that generates a high degree of local knowledge output by taking advantage of scale economies, enhanced communications, resource sharing, and tacit knowledge exchange. (Katz, 1994; Morgan, 2004) Based on the above, it may be expected that MRCs would support greater than average output and involvement of authors.

One of the ways that MRC's can have influence is through stimulating research collaboration. Research collaboration has been conceptualized as a mechanism for crystallizing an idea investigated by isolated scholars into a network. Melin (2000) finds that research is typically not conducted in isolation in the academic world, but through work in teams. Bozeman and Rogers (2001, 2002) originated the term "knowledge value collective" to represent the loosely coupled grouping of knowledge producers and users that is often found in scholarly research. Research output in academic circles is largely a product of teamwork, which has become reinforced through factors such as funding agencies' grant requirements and the nature of university departments, policies, research centers, and facilities. (Genuth et al, 2000) Collaboration has come into focus when examining the proliferation of co-authored articles (Melin, 2000). The pioneering works of De Solla Price and Beaver (1966) and Merton (1973) have highlighted the ongoing growth of co-authored articles and the use of co-produced and authored research output

as a measure of research collaborations. Extending the notion of collaboration across disciplines, it is found that such research activities can form the basis for the eventual institutionalization of new specialty fields such as was the case with biotechnology. Evolution into a stable scientific discipline occurs but it is rather rare because of need for support structures, the setting of boundaries, the emergence of authoritative scientific associations, and the importance of credentialing and educational requirements. (Bechtel, 1986; Lenoir, 1997). Hence, we might anticipate that research done through MRC's would be more collaborative than in the broader emerging field.

Extending the idea of academic collaboration beyond direct linkages is the concept of research influence. It has been argued that research which is highly cited by others is influential in the knowledge domain (Aksnes, 2006). Citations are work that has been mentioned in reference notes or bibliographies of scholarly publications. Merton (1973) suggests that scientific influence reinforces the position of established research leaders, eventually supporting scientific excellence. Adams et al (2004) find that scientific influence is asymmetric, with top institutions more often cited by their peers than less highly-ranked schools. There are several issues with what meaning scientific citations convey. First, citation-based influence is subject to lags although not to the extent of the sources which patents cite. Second, this influence is mitigated to the extent that these citations are self-citations rather than cited by others. (Glanzel, Thijs, and Schlemmer 2004) Third, there are instances of "negative citations" where work is refuted. Fourth, the rate of citation varies by disciplines—higher in medical research than in mathematics. (Dosi et al, 2005) And finally, the inclusion of citations can be the work of referees rather than the author, although the author typically has some flexibility in the decision to include or exclude these citations. Thus with some caution, citations of prior publications are a commonly used measure of research influence (Garfield, 1973; Narin and Hamilton 1996) Based on the above, one could expect that MRC's may do more influential, highly cited work than one would find in the field in general.

3. Data

This analysis tracks changes in the research domain as defined through articles published by the principal investigators (PI's) of the LIFE Center in the pre-LIFE period from 2002 to 2004. We chose these years because they occurred just before the LIFE center received full funding in February 2005¹. Lag times in publishing certain types of articles in peer-reviewed publications suggests that all of this research occurred before the LIFE center received any funding. Repeated here is the caveat that this information should not be used to evaluate the progress or impacts of the LIFE center, rather it should be viewed as a baseline characterization of the research domain (from which the LIFE center emerged) only. The unit of analysis in this study consists of peer-reviewed research articles, reviews, letters, abstracts, proceedings and chapters published by these principals.

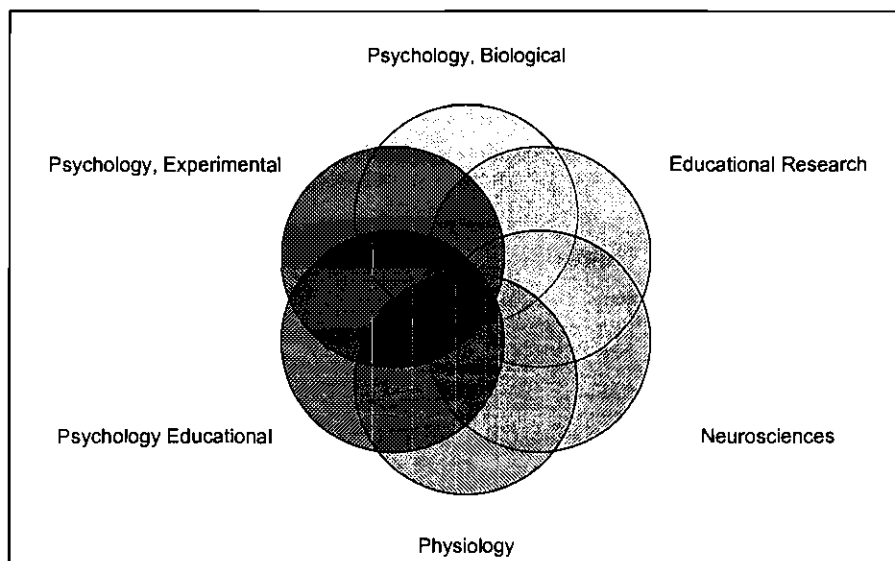
¹ The LIFE center was funded at 15 percent in October 2004, but we do not regard that as sufficient support for extensive research activity. In addition, our data sources do not allow us to include or exclude certain months easily.

This analysis is based on information provided in the Web of Science (WOS) database provided by Thomson Scientific. WOS abstracts 8,700 journals and other publications, allows for citation analysis, and captures multidisciplinary subject relationships. It does tend to be biased toward peer-reviewed publications and does not capture particular subject areas in as much depth as do specialty databases. We also explored the feasibility of utilizing other abstracting databases as well such as and the Education Information Resources Center (ERIC) database administered by the Department of Education. However, we found that ERIC did not capture much information on articles and non journal documents even if it offers more in-depth coverage of education sciences. Moreover, because the science of learning centers conduct research that is not always strictly within the parameters of the education field, it was viewed as important to have a database that covers multiple disciplines.

4. Pre-LIFE Research Domain Definition and Limitations

Science of learning is not a universally recognized formal discipline with a standardized set of journals covering specified subject matter. It is situated at the intersection of educational sciences, psychology, physiology, and neurosciences. Figure 1 illustrates this interdisciplinary nature.

Figure 1. Primary Disciplines in the Pre-LIFE Research Domain



This multidisciplinary characteristic is typical of emerging research areas. At the same time, it makes it difficult to conduct bibliometric analysis, because of the lack of agreed upon definitions and boundaries of the research domain. As a result, this analysis required a substantial consideration of what should be included and excluded in the LIFE research domain.

Our primary method for defining the Pre-LIFE research domain was through the use of subject matter keywords typically developed by authors or journals for classifying research work. We began by focusing on keywords associated with the research of the now LIFE principals during the 2002 to 2004 time period. LIFE principals' names were entered into the WOS search engine in all relevant forms (last name first initial or last name first and middle initial). The resulting database produced 35 publications which were classified through 226 keywords. The most common keywords (associated with two or more publications) were entered into WOS. (See Table 1.) This search term produced over 100,000 publications, the majority of which did not pertain to the Pre-LIFE research domain.

The next step focused on a smaller set of keywords that could be used to identify 70 percent of all LIFE principals' publications in the WOS. The first filter we used was a search term that combined AND and OR operators and included only keywords that were closely associated with the Pre-LIFE research domain. The reduced search term yielded 5,386 unique publication records. Although this number was more reasonable, it still contained many records which were not relevant to the Pre-LIFE research domain. For example, fMRI is important in one of the strands of the Pre-LIFE research domain but it is also used in disease research, which is outside of LIFE's boundaries. An iterative strategy of reducing and adding back keywords was then followed to better pinpoint the domain. Five iterations were conducted to further reduce the database by excluding publications with irrelevant keywords. The resulting database after these five iterations covered less than 60 percent of LIFE principals' publications. To raise the coverage over 70 percent, we added records based on two further searches. Duplicates and publications outside of the target years 2002-2004 were removed and the resulting databases yielded 3973 publications and included more than 80 percent of current LIFE principals' work in total (although for three authors, we could only incorporate one of their two publications into our final domain definition).

It should be noted that the databases we used for this analysis were not primarily intended for such aggregate examinations. As such, these databases may have errors that can affect the figures in small ways. Where possible, we cleaned up these areas as best we could. Nevertheless, due to the large number of records and incomplete knowledge of the authors, we acknowledge that these and other types of errors may have been introduced into the analysis. These errors are not expected to be systematic. Thus, while *absolute* counts should *always* be regarded as approximations, it is anticipated that these errors will not significantly change the *relative* positions of particular states or institutions.

Table 1. Search Strategy to Define the LIFE Research Domain

Search Term	Publications
PERCEPTION OR CHILDREN OR CORTEX OR DISCRIMINATION OR SCHOOL OR ATTENTION OR BRAIN OR (EARLY ADOLESCENCE) OR (LINGUISTIC EXPERIENCE) OR (NEWBORN-INFANTS) OR SCIENCE OR SPEECH-PERCEPTION OR STUDENT OR VICTIMIZATION OR (6-MONTH-OLD INFANTS) OR (8-MONTH-OLD INFANTS) OR ACQUISITION OR AGE OR BEHAVIOR OR (BEHAVIOR PROBLEMS) OR CONFLICT OR GESTURES OR	100,000+

Search Term	Publications
INFANTS OR LANGUAGE OR MECHANISMS OR MIND OR MODELS OR (MOTHERS FACE) OR (MOTHERS SPEECH) OR MOTION OR (PHONETIC PERCEPTION) OR (PSYCHOLOGICAL ADJUSTMENT) OR RESPONSES OR (SOCIAL WITHDRAWAL) OR (SOCIOMETRIC STATUS) OR SONG OR STRATEGY OR SURVIVAL OR (VOCAL IMITATION) OR (YOUNG INFANTS) OR (ZEBRA FINCH)	
(PERCEPTION AND BRAIN) OR (PERCEPTION AND LANGUAGE) OR (PERCEPTION AND CHILDREN) OR (PERCEPTION AND CORTEX) OR (PERCEPTION AND INFANTS) OR (PERCEPTION AND FMRI) OR (SPEECH PERCEPTION AND CHILDREN) OR (CHILDREN AND GAZE) OR (SPEECH PERCEPTION AND INFANTS) OR (VOWEL PERCEPTION AND AGE) OR (COGNITIVE NEUROSCIENCE AND SOCIAL COGNITION) OR (LINGUISTIC EXPERIENCE AND INFANTS) OR (MOTHER'S FACE AND IMITATION) OR (INFANTS AND LOCATION MEMORY) OR (STUDENTS AND EPISTEMOLOGIES)	5386
NOT (DISEASE OR INJURY OR SYNDROME OR DISORDER OR DEATH OR TRAUMA OR ATROPHY OR SURGERY OR DYSTROPHY OR VIOLENCE OR ATTACK OR FAILURE OR HEART OR BLOOD OR TOXIC* OR ANESTHI* OR CANCER)	4171
NOT (FOOD OR LEAD OR ALCOHOL OR ALZHEIMER* OR DEPRESSION OR DEMENTIA OR DOPAMINE OR SENILE OR STROKE OR NANO* OR BONE)	3899
NOT (BUDDH* OR RELIGI* OR ALS OR SCLEROSIS OR ANOREXIA OR ASTHMA OR BIPOLAR OR BISEXUAL OR BLADDER OR BULIMIA OR COCAINE OR COCHLEAR OR IMPLANT OR DELUSIONAL OR DIABETES OR EATING OR EPILEPSY OR ETHANOL)	3616
NOT (BIOINFO* OR GRAIN OR HUNTINGTON'S OR HYPERTHERMIA OR HYPOTHERMIA OR HYPOXIA OR KIDNEY OR MARIJUANA OR MENOPAUS* OR OBESE OR OBSESSIVE OR OPIOID OR PARKINSON* OR SCHIZO* OR SEIZURE OR SENILE OR SENIOR OR SMOK* OR SPINAL OR CORD OR STROKE OR TOURETTE)	3496
NOT (CARBON OR STOMACH OR BATTER* OR MORTAL* OR CARCIN* OR BREAST OR JET OR ION OR FINITE OR SKELET* OR RADIATION OR TABLEWARE)	3427
NOT TS = (IN-VIVO OR INFECT* OR CHRONIC OR HIV OR IMMUNO* OR NITRIC-OXIDE OR PROTEIN OR METHYL* OR ENTROP* OR AMINO OR ACID OR CHEMOTHERAPY OR COPPER OR STREAM OR LESION OR PEPTIDE OR AIDS OR ANGIO* OR ANGINA OR ANTIBIOT* OR ANTIBOD*)	3200
(PEER INTERACTION AND INFANT) OR (PARSING AND SPEECH PERCEPTION) OR (SYNTACTIC AND PROCESSING) OR (INQUIRY AND SCHOOL) OR (DESIGN-BASED AND LEARNING) OR (INVENTING AND INSTRUCTION) OR	3909

Search Term	Publications
(ANCHORED AND INQUIRY) OR (BIOMEDICAL AND LEARNING)	
(MOTOR CONTROL AND PERCEPTION) OR (UNCERTAINTY AND JUDGMENT) OR (PREFRONTAL CORTEX AND MOTHERSFACE) OR (FACIAL EXPRESSIONS AND NEONATAL IMITATION)	4154
Duplicates and older publications removed	3973

Source: Search of Web of Science Database, March 22, 2006 using VantagePoint software.

Table 2. Results of Search Relative to Research Output of LIFE Principals: 2002-2004*

LIFE Principal	WOS Publications 2002-4	WOS Publications After Search**
Meltzoff, AN	11	10
Kuhl, PK	10	8
Schwartz, DL	2	1
Bell, P	2	2
Bransford, JD	2	2
Barron, B	2	1
Pea, RD	2	1
Reeves, BJ	1	1
Total	34	29

*Searches were for Meltzoff, A. and Meltzoff AN, Kuhl, PK and Kuhl P.

**These publications were what were included in the final LIFE research domain.

Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, March 22, 2006 using VantagePoint software.

5. Measures

The information in this dataset will be used to measure the following attributes of the Pre-LIFE domain: output, size, collaborations, and influence. Output is measured by simple counts of publications of LIFE principals (before they were affiliated with the center). We can also look at the number of publications by document type—articles, proceedings, letter, note, etc. This measure will likely be biased toward articles because of the dominance of scientific articles in the WOS database.

The size of the Pre-LIFE domain can be measured by several indicators: the sheer volume of publications, the number of authors publishing in the domain (both primary and secondary authors), and the number of institutions. The latter reflects an aggregation of counts of the number of publications across a given institution. Institutions can be located on a map using geographic information systems (GIS) to show the geographic spread of these institutions.

By examining co-authorships we can get a sense of the research collaborations between individuals within and outside of the formal LIFE center boundaries. One difficulty with this type of analysis is that WOS can typically only accurately associate institution and

address with the first author. The order of names presented in an article is subject to varying norms depending on the discipline. In some disciplines the first author made the greatest contribution to the research; in others the director of the laboratory may be listed first regardless of the contribution of that individual to the particular research topic that the article investigates; and still others list authors in alphabetical order. For most of the analysis that follows, we show all authors, but in some cases (where indicated) we present the primary or first author.

The presence of multiple disciplines is measured by the number of journals in the database. Although journals are by no means formal disciplines, they can represent certain aspects of subfields within disciplines because of the particular emphasis they might have in a specialization. Journals are also more flexible than disciplines and changes in them may presage the presence of new emerging fields.

Citations represent another type of relationship between LIFE-based and other researchers. Researchers with high numbers of aggregate citations generally can be considered to be especially influential in the field. We will examine of the number of times LIFE researchers' articles are cited relative to the total for the field.

These measures are summarized in Table 3.

Table 3. Bibliometric Measures of the LIFE Research Domain

Measure	Indicator
Output	Number of publications by LIFE principals Type of publications produced by LIFE principals
Size of the Domain	Number of publications in the LIFE domain Number of authors publishing in the LIFE domain Number and Type of institutions publishing in the LIFE domain Geographic spread of domain
Research Collaborations	Number of authors per publication Co-authorships across strands within the LIFE center Co-authorships with investigators from other present-day Science of Learning Center Institutions Co-authorships with Minority Serving Institutions Number of journals per publication
Influence	Number of times articles are cited per publication

6. Results

Our analysis not only profiles past work done by present-day LIFE principals. It also examines the broader research domain itself. This more expansive approach allows for greater understanding of the emerging field and its knowledge attributes. It also will enable a comparison of changes in this emerging field when the evaluation replicates this phase of examination.

The broader Pre-LIFE research domain contains approximately 3,973 publications. The publications were created by some 8,600 authors from approximately 1,730 institutions. Most of these publications are journal articles. But also included are reviews, editorials, meeting and conference abstracts, book reviews, and letters. (See Table 4.)

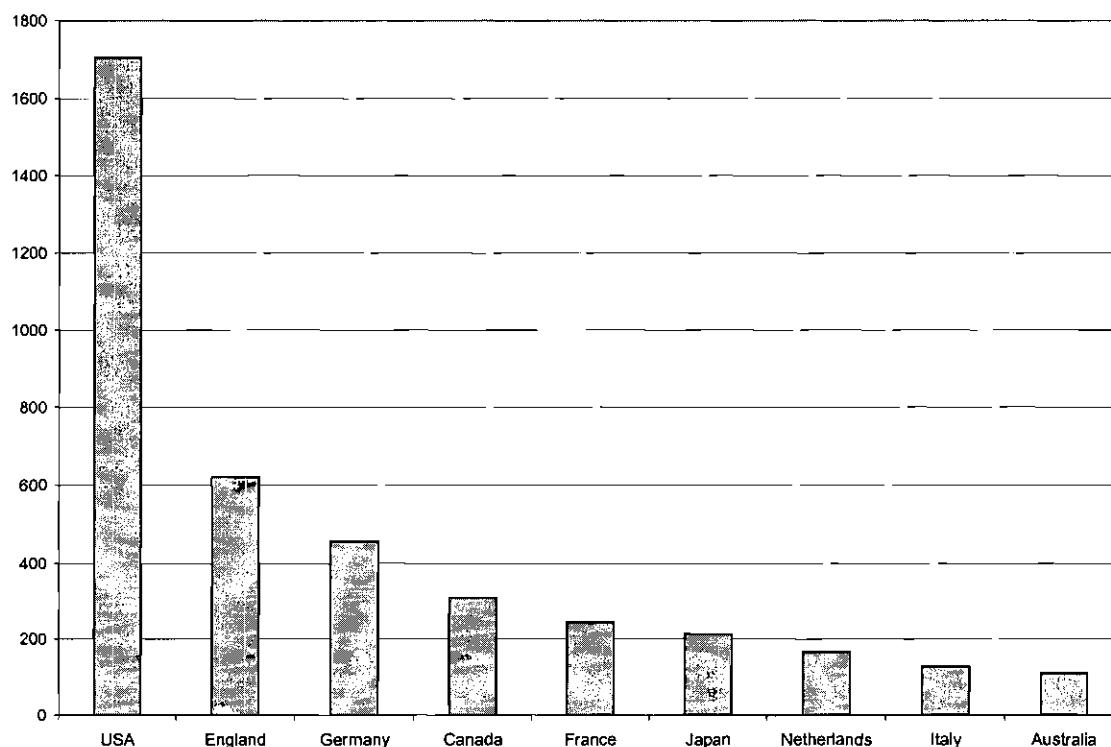
Table 4. Type of Publication in the Pre-LIFE Research Domain: 2002-2004

Document Type	# Publications
Article	3496
Review	247
Editorial Material	131
Meeting Abstract	75
Book Review	9
Letter	6
Other (correction, news item, reprint)	9
Total	3973

Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, accessed March 2006 using VantagePoint software.

There is considerable geographic span in the broad Pre-LIFE research domain. Authors from more than 70 countries were represented research publications in the full domain. The top countries were the US, England, Germany, Canada, France, Japan, Netherlands, Italy, and Australia. (See Figure 2.) Authors from seven countries, including four US states, were represented in collaborative publications with LIFE investigators in the 2002 to 2004 time period.

Figure 2. Number of Publications in the Pre-LIFE Research Domain By Country of Author Institution
(for the Top Countries with 100 or more publications)



Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, accessed March 2006 using VantagePoint software.

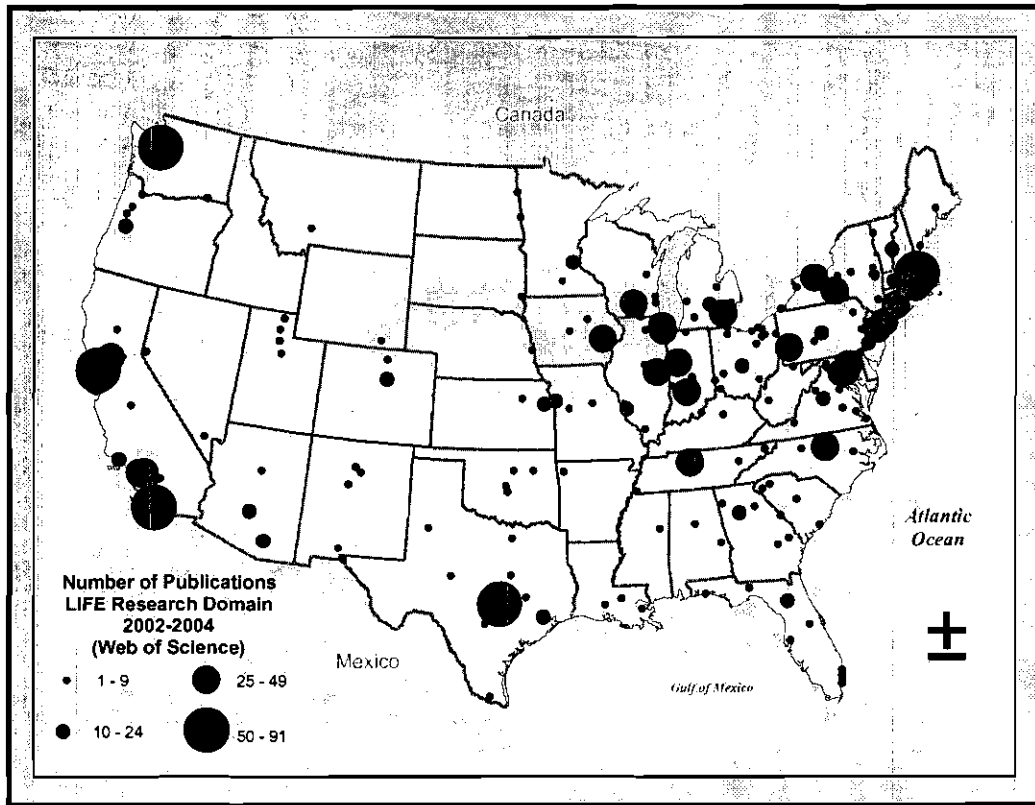
The top research institutions based on author affiliation in the Pre-LIFE domain in the US are shown in Table 5. Nearly all US states have some institution with authors conducting research in the Pre-LIFE domain. Still, Table 5 and Figure 3 suggest that this research is not randomly distributed. It is concentrated in a small group of top institutions including those that anchor the LIFE center. University of Washington is one of the top two institutions in term of research output and Stanford is among the top 20. Based on this exceptional level of output, it is no accident that these institutions were selected to form an NSF Science of Learning Center.

Table 5. Number of Publications in the Pre-LIFE Research Domain By US Institutional Affiliation of Author: Top Institutions based on Number of Publications

Institution	City	State	Publications
Harvard Univ	Cambridge	MA	91
Univ Washington	Seattle	WA	60
Univ Calif Berkeley	Berkeley	CA	55
Univ Texas	Austin	CA	53
Univ Calif San Diego	San Diego	CA	51
MIT	Cambridge	MA	45
Univ Calif Los Angeles	Los Angeles	CA	43
Brown Sch Med	Providence	RI	38
Johns Hopkins Univ	Baltimore	MD	38
Indiana Univ	Bloomington	IN	36
Northwestern Univ	Evanston	IL	35
NYU	New York	NY	35
Yale Univ	New Haven	CT	33
Univ Rochester	Rochester	NY	32
Boston Univ	Boston	MA	32
Carnegie Mellon Univ	Pittsburgh	PA	31
Univ Iowa	Iowa City	IA	31
Duke Univ	Durham	NC	31
Purdue Univ	W Lafayette	IN	29
Stanford Univ	Stanford	CA	29
Cornell Univ	Ithaca	NY	29
Univ Wisconsin	Madison	WI	29
Columbia Univ	New York	NY	28
Univ Illinois	Champaign	IL	28
Univ Maryland	College Park	MD	27
Vanderbilt Univ	Nashville	TN	27
CalTech	Pasadena	CA	27
Univ Calif Davis	Davis	CA	27
Rutgers State Univ	Piscataway	NJ	27
Univ Chicago	Chicago	IL	26
Univ Michigan	Ann Arbor	MI	25
Natl Inst Mental Hlth	Bethesda	MD	25

Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, accessed March 2006 using VantagePoint software.

Figure 3. Map of Number of Publications in the Pre-LIFE Research Domain, 2002-2004, by the Location of the Institutional Affiliation of the Author



In addition to these leading institutions, there was also a presence of minority-serving institutions (MSIs). Researchers at 12 MSIs were involved in research in the LIFE domain. Although no single MSI predominates, taken together MSIs produced 35 publications. (See Table 6.)

Table 6. Number of Publications in the Pre-LIFE Research Domain By Author Affiliation with Minority Serving Institution

Minority Serving Institution	Publications
New Mexico State Univ	6
Univ New Mexico	6
Calif State Univ Fresno	4
Univ Miami	4
Calif State Univ Fullerton	3
CUNY City Coll	3
Florida Int Univ	3
CUNY Herbert H Lehman Coll	2
Calif State Univ Northridge	1
Clark Atlanta Univ	1
Morgan State Univ	1
Tennessee State Univ	1
Univ Texas Pan Amer	1

Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, accessed March 2006 using VantagePoint software.

An examination of research collaborations indicates that there were 68 authors involved in publications with the pre-LIFE center investigators in the 2002-2004 time period. This amounts to 2.6 authors per LIFE principal publication compared with 2.2 authors per publication for the full domain. This suggests that the pre-LIFE investigators were at least as collaborative as the typical author in the full domain. The 68 authors included:

- 8 pre-LIFE PIs: Meltzoff, Kuhl, Bell, Bransford, Barron, Pea, Reeves, Schwartz
- 4 pre-LIFE researchers: Decety, Rao, Imada, Raizada
- 2 pre-LIFE collaborator: Brophy, Martin
- 54 other authors

Figures 4 and 5 illustrate the networked relationships among these authors and their collaborators by author name and by institution. The first network map shows three clusters of authors. These authors are centered on three pre-LIFE leaders. Each of these clusters is dense, involving multiple authors and connections. Although the clusters show most connections emanating from these three individuals, there are additional linkages between some of the authors that do not directly involve these professors. In addition to the three clusters, it is apparent that three additional pre-LIFE principals worked in a bilateral fashion based on articles published in the 2002 to 2004 time period, and others had sole authored publications. Figure 5 can be overlaid to demonstrate institutional ties. It suggests that clusters involving the two less-dense multi-author networks in Figure 4 are the most international, with activity that involves researchers in Japan, Taiwan, France, Germany, and the United Kingdom. The highly dense cluster in Figure 4 is separate as it reflects one of the pre-LIFE principal's ties with a previous educational institution.

Figure 4 Network Map of Present-Day LIFE Principals and their Co-Authors Based on Published Work from 2002-2004

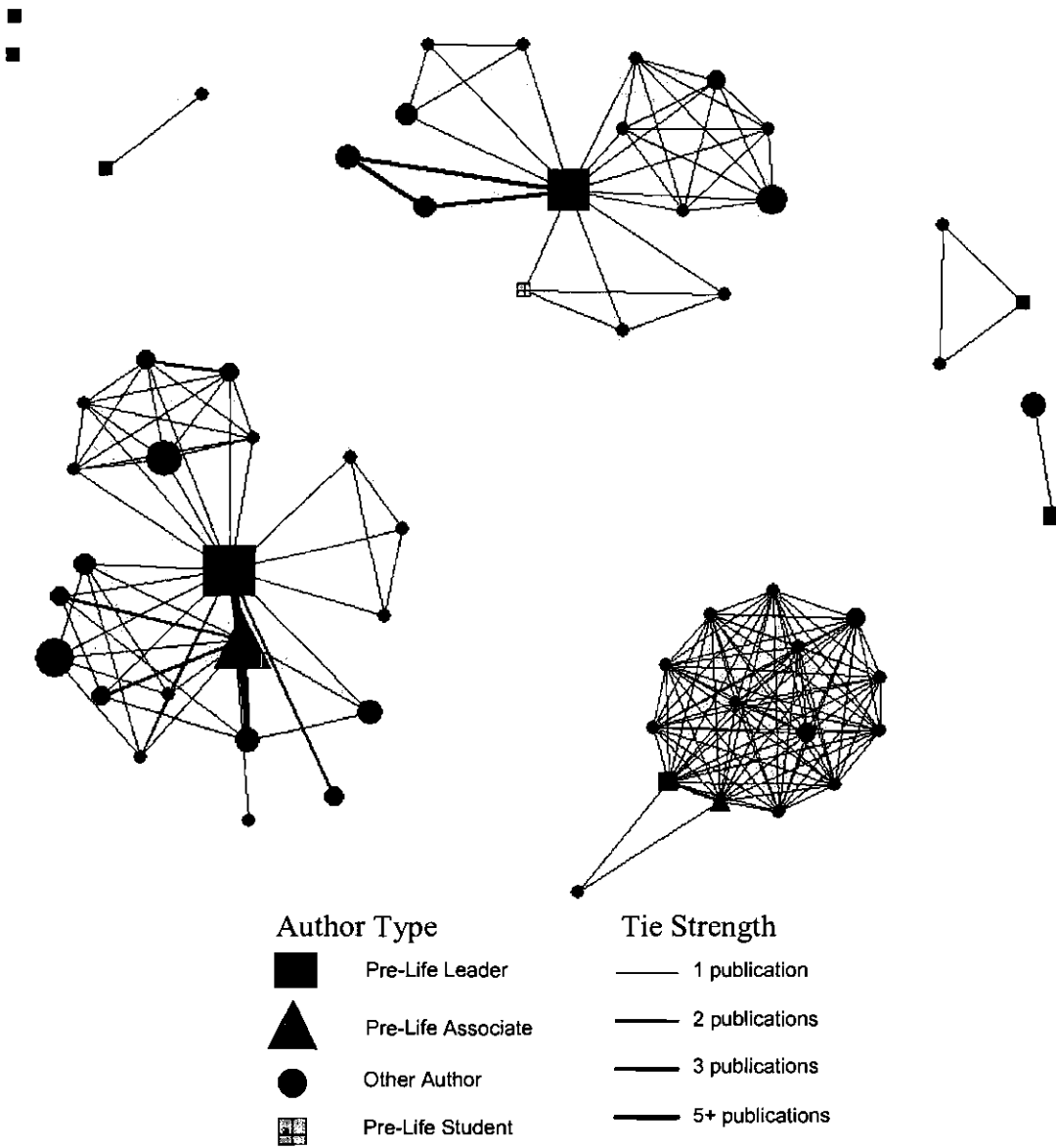
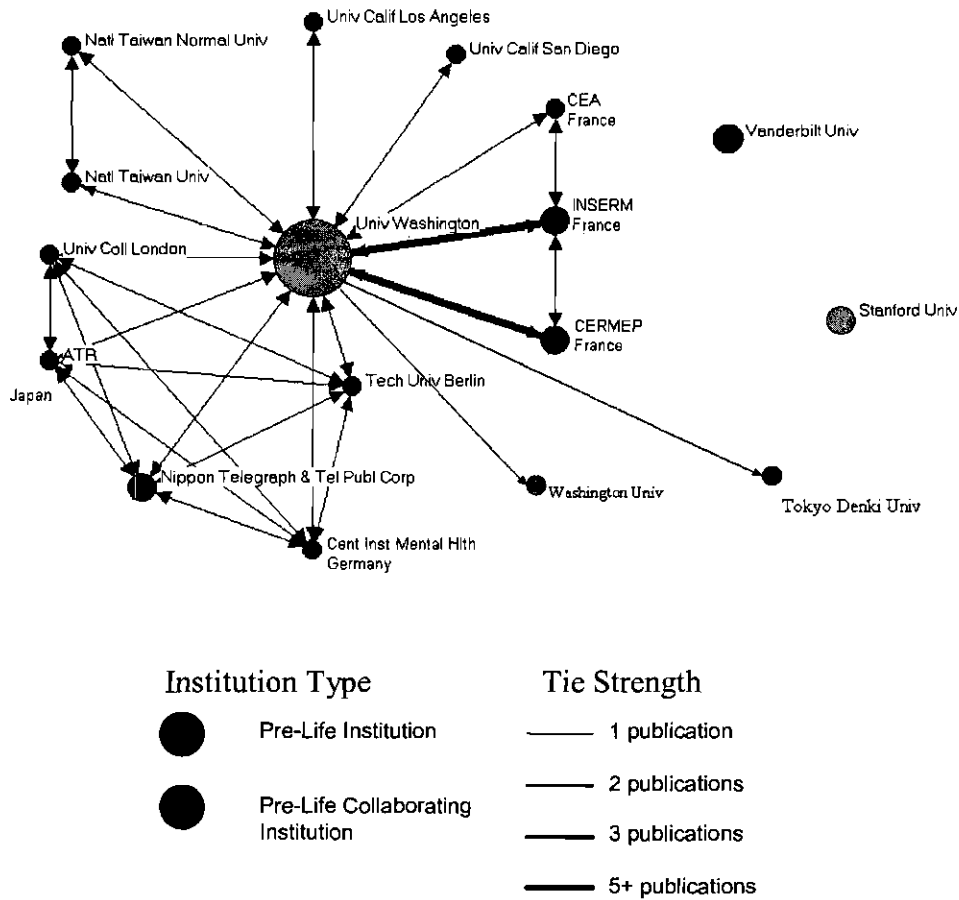


Figure 5. Network Map of Institutional Linkages Among LIFE Principals and their Co-Authors Based on Published Work from 2002-2004



ATR: Advanced Telecommunications Research Institute, Japan

CERMEP: Centre d'Exploration et de Recherche Medicales par Emission de Positons, Lyon, France

INSERM: Institut National de la Santé et de la recherché médicale, France

This baseline analysis examined three types of co-author-based collaborations with current LIFE PIs in the pre-LIFE research domain: (1) cross strand publications, (2) publications with other Science of Learning Centers (SLCs), and (3) publications with MSIs. We did not find co-author relationships in any of these three categories in the pre-LIFE time period. The other authors in other SLCs and MSIs included in the pre-LIFE domain are listed in Table 7.

Table 7. Authors from Other Science of Learning Centers and Minority Serving Institutions in the Pre-LIFE Research Domain: 2002-2004

Author	Institution	Designation
Daniel Bullock	Boston U	SLC
Howard Eichenbaum	Boston U	SLC
Stephen Grossberg	Boston U	SLC
Frank Guenther	Boston U	SLC
Earl Miller	MIT	SLC
Ennio Mingolla	Boston U	SLC
Kurt Koedinger	CMU	SLC
Albert Corbett	CMU	SLC
LA Thompson	New Mexico State Univ	MSI
KL Oliver	New Mexico State Univ	MSI
JK Kroger	New Mexico State Univ	MSI
PA Burtner	Univ New Mexico	MSI
H Ford	Univ New Mexico	MSI
BD Hoffman	Univ New Mexico	MSI
DC Witherington	Univ New Mexico	MSI
L Lachs	Calif State Univ Fresno	MSI
DL Hudson	Calif State Univ Fresno	MSI
PC Price	Calif State Univ Fresno	MSI
JM Ritter	Calif State Univ Fresno	MSI
JC Englehardt,	Univ Miami	MSI
Searcy, WA	Univ Miami	MSI
AM Cox-Petersen	Calif State Univ Fullerton	MSI
NJ Pelaez	Calif State Univ Fullerton	MSI
BL Gonzales	Calif State Univ Fullerton	MSI
AW Gottfried	Calif State Univ Fullerton	MSI
AE Gottfried	Calif State Univ Northridge	MSI
VC Tartter	CUNY City Coll	MSI
S Deregnacourt	CUNY City Coll	MSI
LE Bahrack	Florida Int Univ	MSI
S Levey	CUNY Herbert H Lehman Coll	MSI
MS Kerner	CUNY Herbert H Lehman Coll	MSI
RD Ellis	Clark Atlanta Univ	MSI
Yvonne Bronner	Morgan State Univ	MSI
J Jou	Univ Texas Pan Amer	MSI

Source: Science Citation Index and Social Science Citation Index, Thompson Scientific, accessed March 2006 using VantagePoint software.

The pre-LIFE domain encompasses multiple disciplines. Using journals as a proxy for disciplines, the domain included more than 930 journals. *Neuroimage* was the most common journal in terms of number of articles. Also included were journals relating to neuroscience (e.g., *Vision Research*, *Neuroreport*, *Cognitive Brain Research*, *Journal of Cognitive Neuroscience*, *Neuropsychologia*, *Experimental Brain Research*, *Brain and Language*), cognitive research (e.g., *Trends in Cognitive Sciences*, *Cognition*, *Cognitive Science*), learning, and development (e.g., *Developmental Science*, *Child Development*, *Infant Behavior and Development*, *Developmental Psychology*), and education (e.g., *International Journal of Science Education*, *Science Education*, *Teaching and Teacher Education*, *Educational Psychologist*). Dividing this quantity of journals by the number of publications in the domain yields a rough indicator of multidisciplinaryity. The journal to publication ratio for the full domain was 0.24. The pre-LIFE authors had a journal to publication ratio of 0.69, a somewhat higher ratio than for the domain as a whole, suggesting a level of greater diversity of fields (as measured by journal name) represented by the pre-LIFE investigators.

We examined the influence of pre-LIFE publications by the current principal investigators published in the 2002 to 2004 timeframe. These figures were compared to the total for the full domain. In this distribution, values ranged from 0 to 191 citations. The modal article usually is not cited (994 or 25 percent were not cited in the pre-LIFE domain), the median number of citations is relatively small (median=2 in this distribution), and the distribution appears as a negative logarithm. Citations per publication for pre-LIFE PIs ranged from 0 to 67, with a mean of 11 and a median of 7.5 . On a per publication basis, works of pre-LIFE PIs tended to receive more citations per article than the average article in the domain (11.3 for pre-LIFE PIs versus 5.5 for the domain as a whole).

7. Summary

This report uses bibliometric analysis to establish a baseline information base on the published research output of the investigators that came together to create the LIFE center. There are several caveats about this analysis and the accuracy of the numbers reported within. But the most important qualification is that it is not designed to evaluate the current LIFE center. Rather it seeks to explore approaches to define a research domain within which the LIFE center is eventually formed, and to provide an initial profile of the types and extent of knowledge-based activity that has occurred in the field prior to the creation of the SLCs.

The research domain in which LIFE exists is not a formal discipline with tight boundaries. Identification of the domain is not straightforward. Through an iterative process, this analysis used keywords taken from existing articles of current LIFE principals. A pre-LIFE research domain resulted and was described in terms of four dimensions: output, size, research collaborations, and influence. Comparisons were made

with the subset consisting of the past work of current principals of the LIFE center relative to the broader domain.

The pre-LIFE domain was comprised of nearly 4,000 scholarly publications. These publications represented 8,600 authors at roughly 1,730 institutions located in 70 countries and 48 US states. In this sizable domain, we saw that current LIFE investigators were highly productive in their output in the 2002 to 2004 time period, working with 68 co-authors located in seven countries, and producing 26 publications that received more than 300 citations by other works. In the pre-LIFE time period, current principals tended to be engaged in collaborative activities and their publications were highly influential in the field.

We did not uncover substantial co-authorships across strands, with what now are authors at other SLCs or with MSIs. These are items that could be gauged in a subsequent round of analysis toward the end of the evaluation period.

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