The intellectual structure and substance of the knowledge utilization field: A longitudinal author co-citation analysis, 1945-2004

Carole A. Estabrooks[1], Linda Derksen[2], John N. Lavis[3], Connie Winther[4], Shannon D. Scott[5], Lars Wallin[6], Joanne Profetto-McGrath[7]

[1] Professor & Canada Research Chair in Knowledge Translation, Faculty of Nursing, University of Alberta, Edmonton, Alberta, Canada

[2] Professor & Chair, Department of Sociology, Malaspina University-College, Nanaimo, British Columbia, Canada

[3] Associate Professor and Canada Research Chair in Knowledge Transfer and Exchange, Department of Clinical Epidemiology and Biostatistics & Department of Political Science, McMaster University, Hamilton, Ontario, Canada

[4] Clinical Research Librarian, Department of Pediatrics, Faculty of Medicine, University of Alberta, Edmonton, Alberta, Canada

[5] Postdoctoral Fellow, Department of Pediatrics, Faculty of Medicine, University of Alberta, Edmonton, Alberta, Canada

[6] Researcher, Department of Neurobiology, Care Sciences and Society, Division of Nursing, Karolinska Institutet and Clinical Research Utilization (CRU), Karolinska University Hospital, Stockholm, Sweden

[7] Associate Professor & (Interim) Dean, Faculty of Nursing, University of Alberta, Edmonton, Alberta, Canada

CAE: carole.estabrooks@ualberta.ca
LD: derksenl@mala.ca
JNL: lavisj@mcmaster.ca
CW: connie.winther@ualberta.ca
SDS: shannon.scott@ualberta.ca
LW: lars.wallin@karolinska.se
JPM: joanne.profetto-mcgrath@ualberta.ca

Corresponding author:
Dr. Carole A. Estabrooks
Faculty of Nursing
3rd Floor Clinical Sciences Building
University of Alberta
Edmonton, Alberta
Canada T6G 2G3
Tel: +1 780 492 6187
Fax: +1 780 492 9954

Abstract

Background: Gibbons [1] has argued that science and society are in the midst of a far reaching renegotiation of the social contract between science and society with society becoming a far more active partner in the creation of knowledge. On the one hand new forms of knowledge production are emerging, and on the other both science and society are experiencing a rapid acceleration in new forms of knowledge utilization. Concomitantly since the Second World War, the science underpinning the knowledge utilization field has had exponential growth. Few in-depth examinations of this field exist and no comprehensive analyses have used bibliometric methods.

Methods: Using bibliometric analysis, specifically first author co-citation analysis, our group undertook a *domain analysis* of the knowledge utilization field tracing its historical development between 1945 and 2004. Our purposes were: (1) to map the historical development of knowledge utilization as a field and (2) to identify the changing intellectual structure of its scientific domains. We analyzed more than 5000 articles using citation data drawn from the Web of Science®. Search terms were combinations of knowledge, research, evidence, guideline, ideas, science, innovation, technology, information theory and use, utilization, and uptake.

Results: We provide *a bird's eye view* of the intellectual structure and how it changes over six decades. The field does not become large enough to represent with a co-citation map until the mid-1960s. Our findings demonstrate vigorous growth from the mid-1960s through 2004, as well as the emergence of specialized domains reflecting distinct collectives of intellectual activity and thought. Until the mid-1980s, the major domains were focused on innovation diffusion, technology transfer, and knowledge utilization. Beginning slowly in the mid-1980s and then growing rapidly, a fourth scientific domain, evidence-based medicine, emerged. The field is

dominated in all decades by one individual, Everett Rogers, and by one paradigm, innovation diffusion.

Conclusions: We conclude that the received view that social science disciplines tend to be in a state where no accepted set of principles or theories guide research in the social sciences (i.e., that they are pre-paradigmatic) could not be supported for this field. Second, we document the emergence of a new domain within the knowledge utilization field, evidence-based medicine. Third, we conclude that *Everett Rogers* was the dominant figure in the field and, until the emergence of evidence based medicine, his *general diffusion model* the dominant paradigm in the field.

Abstract word count: 367

Keywords: knowledge utilization, author co-citation analysis, structure of scientific communities, bibliometrics, evidence-based medicine

Introduction

Use of knowledge (and science) for betterment of society is an overarching theme in much of western thought. Knowledge plays such a central role in contemporary societies that they have become known as *knowledge societies* [2, 3]. Many facets of contemporary societies depend increasingly on science and technology [3-5]. Science is not, however, separate from society, and developments in the scientific community are linked to societal changes [1]. How to put knowledge to use is a universal human problem. The problem of putting knowledge to use has been characterized in several ways, for example, as a theory-practice gap [6], as a failure of professionals to adopt evidence-based practices [7], as an inability to bring technological innovations to market [8] and as a lag between discovery and uptake [9, 10]. Differences among the various characterizations often occur along disciplinary lines, and along differences in how knowledge is conceptualized, differences in context, and differences in the nature of the producers and users of the knowledge and the particular goals each holds within their context. In the health arena the consequences of not using new knowledge are believed to be dire [11-14] and the agenda of knowledge use has been taken up with vigor – at least among proponents of evidence based decision-making or evidence informed policy processes.

The field of study in which scholars address these gaps and related issues of importance can be generally labeled *knowledge utilization.* Many variations in terminology exist, among them innovation diffusion, knowledge translation, research utilization, knowledge mobilization and technology transfer. These variations commonly signal different groups of scholars and sometimes different disciplines. Members of these groups constitute an unusually diverse collection of scholars from multiple disciplines and backgrounds. While these scholars are readily identifiable to those familiar with the field or one of its sub-fields – despite calls for a *discipline* of knowledge utilization [15-20], such a discipline has not to date emerged. Although

Cottrill, Rogers and Mills [21] conducted a modified co-citation analysis of 110 authors drawn from the early (1966 to 1972) diffusion of innovation and technology transfer literatures, we could locate no published attempts to map the structure of the scientific community grouped under the rubric of knowledge utilization *across disciplines* or to map its changes *over time*.

Purpose

In the study reported in this paper, we undertook a domain analysis [22, 23] using bibliometric methods, specifically (first) author co-citation analysis to trace historical development of the field of knowledge utilization between 1945 and 2004. Our specific objectives were: (1) to map the development over time of knowledge utilization as a scientific field, and (2) to identify the *intellectual structure* of this scientific community.

Domain Background

Knowledge utilization as a field of study

White, Wellman and Nazer [24] make the case that objective maps of intellectual structure produced using author co-citation analysis have a deep affinity with insiders' perceptions of the structure of their own fields. We held such an *insider perception* as we began and that perception is reflected in the following brief overview of the knowledge utilization field and its most obvious sub sets.

Rich has argued that the roots of the knowledge utilization field date back to the time of the ancient Greeks [25] although most scholars date it no further back than the earliest studies in innovation diffusion credited to the French sociologist Gabriele Tardé over a century ago [26]. Numerous literatures and traditions are subsumed within the broad knowledge utilization domain, some of them overlapping. Some authors [27, 28] have conceptualized knowledge utilization as a broad domain over-arching all others. We believe that there has been a strong thread that constitutes knowledge utilization proper whose scholars concern themselves with the

relationship of knowledge (often in the form of scientific research) to policy [25, 29-38]. The most often cited source from this broad overarching knowledge utilization field is Glaser, Abelson and Garrison's [39] encyclopedic review of the literature on the topic. Backer [40] described the evolution of the knowledge utilization field specifically; Valente and Rogers [41] and Rogers [10] described evolution of the closely related field of innovation diffusion.

Backer [40] argued that there have been three waves in the development of the knowledge utilization field, at least in the United States (US). The *first wave* (1920-1960) was dominated by rural sociologists studying the diffusion of agricultural innovations among individuals. Publications in rural sociology on innovation diffusion declined after 1958 when food production in the US exceeded demand, and the push to improve agricultural production with new innovations declined.

Backer's proposed *second wave* (1960-1980) was typified as a time of increased availability of federally funded resources and interests in knowledge utilization and technical solutions to problems, including social problems such as poverty or the uninsured – all the subject of large-scale social experiments. This was a time of proliferation in the knowledge utilization field in the US and of increasing professional and scholarly advancement demonstrated by the creation of several knowledge utilization journals including the *Journal of Technology Transfer, Knowledge, Knowledge in Society*, etc. The first edition of Rogers' *Diffusion of Innovation* was published during this period. In the US in the 1980's, much of the rate of growth of funding for health, human services and education was cut and, in Backer's *third wave*, American interests returned to knowledge utilization due in part to interests in accountability, quality assurance and developments in information technology.

Beal, Havelock and Rogers [42] offered additional insights into the origins of the field of knowledge utilization, termed by them *knowledge generation, exchange and utilization* (KGEU).

Havelock argued that its (KGEU's) parent discipline was sociology and acknowledged social and organizational psychology as important contributors. Rogers in this same volume clarified the importance of the agricultural extension model and its influence on the thinking of scholars in the field.

Diffusion of innovations

One of the most identifiable domains within a knowledge utilization framework, arguably the most dominant at least until recently, is diffusion of innovation. The history of the development of innovation diffusion as a research tradition is well documented [10, 41, 43]. Rogers [44] credited the Ryan and Gross classical agricultural study on hybrid corn as creating the template for classical diffusion theory for 40 years. Rogers [10, 45] identified nine *diffusion* research traditions: anthropology, early sociology, rural sociology (dominant until the 1960's), education, public health/medical sociology, communication, marketing, geography, general sociology, and a miscellaneous *other*. Valente and Rogers used a Kuhnian framework for their analysis of the rise and fall of the diffusion paradigm among rural sociologists – arguing that the diffusion paradigm faded as a result of a paradigm shift.

Technology transfer

Technology transfer has a 40 year history of scholarship [46] with interest in beginning primarily post World War II with periods of heightened interest in the Western world in response to events such as the Cold War, the development of the Space Age and the emergence of economic competition in the 1970s [47]. In Canada, for example, the role of technology transfer has been spearheaded by the Federal Partners in Technology Transfer while in the United States a legislative approach has been adopted; these different approaches to technology transfer have subsequently affected each country's progress. For instance, post World War II Canada was slower than its American and British counterparts to establish technology transfer policies [47].

An emerging emphasis in the health sciences: Evidence-based medicine (EBM)

In 1992 a new group and a new style of knowledge utilization emerged, heralded by the publication of the influential *Evidence-Based Medicine. A New Approach to Teaching the Practice of Medicine* paper [48]. This group of physicians declared a new way of doing medicine – one based on the explicit incorporation of empirical research findings into clinical decision making processes. Their approach coincided, particularly in the United States, with increasing pressures to manage health care in large part by reducing variation across both individual and group physician practices. They drew their lineage from the work of epidemiologist Archie Cochrane who stressed the importance of evaluating medical interventions. Cochrane's work [49] had an important influence on the field of medicine and ultimately resulted in the establishment of the Cochrane Collaboration in 1993. Since the publication of the 1992 EBM manifesto, western society has witnessed a rapid emergence of numerous evidence based centers, journals and resources.

Methods Background

Intellectual mapping using citation analyses

Bibliometric analyses (bibliometrics) provide insight into the growth of literature and the flow of knowledge within specific fields of scientific inquiry. It uses citation data and quantitative analysis to trace published literature and to study the patterns of publication within a field. Hulme [50] described it as "statistical bibliography"; Merton and Garfield [51] as "scientometrics". Pritchard introduced the term *bibliometrics* in 1963 and described it as "the application of mathematical and statistical methods to books and other means of communication" [52, p. 349]. It has been used to analyze scientific products, offering an objective, quantitative evaluation of rapidly growing bodies of literature [53]. It has been used to evaluate the products of science and technology [53] and to outline the history and structure of a field, including

patterns of collaboration among scientists [54]. Moed [55] outlines five general purposes to which bibliometric methods are applied:

1. Assessments of the contributions made by various individual, groups and institutions to advancing knowledge
2. Analyses of global scholarly systems
3. Analysis of scholarly fields
4. Analyses of the science-technology interface and economic contributions of science, and
5. Analyses of education, social and cultural contributions of basic research

His third purpose is the focus of this paper. In analyzing scholarly fields, investigators map structures over time using techniques such as co-citation, co-word, and author co-citation analyses [55, Chap 1]. In our work we used *author co-citation analysis* (ACA) in the manner of White and McCain [23].

What do citations measure?

Moed [55] argues that there are at least five disciplinary viewpoints from which citations are studied and their meanings constructed: physical, sociological, psychological, historical and information/communication-scientific [55, pp. 193-219]; he argues further that scholars often inhabit more than one *school* of thought. Our understanding of co-citation analysis in this paper is most closely aligned with information scientists Small [56],White [57] and McCain [58]. Our belief that co-citation analysis can be used to represent the intellectual structure of a field originates with White and McCain [23]. From Small [59] we use the idea that cited documents are concept symbols. We have also been influenced in our interpretations by different sociological perspectives, among them normative sociologists Zuckerman [60] who viewed citations as markers of intellectual influence and Merton who viewed citation as both reward and payment of intellectual debts [61], as well as constructivists Latour [62] and Callon [63] who view citation as a way of "enrolling allies" to strengthen one's own knowledge claims.

Merton [61] argued that science was a special institution whose members adhered to a special set of norms – communism, universalism, disinterestedness and organized skepticism

[64, 65]. In his view, scientists' only reward for knowledge production was intellectual property rights, given by the acknowledgement of priority of discovery [65, p. 90]. Scientists claim their property rights by offering their knowledge freely, and they receive the reward of recognition in part through citation of their work by others [66, pp. 334-335]. The individual scientific practice of citing the work of others is controlled strongly by institutional norms going back three centuries "to acknowledge on whose shoulders they stand" [67, p. 439]. Citation is a positive sanction which helps individuals to avoid the negative sanctions of plagiarism, and functions to keep scientific knowledge flowing freely. Merton argued that citations denote scholarly influence [68, pp. 54-55], that they can be used as a measure of scholarly value, and that they serve the instrumental function of transmitting knowledge, and the symbolic function of rewarding scientists by recognizing their intellectual property rights [66, p. 334-335]. In short they are *symbolic payment of intellectual debts* [69].

Alternatively in the sociology of scientific knowledge, constructivists such as Latour [62] have argued that authors use citations to legitimate knowledge claims. Latour views stable knowledge as the outcome of strong actor-networks formed partly by "enrolling allies." By citing another's work, an author strengthens his or her own knowledge claim by tying it to those cited, and anyone wishing to contest the knowledge claim must also take on all the stabilized knowledge claims represented by the author's citation list. The social process of making knowledge consists of the successful alignment of initially diverse claims, and if the network is strong enough, the author's knowledge claim becomes an *obligatory passage point* [63]. Any future authors wishing to make claims on the topic must "go through" this passage point (the author's work), which is done most frequently by citation. Baldi [70], in attempting to empirically test the constructivist versus normative explanations, argued that his evidence supported a normative interpretation of citations. Our perspective however, is more congruent

with that of Small [69], who argued that both normative and constructivist interpretations of citation patterns are valid.

Recently, *longitudinal* analyses of the structure and evolution of fields have been reported by White and McCain [22, 23]. White [57], McCain [58], White and Griffith [71] and White and McCain [23] have argued that co-citation maps/citation analyses are powerful tools for mapping the intellectual structure of a field over time.

Author co-citation analysis (ACA)

In author co-citation analysis (ACA) frequently cited and co-cited authors are the unit of analysis [58]. "Cocitation of authors results when someone cites any work by any author along with any work by any other author in a new document of his own" [71, p. 163]. Spatial maps are produced using one of a number of statistical techniques (e.g., cluster analysis, multi-dimensional scaling, factor analysis). Heavily co-cited authors will appear grouped in space with authors having many links occupying central locations on the maps and authors with weaker links (fewer co-citations) appearing on the periphery of maps [58]. White and McCain argued that ACA simplifies literatures to "writings by use" providing "a more rigorous grouping principle than typical subject indexing, because it depends . . .on repeated statements of connectedness by citers with subject expertise" [23, p. 329]. The actual maps in ACA represent an author's *citation image* [23, p. 329]. They proceeded to argue that:

> "The decisive argument for ACA is that it enables one to see a literature-based counterpart of one's own overview of a discipline. In our experience, the agreement between the computed and the private overview is generally quite good. We thus have an answer for the person who looks at our graphics and says "I know all that already." If that indeed is the case, then we have made technical progress, since we can now reproduce much of the disciplinary expert's view on behalf of someone who does not know as much, and we can do it without benefit of the expert." [23, p. 329]

Several reports of ACA are available in the literature. White and Griffith [71] are credited as having published the first *author* co-citation showing intellectual structure. They covered seven years of the information science literature, finding identifiable author groups, which they call *schools*. They identified *border authors* who connect areas of research. White and colleagues argued recently that co-citations reflect *intellectual* structure more strongly than they reflect social structure [72]. The co-citation patterns of a global group of scholars with varying degrees of social ties shows that citation patterns do not follow friendship or acquaintance ties:

> Not only is there an independent effect of intellectual affinity, when it is present there is no effect of social or collegial ties. Although cocitation may well have led to social or collegial relationships in the past – as cocited authors notice each other and develop contact through conferences and correspondence – it is the intellectual affinity reflected in cocitation that the regressions point to, and not the social ties. As a direct effect, it is intellectual affinity, *what they know*, that matters and not social ties, *who they know* [24, p. 125, original emphasis].

Baldi [70] also found evidence that authors are cited for the *content* of their work, rather than citation reflecting relative prominence within a field. The implication is that prominence is the *outcome* of intellectually important work.

Cottrill, Rogers and Mills [73] reported an ACA examining sets of works from the diffusion of innovation and the technology transfer literatures (1966 to 1972), using sets of documents (*oeuvres*) of 90 authors drawn from the diffusion literature, and 75 from the technology transfer literature. They found overlap between the works of the authors that is, people belonged to more than one specialty. Using multi-dimensional scaling and content analysis, they clustered the 110 authors from the two major fields into five subfields: technological innovations and economic growth, organizational innovativeness, diffusion research, communication of scientific and technological information, and geography and quantitative methods.

White and McCain [23] used ACA to look longitudinally at the field of *Information Science* (1972-1995). They argued that change over time was not a given, reporting "overall stability of information science" across the period of study. They concluded that in their case ACA was useful for "rendering the *inertia* of fields" [23, p. 342], noting that their longitudinal maps did not differ from the original map of the information science literature produced by White and Griffith [71].

Invisible colleges

One of the uses to which co-citation analysis is put is the identification of *invisible colleges* [54, 74] – groups of elite, interacting, scientists geographically dispersed but who exchange information to monitor progress in their field [43, 75, 76]. These invisible colleges unify and provide coherence to a research field [77] by mediating large proportions of the informal communication within a field with those most central scholars having most access to critical communication channels [78]. Although the concept dates back to the 1600's in England and the literature is replete with definitions of invisible colleges [76, 77] they are generally agreed to represent social networks or *significant thought (i.e., cognitive) collectives* within a field. The former are commonly studied with sociometric methods, the latter with bibliometric methods. Invisible colleges are aligned with the major domains in a field. Hence a *college* of diffusion scholars are aligned with the diffusion of innovation domain and so forth. The emergence or strengthening of an *invisible college* on one hand or the weakening or loss of one altogether on the other, signal important changes scientifically and intellectually – potentially serving as *canaries* that may herald significant changes in the *ongoing* negotiations between science and society of their (sometimes uneasy) social contract. Although authors who are frequently co-cited may communicate or even know each other, author co-citation as a method maps *intellectual structure* and does not provide direct evidence of *social networks* in a field.

Methods

Search Strategy

We searched the Web of Science online database covering 1945 to October 2004,[1] with combinations of keywords derived from concepts within the scope of the study (see Appendix A for the complete search strategy). Bibliographic information from 14,968 papers was downloaded. The goal of the search was for a balance between *recall* (exhaustivity) and *precision* (specificity). Recall is the number of relevant documents retrieved compared to the total relevant documents [79, p. 304]. To ensure high recall we took additional steps beyond searching with our search strategy. We first reviewed reference lists of key works and second, we searched for the works of key authors. Reference lists were searched that represented health and were relevant to clinicians, managers and policy-makers and were chosen by the investigator group based on expert opinion. Key author names were also searched. An initial list of key players in the knowledge utilization field was compiled and then sent to current experts in the field[2] for review. The list of experts chosen represented different countries, target audiences, and domains of knowledge utilization to ensure a representative and comprehensive list. Additional searching using the reference lists and key author names resulted in an additional 928 titles being downloaded. We calculated our recall at 88.7%, based upon how many of the possible 200 most cited documents were retrieved in our initial search.

Precision is the number of relevant documents retrieved compared to the total documents retrieved [79]. We addressed precision by reviewing all titles and screening for inclusion/ exclusion based on pre-determined decision rules.[3] The titles were reviewed for inclusion/exclusion into the study by the project coordinator (CW) and a group of graduate

[1] The number of documents for 1995-2004 was annualized in the publication counts, with October 27 being the 300th day of 365 days.
[2] Available on request
[3] Available in technical report on request

students studying in the area of knowledge utilization who were paired with an investigator. All pairs had an inter-rater agreement of more than 80%. A total of 7,183 titles were excluded based upon review of the titles using the decision rules for inclusion and exclusion. As a final precision check, the first author reviewed all titles that were excluded from the study to ensure that no titles were inappropriately excluded.

Data Management

Data cleaning involved removing 336 duplicates using the Bibexcel[4] freeware's "remove duplicates" feature; we supplemented this with a manual review of the titles. A total of 3,099 titles that were not "articles" (from the document type field) were excluded, as articles most often represent new scientific production in a field of study [80, 81]. From the initial download of 14,968 titles, 5,278 articles were retained.

Bibliographic data were downloaded from Web of Science. The data files were cleaned prior to analysis by correcting for variance in author name, cited author name, cited documents, journal name and country.[5] The data were categorized by decade, according to the year of publication of the document, resulting in separate files for the periods 1965-1974, 1975-1984, 1985-1994, and 1995-2004.

Prior to analysis, each title was also reviewed by the project coordinator (CW), a health sciences librarian with experience in the knowledge utilization field, and classified according to one or more *domains* of knowledge utilization. The ten domains of knowledge utilization were created by the investigators based upon review of the most frequent keywords used in all of the papers. The domains included *knowledge utilization, policy, evidence-based medicine, technology transfer, diffusion of innovation, guideline, systematic review, knowledge*

[4] http://www.umu.se/inforsk/Bibexcel/index.html

[5] Examples of corrections needed included: in journals, BMJ was identified as both the British Medical Journal or BMJ; in authors, Everett Rogers was identified as E. Rogers or E.M. Rogers; in countries, USA was not identified, but rather states were identified.

management, decision making and *other*. The domains were not mutually exclusive; each title could appear in more than one domain.

Analysis

Analyses were conducted for each decade, starting with 1965-1974. The data were analyzed using Bibexcel freeware, Excel and Systat 4.0. Descriptive analysis including most prolific countries, journals, cited authors and cited documents were completed by aggregating the data. For co-citation analysis, selection of authors was by frequency of citation. Selection of authors for co-citation analysis can be by a variety of means such as personal knowledge, review articles or directories [82, 83].

Maps were produced for each decade using the twenty-five most cited authors. Twenty-five was chosen as a reasonable number of key authors to include maps that were interpretable and not visually overwhelming. In one instance (1965-1974), 13 authors were chosen, as greater or less than 13 authors produced a map that was not readily interpretable. In order to create the author co-citation maps, co-citation matrices were first developed from raw citation co-occurrences using Bibexcel. The matrix of co-citation frequencies were input into Systat 4.0, which uses a multidimensional scaling (MDS) algorithm to find the best-fitting two-dimensional representation of the matrix co-citation entries in the form of a visual map. The goodness of fit between the map and the data matrix is measured with a stress value, with a stress value of 0.2 considered to be acceptable [82]. We assessed each of the co-citation maps produced using Kruskal's Stress measure [23, p. 342] as a reflection of *Goodness of Fit.* Values for Kruskal's Stress 1 measure were 0.06, 0.16, 0.12 and 0.13 for each of the decades respectively. We elected to present raw frequency maps as they were more interesting, with variation in the size of the nodes indicating frequency of citation. We did however reproduce our maps using Salton's

cosine normalization, a standard measure of similarity used in bibliometric studies [84, 85], and found no significant differences and no changes to interpretation of the maps.

The two dimensional author co-citation maps included circles or nodes that represent frequency of author citations, and lines joining the circles represent author co-citation [82, 86]. Thicker lines and closer nodes indicate that the pair are co-cited more frequently and therefore their work is considered to be conceptually similar [86]. These visual maps represent the "important structural features, themes, and relationships in the literatures being studied" [87, p. 125]. We demonstrated structural change over time by producing a separate map for each decade [87, p.129]. To interpret the maps, lists of the cited documents for each of the most cited authors, and information about the domain of study and biographical information about the author were compiled. Using this information, and expert knowledge of the field, the domains of knowledge utilization[6] were overlaid onto the co-citation maps for ease of interpretation of the maps. We present co-citation[7] maps by decade (1965 to 2004); these aggregate the citation behavior of individual citers, resulting in a visual representation of the intellectual structure of the field [71].

Descriptive findings (mapping the field)

Domains and Countries

Table 1 shows that the number of distinct domains in which diffusion research occurs increases over time, with the largest increase in the 1995-2004 decade, when the number of identifiable domains grows to more than ten. Almost half of the articles (2,363 or 44.7%) identify the US as their country of origin. The next largest producers are the United Kingdom

[6] The size of circle on the maps should not be interpreted to reflect the article pool
[7] Our first map is for the decade of 1965-1974 because prior to that there were insufficient authors to create meaningful maps, but our analysis starts in 1945.

and Ireland, with 13.1% of the articles (England (580) + 83 Scotland + 16 North Ireland + Wales 9 + Ireland 7), and Canada 7.6% (400).[8]

Most prolific journals

Bradford's Law of Dispersion or Scattering [88] asserts that the core journals in a field can be divided into three groups, with each group containing the same number of articles. In a given field, the first group will comprise a relatively small number of prolific, or core, journals. The second group comprises a larger group of journals, and the last group includes a much larger number of journals [88].

The 5,278 articles in the analysis were published in 1,897 journals. The journals were rank ordered according to the number of articles they had published from the dataset. Consistent with Bradford's law, there were 95 "core" journals, representing the location of most published research on a topic, 407 journals in the middle zone, and 1,395 journals in the lowest zone.[9]

Table 2 lists the 20 most prolific journals across all decades (out of the 95 core journals), and the total number of articles on knowledge utilization published in each journal between 1945 and 2004. The two top journals across all decades are journals that specialize in knowledge diffusion and innovation: *Knowledge: Creation Diffusion Utilization* (changed its name to *Science Communication* in 1994) and *Technovation* (both are in the top 20). The wide variety in just the top 20 core journals (Table 2) shows a striking degree of inter-disciplinarity in the knowledge diffusion literature.

Table 3 represents the five most prolific journals in Table 2 by decade. Table 3 shows how research on knowledge utilization diffused across disciplines and how the number of

[9] Clearly, knowledge utilization is a problem or topic of interest in many fields, as the 1,897 journals represent a very wide array of academic disciplines. Moreover, Garfield argued that by covering between 500 and 1,000 journals, the ISI database could capture 95% of *all* publications in science [183]. The fact that KU literature is so widely dispersed needs interpreting – but it also shows that even though ISI coverage is limited, the citation lists capture *far* more journals than ISI indexes – adds to validity of search.

publications increased over time. Between 1955 and 1964, publications in *Rural Sociology* dominate among the core journals. This is consistent with accounts that note that until the late 1960s, most diffusion research took place in rural sociology [10, 89].[10]

In the next decade (1965-74), most diffusion publications are located in social science journals, and one library science journal.[11] By 1975, the field of knowledge utilization had become sufficiently cohesive to warrant a specialist journal: *Knowledge: Creation, Diffusion, Utilization* (later *Science Communication*). This journal is the core journal in the field for the next two decades. In the 1975 – 1984 decade two journals emerged – the *Journal of Technology Transfer* in 1975, *Knowledge: Creation, Diffusion, Utilization* in 1979*,* and a third *Knowledge in Society* shortly thereafter in 1988. Two professional societies also emerged: the Technology Transfer Society founded in 1975 and the Howard R. Davis Society for Knowledge Utilization and Planned Change, founded in 1985 [40]. In 1985-1994 the *Journal of the American Medical Association* enters the field of core journals, and in the next decade (1995-2004), three of the most prolific journals are health journals.

Most Cited Authors

Table 4 indicates the top-cited authors in each decade in the reference lists of the 5,278 articles in the dataset, broken down by decade. Table 5 shows the top-cited document in each decade. The top-cited author in 1945-1954 is H. W. Seinwerth, an industrial relations manager in the field of animal husbandry, from Chicago. In 1955-64, the top-cited author is Eugene Wilkening, a rural sociologist at the University of Wisconsin, Madison.[12] His technical bulletin

[10] The larger data file shows that 21% of the 81 journals that published articles in this decade have the ISI Subject Code "Sociology."

[11] Note: at this time "Special Libraries" was a journal devoted to picture and art librarianship. It published 10 articles total on this topic.

[12] The University of Wisconsin, Madison was one of the first, if not the first rural sociology departments in the US.

on improved farm practices is the top-cited document in this decade. This reflects the prominence of rural sociology in diffusion research at this time.

Looking at the domain field in Table 4, we see that most citations across all decades (except 1945-54) refer to work in the diffusion of innovations field. This field is the parent domain, which arguably provides the conceptual and theoretical core for work in other domains. Everett Rogers had a significant impact on this field; he is the top-cited author in all decades from 1965 to 2004 (Table 4), and various editions of his book *Diffusion of Innovations* are the top-cited document from 1964 to 1994 (Table 5). In the last decade, Rogers' book is supplanted as top-cited document by what was to become the index paper for the newly emerging field of evidence-based medicine [48].

"Top cited" documents are important as they indicate the content and meaning that is most often employed by citing authors [56, p. 200]. Rogers' centrality in both Table 4 and Table 5 indicates that his work is highly used by all fields. Each edition of his book covered all known diffusion studies at the time of publication, and through its wide citation he created a language of diffusion that scholars from widely disparate fields shared. He became synonymous with the theory of innovation diffusion for more than six decades, becoming what Callon [63] has called an "obligatory passage point" for knowledge claims about diffusion. The first edition of Rogers' book was published in 1962 and, as Table 4 and Table 5 indicate, from this point forward his work holds significant place and meaning for the community of scholars studying diffusion.

Longitudinal findings (the intellectual structure)

The field over time

The evolution of the knowledge utilization field by decade illustrates the emergence of both new more robust domains over time. Collins has argued that relatively small numbers of privileged scientists exist at the *coal face* of knowledge production. These scientists produce

their "scientifically certified knowledge" through not only experimentation but also the resolution of scientific controversies. Collins labeled these scholars *core sets* [90, 91].[13] The authors we identified as *core set* authors are represented in the maps in Figures 1 – 4 and highlighted in Table 6 by decade. The core set of scholars on the map in the first decade (1965-1974) are from very different disciplines (sociology, economics, geography, management, information science), but are linked by their work in innovation diffusion. The maps show that over time, the members of this core set become central figures in the distinct subfields which represent their original disciplinary orientation. However, the maps also show that no theory of innovation diffusion supplants that produced by Everett Rogers (1931 – 2004).

1965-1974

The first first-author co-citation map (Figure 1) shows a cohesive [92] group of co-cited authors who come from disparate disciplines. They are linked by their common focus on aspects of the diffusion process and the gap between research and practice, and constitute the core, or parent domain of diffusion of innovations. The largest, most central node belongs to Everett Rogers who in this decade published two editions of his groundbreaking work *Diffusion of Innovations* [93] (the second edition was titled *Communication of Innovations: A Cross Cultural Approach* [94]). This work marks the first analysis of all known diffusion studies [93, 94], and also the first, and most successful, attempt at a general theory of diffusion. The citation patterns show that from the outset, Rogers' theory of innovation diffusion constituted the main paradigm guiding intellectual work in diffusion of innovations.

[13] Collins distinguished these *core sets* [90, 91][0] from collections of scientists such as *invisible colleges* who are closely connected in a variety of ways. He argued that core-set members are not necessarily in frequent or sustained contact. So while Collins' understanding of core-sets differs significantly from the idea of invisible colleges in this paper, it is useful to the extent that it enables us to identify a small group of scholars who were actively engaged in the production and certification of knowledge.

Above Rogers' node is Elihu Katz, a sociologist and diffusion researcher who was linking disparate fields of diffusion research, such as communication and agricultural innovation [95, 96]. Katz' and Rogers' nodes are close to and strongly linked to the nodes of sociologists James S. Coleman and Herbert Menzel, who worked with Katz on the social aspects of the diffusion among doctors of the new antibiotic tetracycline [97, 98].

Below Rogers' node, and close to it, is Edwin Mansfield, an economist then writing about the diffusion of innovations in business firms [99-101]. Mansfield is linked to both Rogers, and another economist, Zvi Griliches, who examined the economic factors affecting the diffusion of hybrid corn [102]. Directly below Mansfield is Thomas J. Allen, whose work is linked to Rogers through Mansfield. In this period, Allen studied research and development organizations, looking at how engineers and scientists communicated and solved problems in organizations [103]. Although all three of these scholars were associated with technology transfer, the content of their work was quite different [104, 105] from each other.

To the right of Rogers, and strongly linked to him and to Griliches, are geographers Torsten Hägerstrand and Lawrence Brown, who researched the spatial aspects of diffusion theory [106-108]. Hägerstrand also did research in the diffusion of agricultural innovations, using Monte Carlo game theory to simulate the diffusion of farm practices [109, 110].

To the left of Rogers are sociologist Alvin Gouldner, management theorist W. Jack Duncan and philosopher C. West Churchman. Gouldner [111] studied the differences between "cosmopolitans" (people who went fairly often to a larger city) and "locals" – and the roles that they played in organizations. Duncan wrote widely in the area of organization and management theory, studying how to transfer management theory to practice [112]. Churchman studied the gap between managerial decisions and scientific knowledge [113, 114]. At the very bottom of the map, very distant and not linked to the rest of the scholars, is Gerard Salton, an information

scientist who examined the link between information dissemination and automatic information systems [115, 116].

1975-1984

The map of this decade shows a rapid uptake of diffusion scholarship by authors from a variety of fields. The parent domain diffusion of innovations grows; Rogers' node remains the largest on the map. This decade also shows the emergence of two new branches from the parent domain: technology transfer and knowledge utilization (Figure 2).

Diffusion of innovations: Everett Rogers' node is again the largest and most central on the map. Sociologists James Coleman and geographer Lawrence Brown remain with Rogers in the parent domain of innovation diffusion.

Knowledge utilization: At first glance, it appears as if the domain of knowledge utilization developed out of nowhere. However, key scholars in this field Edward Glaser and Ronald Havelock were among the most cited authors in the previous decade (1965-1974) but were not on the map.[14] The conceptual center of this new domain is the work of a new group of scholars: Carol Weiss, Nathan Caplan and Robert Rich. In this decade they share a research focus on the use of social science research in public policy [34, 38, 117]. They are also all strongly linked to the parent domain of diffusion of innovations, particularly to the work of Everett Rogers. The large number of links between clusters within this domain indicates that there is a high degree of use of these scholars' ideas by citing authors. The field is also fairly tightly clustered, suggesting a high degree of conceptual similarity among authors.

Moving out from the center, we find the nodes of Edward Glaser, Ronald Havelock and Robert Yin. Havelock's earlier research [19, 118, 119] examined how knowledge could be used to *plan* for innovation. Almost 15 years later, Glaser followed on this theme by co-authoring the

[14] That they are not on the map is a function of numbers, they do appear if we allow 50 authors

influential *Putting Knowledge to Use: Facilitating the diffusion of knowledge and the implementation of planned change* [39]. Yin's research is conceptually different, focusing on how new practices become routine [120], and the role of networking in knowledge utilization [121].

On the other side of the central core are Mark van de Vall, Ian Mitroff and Robert Merton. Van de Vall's main research interest in this decade was on the theory and methods used in applying social science research [122, 123]. Merton, although known for his work in the sociology of science, particularly the *Matthew Effect* [124] is cited in this decade for the first and revised editions of his book *Social Theory and Social Structure* [125, 126], and for his work on focused interviewing [127]. The links on the map show that he is fairly strongly linked to fellow sociologist James Coleman, in part at least because their careers overlapped **--** Merton was at Columbia from 1941-1984 and Coleman received his PhD from Columbia in 1955. Merton had done previous research in medical sociology on the training of student physicians [128]. Ian Mitroff was also a sociologist of science. In this decade he was most cited for his 1974 book *The Subjective Side of Science* [129] where he examines the wide gap between the finished products of scientific work (publications) and the actual processes of forming knowledge. Mitroff is particularly important for identifying "counter-norms" (counter to Merton's set of norms) which also guide scientific practice. For example, the norm of disinterestedness exists alongside the counter-norm of being deeply, personally committed to one's own work and theories.

Technology transfer: The domain of technology transfer is characterized by a relative lack of links between individuals within the domain, and more links back to the domain of diffusion of innovations. There is no one single conceptual core in this field in this decade. Mansfield and Allen have moved from the parent domain of diffusion of innovation. However,

as noted above, and by the citation lines, their work is quite different, as each is more closely linked to the domain of diffusion of innovations than they are to each other.

The economist Mansfield has the largest node, his work is at the "geographical" center of the field and has the most links to others' works. However, even with Mansfield whose work differs significantly from that of Rogers, most links are back to the parent domain of diffusion of innovations. Mansfield's top citations are to works from the late 1960s and early 1970s that examine the economic aspects of technological change in organizations [130-132].

Allen's most cited research is focused specifically on Research and Development laboratories, including his 1977 book titled *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization* [133-135].

Quite distant from Mansfield (indicating conceptual distance), the work of geographer Brown is also still strongly linked to that of Rogers in the parent domain. However, Brown is linked to the economist Mansfield through the work of Mahajan.

The domain of technology transfer is quite different from both the parent domain and knowledge utilization. It also has writers that are quite conceptually distant, and whose work is quite distinct, such as the Federal Insurance Corporation, and Vernon who studied international technology transfer including the role of timing of the innovation [136]. There are also writers whose work spans domains, such as Utterback who writes on technological innovations within organizations [137] and Aiken who writes on the effect of organizational structure on technical and administrative innovation [138].

1985-1994

Figure 3 shows three trends in the 1985 and 1994 decade. First is the emergence (at the left of the map) of evidence-based medicine – see the work of Lomas, Eddy and Haynes. Second,

the domain of diffusion of innovations shrinks although Rogers' node continues to dominate the map. While the field of innovation diffusion continues to be vibrant, most of its activity was in the style of Everett Rogers. Additionally, Rogers came out with another edition of his book in this decade. Rogers continued to be active in this decade, and in fact until his death in 2004. Several other important authors in this field in this decade have also continued to be active, among them Kimberley (http://www.wharton.upenn.edu/faculty/kimberly.html), Allen (http://esd.mit.edu/HeadLine/allen030106/allen030106.htm) and Zaltman (http://drfd.hbs.edu/fit/public/facultyInfo.do?facInfo=pub&facEmId=gzaltman).

Third, the knowledge utilization field shows signs of strengthening. The two new journals started during the previous decade created arenas in which scholars in knowledge utilization and diffusion could exchange ideas and develop the interdisciplinary application of science knowledge [73, p. 182]. The emergence of these and other journals and societies as noted earlier were indicators of growing disciplinary cohesion. The domain of knowledge utilization became more homogenous than in the previous decade. Authors who remain highly cited in the knowledge utilization domain comprise the current intellectual core set of the field. Some authors whose work has not continued to be central to the domain of knowledge utilization no longer appear, among them Van de Vall, Mitroff, Merton and Yin.

1995-2004

The map for 1995-2004 (Figure 4) shows a continuation of the trends that emerged in the previous decade. Most notably, the field of evidence-based medicine (EBM) exhibits significant growth, with the entrance of several new authors. While it appears that the other domains have gotten smaller in this decade, the maps are limited to the 25 top cited authors. To check to see if the shrinkage was real or an artifact of the number of authors on the map, we re-ran the map with

the 50 top cited authors.[15] That map showed even more growth in the field of evidence-based medicine, but also showed the technology transfer and knowledge utilization domains continuing as vibrant.

The innovation diffusion domain appears to have retracted, although Rogers' citation node continues to grow. On the map of the 50 top cited authors, the only author to enter the innovation diffusion domain is Bozeman, who had previously been in the knowledge utilization domain. Other than this, even with 50 authors, the innovation diffusion domain had largely been conflated to represent Rogers' work. Given the dominance of Rogers' node in all decades, we argue below that Rogers is a canonical author [23], that his book *Diffusion of Innovations*[16] is a canonical text for all the domains, and that his approach to innovation diffusion by this decade (and probably earlier) represents the dominant paradigm for conducting diffusion research. The presence of such a dominant author stands in contrast to, for example, the information sciences field characterized by the absence of a strong central author [23].

In this decade, the most cited article is the index evidence-based medicine paper. For the first time this new group is named (Evidence-Based Medicine Working Group) and the term enters the lexicon [139]. The paper was published in a highly visible and accessed medical journal and included 29 members, among them members on the map for this decade, Guyatt, Haynes, Oxman and Sackett (chair of the group). After the article was published, the authors wrote more articles, cited the original article [140-143], toured and gave numerous talks – and asked physicians *why wouldn't you want to use the best available evidence to guide your practice*? Their work also coincided with emerging concerns about rising health costs and

[15] Available on request
[16] The fifth edition of his most cited book *The Diffusion of Innovations* was published in 2003, and Rogers died late in 2004.

increasing accountability pressures (the timing was right) such as have been described by Nowotny and others [2, 144-146].

Sociologist James Coleman reappears in this decade, in the domain of diffusion of innovations. He was a prominent American sociologist who focused on the sociology of education and public policy, but his early work was in the sociology of medicine. The work most cited is the well known tetracycline study in *Medical Innovations: A diffusion study* [98]. While this reappearance of older work has been described by White and McCain and may be a sign of the revival of a domain [23, p. 342], we argue there is not a "revival" of a domain, but rather a reappearance of this one work, which is highly relevant to the new project of evidence-based medicine. Coleman is highly cited in works related to the diffusion of innovations within healthcare (e.g., [147-149]).

During the last two decades, the significant majority of new people entering are in the field of evidence-based medicine. Key figures exiting are Bozeman, Dunn, Glaser and Rich from knowledge utilization; Kimberley and March move from diffusion of innovation. Glaser's citations, for example, are all to his 1983 book which at the time was a momentous achievement in a relatively sparsely populated field. By the mid-nineties with no updated edition not only it is cited less, but also there are many additional papers in a rapidly expanding field and set of sub-fields. Over time, the separate domains show increasing conceptual cohesiveness – citation nodes move closer to each other within the field, and the fields as wholes are more easily separable from the other fields (the contrast is particularly vivid when compared to the 1965-1974 decade in Figure 1).

Canonical authors and canonical works

We identified a number of "canonical authors" whose work has enduring importance to the field. White and McCain [23, p. 349] defined a canonical author as someone who appeared

on the citation maps in three or more decades. We define a canonical author as someone who was on at least the last three maps (1975-2004) and any maps prior to that. Our canonical authors were: Everett Rogers and Gerald Zaltman (innovation diffusion), Carol Weiss and Ronald Havelock (knowledge utilization), and Edwin Mansfield and Thomas Allen (technology transfer). Rogers, management scientist Allen, and economist Mansfield were the only authors who were *top-cited* in all decades, excluding 1945-1954. The most cited works of these authors constitute, we argue, the canonical literature of the science of knowledge utilization as it entered the 21st century.[17] It is clear from the size of the nodes on all maps and the number of citations accrued that, over all decades, the intellectual structure of the field is dominated by the work of Everett Rogers. Rogers' work *is* the paradigm for diffusion research, until the emergence of evidence-based medicine in the last decade. Of the four domains, only technology transfer and diffusion of innovation have authors associated with them in all four decades.

Diffusion of innovations

Since the 1962 publication of Roger's now classic book *Diffusion of Innovations*, which went through five editions before his death in 2004 (1971, 1983, 1995, 2003), Rogers was and remained the central author in the broad field of knowledge utilization. Rogers' theory has been the dominant and most consistently used theory since inception of diffusion research [150, 151]. He based each edition on an analysis of all retrievable diffusion studies, regardless of field. For some canonical authors such as Mansfield, it is only their earliest work that is top-cited in all decades. However, different versions of Rogers' general theory are cited throughout the decades [10, 93, 152-154] suggesting that Rogers' influence was and continues to be a fundamental force.

Gerald Zaltman's most cited works were *Innovations and Organizations* [155] and *Strategies for Planned Change* [156]. His work although strongly pro-innovation also reflected a

[17] Given publication delays of sometimes up to two years it is unlikely that we have captured the state of science in the field beyond about 2002.

belief that innovation should not be accepted unquestionably. His main contribution to the field was to offer insight into the importance of individual users of innovations to the diffusion process. He proposed that to understand how innovation diffusion truly occurs we need to study demand characteristics, such as users' ability and willingness to seek and process innovations.

Along with Katz and Menzel, Coleman conducted a widely cited diffusion study that investigated the spread of the prescribing of a new antibiotic among physicians [157]. The finding of this study highlighted the importance of interpersonal networks in the diffusion of new medications. It was a catalyst for future investigations in this area. Rogers found this work of key importance in formulating his first version of his theory of innovation diffusion. Later, Coleman advocated for a new approach to policy research, one that engaged real world problems and produced relevant action oriented solutions. He is known for his publication *Foundations of Social Theory*, and is considered one of the earliest users of the term "social capital".

Knowledge utilization

Carol Weiss was most cited for her works *Knowledge Creep and Decision Accretion* [38] and *Using Social Research in Public Policy Making* [158]. She continues to publish [159, 160]. She expanded initial views of research use as an *instrumental* application of research to inform a decision, to include *conceptual* or *enlightened* use **-** when findings from research influence decision makers' attitudes to and perceptions of a social problem [161]. She described several models of utilization: knowledge driven, problem solving, interactive, political, tactical and research as part of the intellectual enterprise of society [37]. An advocate of using research findings to inform public policy, she was among the first to examine the utilization of evaluation findings in improving program processes and program outcomes [162]. Her articulation and extension of the concept *research utilization* was an important contribution to the field of knowledge utilization [163].

Ronald G. Havelock is recognized in the knowledge utilization field for his extensive work on knowledge use, change planning and technology transfer. Author of *Planning for Innovation through the Dissemination and Utilization of Knowledge* [118], his work spanned many fields most notably education and medicine. Building on Rogers' *Diffusion of Innovations* [93], Havelock developed a framework to aid in the understanding and improvement of the dissemination and utilization (D & U) of knowledge in the social sciences. Guided by an extensive search and analysis of the D & U literature from education and beyond, he proposed an often cited "linkage model" that connects researchers with end users in a two-way exchange of information that mutually enhances problems solving.

Technology transfer

Edwin Mansfield exerted a significant impact – even in later decade maps citations to his early work are high. An influential economic analyst of technology, his contributions included generation of information regarding the length of time required for firms to uptake decisions and products used by rival firms and how this information is spread from one firm to the next. He also studied the proportion of new products and processes that are based on academic research and the amount of time needed for such research findings to be incorporated into the commercial environment. Citations in all decades are to Mansfield's work in the early 1960s [132, 164, 165]. In other words, he wrote some articles that became concept symbols [59] or canonical pieces.

Thomas J. Allen has made significant contributions to various fields, including technology transfer. Allen studied the ways in which formal and informal associations within organizations contribute to the diffusion of knowledge. He identified "gatekeepers" as important individuals within organizations who bring new knowledge into their organization both by reading literature and by engaging with others outside of the organization. He found that new ideas are spread most commonly through informal mechanisms such as personal contact in small

manufacturing firms. Allen also studied the influence of distance on information transfer and developed the *Allen curve* which depicts the inverse relationship that exists between distance and the frequency of communication [133, 134, 166].

Vijay Mahajan, in the department of marketing at the University of Texas at Austin, writes on developing knowledge in the areas of marketing strategies, product diffusion and research methodology. Mahajan is responsible for adding the temporal element into a model originally designed by Blackman [167] to explain technological substitution. He has made important contributions in the area of product diffusion and has studied the diffusion process in developing countries, which he argues is an important but understudied area [168, 169].

Discussion

We set out to trace the historical development of the field of knowledge utilization by mapping its development over time, and identifying the intellectual structure of this scientific community. The major contribution of this paper is its "birds eye view" of the field and how the field has changed over time. In this discussion we contextualize the major findings and expand on four discussion points: (1) development of the field, its specialization and changing perspectives, (2) our inability to claim that this field (perhaps emerging discipline) is pre-paradigmatic, (3) the emergence of Everett Rogers as a canonical figure in the field and (4) the emergence of a new domain – evidence-based medicine – within the knowledge utilization field.

By simplifying bodies of scholarly literature to "writings related by use" [23, p. 329] the maps and tables presented in this paper represent whose scholarly work in the knowledge utilization literature has been most utilized by citing authors, and how an aggregate view of use depicts the intellectual structure of the field. The maps in Figures 1 through 4 compiled from

aggregate author co-citation data, link *oeuvres* (the collection of works by a cited author[18]) and offer a panorama of the changing intellectual structure of the field, showing the "history of the consensus as to important authors or works" [57, p. 100].

1. Development of the field and its intellectual history

Our first major finding is that new domains within the field now generally referred to in the literature as *knowledge utilization* have emerged over time; in earlier generations, the term most widely used was *innovation diffusion*. We argue that although all of the domains we identify are concerned with the use of knowledge in some way, they change and take on distinct specializations and perspectives over time and continue to be strongly linked to innovation diffusion. This finding is in contrast to White and McCain's [23, p. 342] longitudinal author co-citation analysis of the information science literature, where they found tremendous *inertia*, or lack of change over time. They argue that their maps could have looked different at the separate time points if there had been major changes in the field. Our maps *do* look different in each decade, reflecting continuing change and growth in the intellectual structure of the field. The 1965 map represents authors from a wide variety of academic disciplines whose common object of inquiry is conditions surrounding the use or application of scientific knowledge. In the 1975-1984 decade knowledge utilization and technology transfer emerge as distinct areas of study, and in the 1985-94 decade evidence-based medicine emerges. Over the decades new areas emerged, centered on the work of canonical authors who were already working in the field, before it divided into sub-fields.

[18] White and Griffith [71, p. 163] describe *oeuvres* as a set of writings by a co-cited author. It is important to note that while an author's node on the map likely represents more than one of their publications, it does not guarantee that *all* of the author's publications are represented. The only works that will be represented are those that are co-cited with the other authors in the analysis. So, for example, someone might write one article early in their career that is cited for many years, but other works by the same author might not be co-cited.

The origins of this broad knowledge utilization field lie in the study of the diffusion of agricultural innovations in rural sociology, credited by Rogers as dating back Ryan and Gross' hybrid corn study. In a modified co-citation analysis of the diffusion of innovation and technology transfer literature between 1966 and 1972, Cottrill, Rogers and Mills found that the majority of the members of their diffusion of innovations cluster were from sociology [73, p. 200]. In Table 5, Wilkening's work on the diffusion of agricultural innovations is the top-cited work in the 1955-1964 decade. By the late 1960s, research on the diffusion of innovations in rural sociology had virtually died out, possibly because it solved the particular problem of producing and disseminating means by which high yield crops are produced. Table 1 shows that in each decade since 1945, the broader field of diffusion of innovation has branched off into sub-fields.

A second important finding is that, over time, the initial core set of authors in diffusion research branched off to become the intellectual center of their new fields. In other words, new fields branch off from the original field of innovation diffusion, and at the core of each of these new fields (with the exception of evidence-based medicine), we see one of the authors in the first or second decades. Rogers and Mansfield emerge from the first decade as central to innovation diffusion and technology transfer in later decades respectively. Weiss, Caplan and Havelock appear in the third decade and remain in each subsequent decade under the knowledge utilization domain. Evidence-based medicine first appears in the 1985-1994 decade with three authors, Eddy, Haynes and Lomas. Lomas is a *border author* providing the primary connection between evidence-based medicine and innovation diffusion (and to a lesser extent knowledge utilization) [71].

2. Challenging Kuhn's notion of pre-paradigmatic: The diffusion of diffusion

The social sciences have been characterized, most famously by Kuhn, as being "pre-paradigmatic," a state where no accepted set of principles or theories guide research in the area [170]. Kuhn suggested that the social sciences were characterized by disagreement and lack of consensus and argued that the natural sciences are characterized by long periods of *normal science* where practitioners are guided by a single theoretical model, which aids them in solving puzzles that fit within the paradigm. During times of *normal science*, knowledge accumulates because work is guided by a single paradigm with scientists working to solve puzzles in their areas of specialization. In 1979 Small and Crane [92] found evidence that the fields of economics, psychology and sociology were developing in a manner more characteristic of the natural sciences. Kuhn further argued that natural science does not progress in a cumulative fashion, but is instead punctuated by revolutions that radically alter the theoretical rules that inform practice. Here, in the overarching field of knowledge utilization, we find no evidence of the fragmentation and allegiance to multiple-paradigms predicted by Kuhn [171].

Valente and Rogers [89] claim that the pre-paradigm period in innovation diffusion was in the 1930s, and that the paradigm was set by Ryan and Gross [172]. Although in 1983 Rogers [152] claims the Ryan and Gross article as the top cited one in diffusion literature, our analysis found that that various editions of Rogers' books are by far the highest cited documents in the innovation diffusion literature. Our findings also provide strong evidence that this social science field is more like Kuhn's portrayal of the natural sciences during periods of normal science. There is a paradigm from the beginning – when Rogers publishes the first edition of his book. We believe that Rogers' work had such a significant impact because it was the first, and continued to be the only work that offered a general theory of innovation diffusion. Further, Rogers' synthesis of most known empirical studies of diffusion remained useful to scholars.

From the outset, by studying widely across fields, looking for commonalities in the diffusion of innovation, Rogers established himself as an *obligatory passage point* [63]. All subsequent scholars *had* to cite Rogers to acknowledge his work and pay their intellectual debt [61]. But more than this, Rogers' theory was the only general theory of diffusion, and perhaps because it was developed based on studies of diffusion in many fields, scholars and practitioners found it useful in guiding research in their own more specialized fields. Over time Rogers' work remains central, likely because he was the only one who continued to analyze all known diffusion studies, regardless of field, in the service of updating and refining his theory, to make it more widely applicable. Over the decades, we see people in other fields take up his theory, import it and apply it to their own more specialized problems. They use it to solve "puzzles" in their own, increasingly specialized fields.

The maps show growth and specialization over time, not fragmentation as predicted by Kuhn. Our study suggests that if Kuhn was correct, then we have an atypical social science field, growing in an atypical way. The knowledge produced about diffusion gets taken up and used – it does not languish. People on this map share many assumptions, and their intellectual debt to the work of Everett Rogers shows in the persistent size of his node, and in the strong links to each newly emerged field, including EBM. Zuckerman [60] argued that citations indicate intellectual influence. If so, no single person has been more influential in this field than Rogers; many if not most on this map share an intellectual debt to him. Rogers put forth a "generalized model of diffusion" [10, p. 16] in his first book [93] and "set forth common findings to date, arguing for a general diffusion model, and for more standardized ways of adopter categorization" [10, p. 16].

Although the study of diffusion in rural sociology became exhausted in the 1960s [41], Rogers argued [10, p. 19] that diffusion research was not dead or dying: "The number of diffusion publications completed per year continues to hold steady. Unlike most models of

human behavior that begin to fade after some years of use, the diffusion model continues to attract strong interest from scholars." We also did not find a "fading" of the diffusion paradigm. Our citation maps show that there is not a shift away from the diffusion paradigm; rather, there is a spread of the paradigm to other fields and areas of specialization. There is clearly a content shift away from the concerns of agriculture; this is clear from the titles of the articles of the most-cited authors.

The influence of Everett Rogers

Everett Rogers with the publication of his 1962 book became, as we have argued, an *obligatory passage point* [63]. His continued publication of updated editions of that book [10, 93, 152-154] ensured that he *remained* an obligatory passage point making it we propose nearly *de rigueur* to cite Rogers when writing in the knowledge utilization field. This may change if evidence-based medicine continues its explosive growth; we observed that its proponents were less consistent in their citation of Rogers than those in other sub-fields.

Rogers is generally viewed as one if not the most influential social scientist of the last hundred years. His book is one of the second most cited in the social sciences. Some reasons for this influence are obvious. He worked in several universities (among them Iowa State, Michigan State, University of Southern California, University of Michigan, University of New Mexico) and had many academic associates, among them some of the original diffusion scholars – Beal, Coleman, Gross, Ryan and Wilkening. He worked on projects in many countries; he was invited to speak widely and often. He had many graduate students and colleagues and was known for his generosity and gift for bringing people and institutions together. He shared authorship and ideas widely. He lived a long and productive life. Rogers completed his doctoral work in 1957 at the age of 26 and remained active as a scholar for the next 47 years. He wrote 36 books and more than 350 refereed journal articles [173] including a new edition of his well known *Diffusion of*

Innovations about every ten years (1962, 1975, 1983, 1995, 2003). His last published paper appeared posthumously in 2005 [174]. In it, Rogers reflected on his own unique place in the emergence of the diffusion model and on the model's origins in the literature review chapter in his dissertation. Of central importance is that he created a common language with which scholars could talk about diffusion – by emphasizing the term diffusion "rather than the plethora of terms that had been used for this concept" [175, p. 16]. He concluded that "… it seems there is indeed a general diffusion model" [175, p. 19].

From a science studies perspective, by studying every known diffusion study regardless of discipline, Rogers unknowingly enrolled thousands of *allies* to his cause [62]. We are not claiming this as his intent, but by taking something from a wide range of fields (the empirical studies of diffusion), and by giving back something to every field (a general theory of diffusion and a common language), Rogers built a formidable knowledge claim. It is also important to note, however, that citation studies find that authors are cited for their usefulness and for their merit. The story could have unfolded differently if the scholars in the field had not found Rogers' theory to be of use in solving problems in their own areas. In other words, Rogers is not important just because he studied all known diffusion studies, but because he did this and produced a useful theory; *he got it right,* so to speak. His theory of innovation diffusion has been shown to be stable and predictive and of use to a wide array of scholars in diverse fields. However, *getting it right* is no guarantee of success. The history of science is replete with people who *got it right* but who were not credited as such, or people that only time proved were right. Perhaps most famously, in the 19th century Pasteur's germ theory won out over Pouchet's theory of spontaneous generation – not because the evidence supported Pasteur, but because the members of the French Académie des Sciences were biased in favor of Pasteur, and because he got lucky. At the time, an "evidence based" decision would have supported Pouchet's theory

[176]. In addition to getting it right, success of the kind that Rogers and his theory of innovation diffusion have earned over the decades is a complex blend of crafting and winning credibility among peers [177], and having one's knowledge claim noticed and taken up by some relevant community [62, 91].

The emergence of evidence-based medicine

In this paper we have presented a largely descriptive picture of the growth of the field known broadly as innovation diffusion. We have shown that until recently, research in this field has been informed largely by one theoretical paradigm, laid out in the work of innovation diffusion scholar Everett Rogers. We have shown how the field began with a core set of scholars from many disciplines with a common interest in innovation diffusion. We have shown that over time, this core set of scholars formed the core of new but related fields. We demonstrated that in the mid-1980s another field emerges (evidence-based medicine). This field is linked intellectually particularly to Everett Rogers, primarily through the work of Jonathan Lomas who is strongly linked to Haynes in evidence-based medicine.[19] The work of Eddy pulls more widely from the field of knowledge utilization, as well as from scholars in the parent domain of innovation diffusion. In the 1990s, we see the field of evidence-based medicine growing and drawing from the fields of technology transfer, knowledge utilization and innovation diffusion.

We argue that the rapid emergence of this new domain is possible because its adherents practice a form of scientific output that differs significantly from those in related fields. This production of outputs is characterized by an emphasis on systematic reviews of the research literature in particular. Its adherents tend to publish in journals with unusually high impact factors and wide dispersion. Their emphasis is arguably more vigorously focused on instrumental

[19] For many in this field that we have labeled with the cover term *evidence-based medicine*, the cover term would need to be broader, for example –evidence-based practice, evidence-based nursing, evidence-based decision making, etc. Terminology in this field is complex even when within the health disciplines. For instance, recently we have seen the emergence of the term *evidence-informed* decision –making.

ends (the use of clinical research to improve outcomes) and their emergence coincided with emerging foci on accountability and cost containment, and more recently foci on value for money and accountability for performance in health services. Although not yet apparent in this decade, it is likely that subsequent decades if mapped with a wide enough net will reveal an explosion of related fields within evidence-based medicine, comprised at least of quality improvement and safety sub-sets. Evidence-based medicine adherents may represent a new epistemic culture of knowledge production [178].

We believe it is the Evidence-Based Medicine Group's emphasis on systematic reviews and their dissemination, in particular, that creates the conditions for this new form of knowledge production. Rogers, working without the aid of computer databases (for much of his early career at least) did the same thing. He poured laboriously through all known diffusion studies. In this regard there are similarities. Rogers' goal, however, was a general theory of innovation diffusion. Evidence-based medicine's goal is prescriptive while being rigorously empirical – to guide and inform medical practice, working from a model in which the "gold standard" in medical knowledge has been defined. Rogers sought to understand *the process* of how new innovations were diffused. EBM may be creating by example a new way of diffusing innovations. Its members have *used* the innovation diffusion literature and are linked in many ways to this literature. But this epidemiology based group has not as yet evidenced an intent (nor we argue should they necessarily) to build theory about knowledge utilization, technology transfer or innovation diffusion. Rather, it is highly prescriptive and characterized by a strong underlying assumption that practitioners of evidence-based medicine have (or can get) the best knowledge and the best knowledge production model. They are linked to the original problematic of innovation diffusion through the age-old problem of the theory – practice gap.

Limitations

Most of the limitations of this study are typical of bibliometric studies generally, including the inclusiveness of the Web of Science, inaccuracies in the various databases, analysis by first authors only, and limited knowledge of the context of citation. We chose the Web of Science as it contains all of the necessary fields to conduct bibliometric analysis and is a multidisciplinary database [179]. The Web of Science, however, does not represent all disciplines equally and therefore knowledge utilization articles within sciences or health care are more likely to be represented than knowledge utilization articles within the social sciences. Publication counts such as number of publications by author or country, number of journals and so on are therefore biased toward sciences and medicine. However, citation analysis such as author co-citation analysis is not affected by the journals indexed in the Web of Science, as all cited documents are listed regardless of whether or not the journal is indexed in the database. Spelling and bibliographic variances are common in databases [180], and can cause errors in publication counts. We corrected for these variances by undertaking a detailed manual review and correction of variances. Lastly, conducting analyses by first authors attributes all contributions of a work to only the first authors.

Three specific criticisms are leveled at author co-citation. First, resulting maps may omit authors an informed reader may view as central [57]. In this case, the reader may disagree (as he or she is free to) with our judgment sample. Second, such maps may fail to reflect an informed reader's knowledge of new directions to which authors' recent papers and interests may have led [57]. This is unavoidable, but such directions can be traced and assessed with future analyses. Third, a more fundamental *epistemological* criticism exists – one which asks whether the maps yield the *true* picture. However, it is unlikely that there is any one *true* picture; all maps leave some information out, and include other information. If a reader's views differ from ours, whose

view is preferred? In response, White has argued: "… the status of the maps is neither preferred nor nonpreferred a priori; it must be decided in light of the claims being made and the overall evidence brought to bear" [57, pp. 100-101]. Finally, we could have restricted the cited year window, by only accepting citations, for example, not older than 10 years. Had we done this it would have resulted in a more dynamic picture focusing more attention on currently active scholars. However we were interested in an historical, longitudinal mapping and including older citations was important to see work that has continued to be cited actively.

Conclusion

In this paper, we used author co-citation analysis to show that new forms of knowledge production and utilization – in particular, evidence-based medicine – are emerging and are rapidly accelerating. It might seem that evidence-based medicine has no relation to the hybrid corn study of so long ago or innovation diffusion as a field. Our longitudinal analysis shows clearly that this new field of activity in the medical sciences has strong intellectual roots, and is indebted to the social science discipline of innovation diffusion. The relevance of such a finding lies in the particular pattern of emergence of evidence-based medicine. We argue this pattern is representative of a broader societal shift to a different form of knowledge production than has characterized innovation diffusion for almost six decades. With this shift, the social contract between science and society is undergoing a renegotiation, a renegotiation with society as a far more active partner in the creation of knowledge.

Gibbons and Nowotny [2, 181] have characterized this renegotiated form of science as *Mode II knowledge production*. They have described it as involving non-hierarchical relationships with stakeholders, such as industry, government, and health care decision-makers. Its features are: (1) knowledge production in the *context of application*, (2) transdisciplinarity, (3) a much greater diversity of sites of knowledge production, (4) high reflexivity and (5) novel

forms of quality control [145]. Such Mode II knowledge production, based on the needs of end users in the health care system, is arguably a more socially accountable form of knowledge production. This is in contrast to *Mode I production* which reflects what have historically been the traditional, academic norms of scholarship in the disciplines and institutions in which researchers work, such as academic tenure and promotion based on high impact, peer-reviewed publication [2]. The foundations of *Mode I production* rest on principles of scientific expertise, peer review and non-interference.

The health care environment is characterized by ever increasing demands for accountability in the wake of troubling reports suggesting that quality of care is less than optimal [12, 182]. This, coupled with unusually high volumes (relative to the social sciences for example) of peer reviewed outputs from elite medical researchers, creates at least two of the necessary conditions for the rapid emergence of a new domain, namely evidence-based medicine. The study of this new domain will be of interest to a wide range of scholars, for example those interested in bibliometric methods, those studying the sociology of knowledge and those engaged in science studies. The emergence of evidence-based medicine is also a potentially compelling story in its own right and one deserving of a detailed examination. The first 15 years of its history currently reside in its artifacts (a central example of these artifacts being peer reviewed papers). Its originators are also still actively engaged in creating its history. In this regard we can do better than history of the cliometric sort suggested by White and McCain [23, p. 327]:

> "Because the data of ACA are merely noun phrases and associated citation counts, they produce history of the cliometric sort, which leaves out almost all the good parts, such as who had shouting matches, who slept with whom, and what actually gave rise to the most significant work".

Few social science studies provide the "good parts" or the good parts are written out in an attempt to make a qualitative analysis sound more objective. In this analysis we argue that the

emergence of evidence-based medicine is a striking example of a shift in knowledge production mode that is actually a “part” worthy of closer examination.

Reference List

1. Gibbons M: **Science's new social contract with society**. *Nature* 1999, **402**:C81-84.

2. Nowotny H, Scott P, Gibbons M: *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Cambridge, MA: Polity Press; 2001.

3. Stehr N: **Modern society as knowledge societies.** In *Handbook of Social Theory*. Edited by Ritzer G and Smart B. Thousand Oaks: Sage; 2001:494-508.

4. Stehr N: *Knowledge Societies*. Thousand Oaks: Sage; 1994.

5. Stehr N: **A world made of knowledge**. *Society* 2001, **39**:89-92.

6. Allmark P: **A classical view of the theory-practice gap in nursing**. *J Adv Nurs* 1995, **22**:18-23.

7. Grimshaw J, Eccles M, Tetroe J: **Implementing clinical guidelines: Current evidence and future implications**. *J Contin Educ Health Prof* 2004, **24 Suppl 1**:S31-37.

8. Serpa R: **A systematic approach to technology transfer**. *J Technol Transf* 1992, **17**:16-19.

9. Ogburn WF: **Cultural lag as theory**. *Sociol Soc Res* 1957, **41**:167-174.

10. Rogers EM: *Diffusion of Innovations*. New York: Free Press; 2003.

11. Baker GR, Norton PG, Flintoft V, Blais R, Brown A, Cox J, Etchells E, Ghali WA, Hebert P, Majumdar SR, O'Beirne M, Palacios-Derflingher L, Reid RJ, Sheps S, Tamblyn R: **The Canadian Adverse Events Study: The incidence of adverse events among hospital patients in Canada**. *Can Med Assoc J* 2004, **170**:1678-1686.

12. Grol R, Grimshaw J: **From best evidence to best practice: Effective implementation of change in patients' care**. *Lancet* 2003, **362**:1225-1230.

13. McGlynn EA, Steven MA, Adams J, Keesey J, Hicks J, DeCristofaro A, Kerr EA: **The quality of care delivered to adults in the United States**. *N Engl J Med* 2003, **348**:2635-

2645.

14. Schuster M.A., McGlynn E.A., Brook R.H.: **How good is the quality of health care in the United States?** *Milbank Q* 2005, **83**:843-895.

15. Estabrooks CA, Scott-Findlay S, Winther C: **Knowledge utilization in nursing and the allied health sciences.** In *Multidisciplinary Perspectives on Evidence-Based Decision-Making in Health Care*. Edited by Champagne F and Lemieux-Charles L. Toronto: University of Toronto; 2004:242-295.

16. Lang ES, Wyer PC, Haynes RB: **Knowledge translation: Closing the evidence-to-practice gap**. *Ann Emerg Med* 2007, **49**:355-363.

17. Rich R: **Knowledge creation, diffusion, and utilization: Perspectives from the founding editor of Knowledge**. *Knowledge: Creation, Diffusion, Utilization* 1991, **12**:319-337.

18. Dunn WN, Holzner B: **Knowledge in society: Anatomy of an emergent field**. *Knowledge in Society: The International Journal of Knowledge Transfer* 1988, **1**:3-26.

19. Havelock RG, Havelock MC: *Training for Change Agents; a Guide to the Design of Training Programs in Education and Other Fields*. Ann Arbor: Center for Research on Utilization of Scientific Knowledge, University of Michigan; 1973.

20. Weiss CH: *Social Science Research in Decision Making*. New York: Columbia University Press; 1980.

21. Cottrill CA, Rogers AM, Mills J: **Co-citation analysis of the scientific literature of innovation research traditions**. *Knowledge: Creation, Diffusion, Utilization* 1989, **11**:181-208.

22. McCain KW, Verner JM, Hislop GW, Evanco W, Cole V: **The use of bibliometric and knowledge elicitation techniques to map a knowledge domain: Software Engineering in the 1990s** . *Scientometrics* 2005, **65**:131-144.

23. White HD, McCain KW: **Visualizing a discipline: An author co-citation analysis of information science, 1972-1995.** *J Am Soc Inf Sci* 1998, **49**:325-355.

24. White HD, Wellman B, Nazer N: **Does citation reflect social structure? Longitudinal evidence from the "Globenet" interdisciplinary research group"**. *J Am Soc Inf Sci Technol* 2004, **55**:111-126.

25. Rich RF: **The pursuit of knowledge**. *Knowledge: Creation, Diffusion, Utilization* 1979, **1**:6-30.

26. Tarde G: *The Laws of Imitation*. New York: Holt; 1903.

27. Loomis ME: **Knowledge utilization and research utilization in nursing**. *Image J Nurs Sch* 1985, **17**:35-39.

28. Shaperman J, Backer TE: **The role of knowledge utilization in adopting innovations from academic medical centers**. *Hospital & Health Services Administration* 1995, **40**:401-413.

29. Lindquist EA: **What do decision models tell us about information use?** *Knowledge in Society* 1988, **1/2**:86-111.

30. Lomas J: **Connecting research and policy**. *Isuma* 2000, **1**:140-144.

31. Nilsson K, Sunesson S: **Strategy and tactics: Utilization of research in three policy sector contexts**. *J Appl Behav Sci* 1993, **29**:366-383.

32. Sunesson S, Nilsson K: **Explaining research utilization**. *Knowledge: Creation, Diffusion, Utilization* 1988, **10**:140-155.

33. Sunesson S, Nilsson K, Ericson B, Johansson B-M: **Intervening factors in the utilization of social research**. *Knowledge in Society: The International Journal of Knowledge and Transfer* 1989, **2**:42-56.

34. Rich RF: **Uses of social science information by federal bureaucrats: Knowledge for action versus knowledge for understanding.** In *Using Social Research in Public Policy Making*. Edited by Weiss CH. Lexington: DC Heath; 1977:199-211.

35. Rich R: **Knowledge creation, diffusion, and utilization: Perspectives from the founding editor of Knowledge**. *Knowledge: Creation, Diffusion, Utilization* 1991, **12**:319-337.

36. Valente TW: **Diffusion of innovations and policy decision-making**. *J Commun* 1993, **43**:30-45.

37. Weiss C: **The many meanings of research utilization**. *Public Adm Rev* 1979, **39**:426-431.

38. Weiss CH: **Knowledge creep and decision accretion**. *Knowledge: Creation, Diffusion, Utilization* 1980, **1**:381-404.

39. Glaser EM, Abelson HH, Garrison KN: *Putting Knowledge to Use*. San Francisco: Jossey-Bass; 1983.

40. Backer TE: **Knowledge utilization. The third wave**. *Knowledge: Creation, Diffusion, Utilization* 1991, **12**:225-240.

41. Valente TW, Rogers EM: **The origins and development of the diffusion of innovations paradigm as an example of scientific growth**. *Sci Commun* 1995, **16**:242-273.

42. Beal GM, Dissanayake W, Konoshima S: *Knowledge Generation, Exchange and Utilization*. Boulder: Westview Press; 1986.

43. Crane D: *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: University of Chicago; 1972.

44. Rogers EM: **Models of knowledge transfer: Critical perspectives.** In *Knowledge generation, utilization, exchange and utilization*. Edited by Beal GM, Dissanayake W, and Konoshima S. Boulder: Westview Press; 1986.

45. Rogers EM: **Lessons for guidelines from the diffusion of innovations**. *Jt Comm J Qual Improv* 1995, **21**:324-328.

46. Seely B: **Historical patterns in the scholarship of technology transfer**. *Comparative Technology Transfer & Society* 2003, **1**:7-48.

47. Koerner ST: **Technology transfer from Germany to Canada. A study in failure?** *Comparative Technology Transfer & Society* 2004, **2**:99-124.

48. Evidence-Based Medicine Working Group: **Evidence-based medicine. A new approach to teaching the practice of medicine.** *JAMA* 1992, **268**:2420-2425.

49. Cochrane AL: *Effectiveness and Efficiency: Random Reflections on Health Services*. London: Nuffield Provincial Hospitals Trust; 1972.

50. Hulme EW: *Statistical Bibliography in Relation to the Growth of Modern Civilization*. London: Butler and Tanner Grafton; 1923.

51. Merton RK, Garfield E: **Foreword.** In *Little Science, Big Science...and Beyond*. Edited by Price DJdS. New York: Columbia University Press; 1986:vii-xxiii.

52. Pritchard A: **Statistical bibliography or bibliometrics**. *J Doc* 1969, **25**:348-349.

53. Narin F, Olivastro D: **Bibliometrics/theory, practice, and problems**. *Eval Rev* 1994, **18**:65-76.

54. Lievrouw LA: **The invisible college reconsidered: Bibliometrics and the development of scientific communication theory**. *Communic Res* 1989, **16**:615-628.

55. Moed HF: *Citation Analysis in Research Evaluation*. Netherlands: Springer; 2005.

56. Small H: **Visualizing science by citation mapping**. *J Am Soc Inf Sci* 1999, **50**:799-813.

57. White HD: **Author co-citation analysis: Overview and defense.** In *Scholarly Communication and Bibliometrics* . Edited by Borgman C. Newbury Park: Sage; 1990:84-106.

58. McCain KW: **Mapping authors in intellectual space: A technical overview**. *J Am Soc Inf Sci* 1990, **41**:433-443.

59. Small HG: **Cited documents as concept symbols**. *Soc Stud Sci* 1978, **8**:327-340.

60. Zuckerman H: **Citation analysis and the complex problem of intellectual influence**. *Scientometrics* 1987, **12**:329-338.

61. Merton RK: *The Sociology of Science: Theoretical and Empirical Investigations*. Chicago: University of Chicago Press; 1973.

62. Latour B: *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge: Harvard University Press; 1987.

63. Callon M: **Elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay.** In *Power, Action, and Belief: A New Sociology of Knowledge?* Edited by Law J. London: Rutledge; 1986:196-233.

64. Merton RK: **The normative structure of science.** In *The Sociology of Science*. Edited by Storer NW. Chicago: University of Chicago Press; 1942:267-278.

65. Merton RK: *Social Theory and Social Structure*. New York: Free Press; 1957.

66. Merton RK: **The Matthew Effect in science II. Cumulative advantage and the symbolism of intellectual property.** In *On Social Structure and Science*. Edited by Merton RK. Chicago: University of Chicago Press; 1996:318-336.

67. Merton RK: **On the Garfield input to the sociology of science: A retrospective collage.** In *The Web of Knowledge: A Festschrift in Honor of Eugene Garfield*. Edited by Cronin B and Atkins HB. Medford: Information Today; 2000:435-448.

68. Merton RK: **The sociology of science: An episodic memoir.** In *The Sociology of Science in Europe*. Edited by Merton RK and Gaston J. Carbondale: Southern Illinois University Press; 1977:3-141.

69. Small HG: **On the shoulders of Robert Merton: Towards a normative theory of citation**. *Scientometrics* 2004, **60**:71-79.

70. Baldi S: **Normative versus social constructivist processes in the allocation of citations: A network-analytic model**. *Am Sociol Rev* 1998, **63**:829-846.

71. White HD, Griffith BC: **Author cocitation: A literature measure of intellectual structure**. *J Am Soc Inf Sci* 1981, **32**:163-171.

72. White HD, Wellman B, Nazer N: **Does citation reflect social structure? Longitudinal evidence from the "Globenet" interdisciplinary research group"**. *J Am Soc Inf Sci Technol* 2004, **55**:111-126.

73. Cottrill CA, Rogers AM, Mills J: **Co-citation analysis of the scientific literature of innovation research traditions**. *Knowledge: Creation, Diffusion, Utilization* 1989, **11**:181-208.

74. Gmür M: **Co-citation analysis and the search for invisible colleges: A methodological evaluation**. *Scientometrics* 2003, **57**:27-57.

75. Price DJdS: *Little Science, Big Science...and Beyond*. New York: Columbia University Press; 1963.

76. Zuccala A: **Modeling the invisible college**. *J Am Soc Inf Sci Technol* 2006, **57**:152-168.

77. Tuire P, Erno L: **Exploring invisible scientific communities: Studying networking relationships within an educational research community. A Finnish case**. *Higher Education* 2001, **42**:493-513.

78. Matzat U: **Academic communication and Internet Discussion Groups: transfer of information or creation of social contacts?** *Soc Networks* 2004, **26**:221-255.

79. Walker G, Janes J: *Online Retrieval: A Dialogue of Theory and Practice*. Englewood, Colorado: Libraries Unlimited; 1999.

80. Okubo Y: *Bibliometric Indicators and Analysis of Research Systems: Methods and Examples*. Paris: OECD; 1997.

81. Glänzel W . **Bibliometrics as a research field. A course on theory and application of bibliometric indicators. Course Handouts**. [http://www.norslis.net/2004/Bib_Module_KUL.pdf].

82. McCain KW: **Mapping authors in intellectual space: A technical overview**. *J Am Soc Inf Sci* 1990, **41**:433-443.

83. Gmür M: **Co-citation analysis and the search for invisible colleges: A methodological evaluation**. *Scientometrics* 2003, **57**:27-57.

84. Leydesdorff L: **Similarity measures, author cocitation analysis, and information theory**. *J Am Soc Inf Sci Technol* 2005, **56**:769-772.

85. Hamers L, Hemerick Y, Herweyers G, Janssen M, Keters H, Rousseau R, Vanhoutte A: **Similarity measures in scientometric research: The Jaccard index versus Salton's cosine formula**. *Information Processing and Management* 1989, **25**:315-318.

86. Persson O: **A tribute to Eugene Garfield -- discovering the intellectual base of his discipline.** *Curr Sci* 2000, **79**:590-591.

87. White HD, McCain KW: **Visualization of literatures**. *Annual Review of Information Science and Technology* 1997:99-168.

88. Bradford SC: **Sources of information on specific subjects**. *Engineering* 1934, **137**:85-86.

89. Valente TW, Rogers EM: **The origins and development of the diffusion of innovations paradigm as an example of scientific growth**. *Sci Commun* 1995, **16**:242-273.

90. Collins HM: **The place of the 'core-set' in modern science: Social contingency with methodological propriety in science**. *Hist Sci* 1981, **19**:6-19.

91. Collins HM: *Changing Order: Replication and Induction in Scientific Practice*. Chicago: University of Chicago Press; 1992.

92. Small HG, Crane D: **Specialties and disciplines in science and social science: An examination of their structure using citation indexes**. *Scientometrics* 1979, **1**:445-461.

93. Rogers EM: *Diffusion of Innovations*. New York: The Free Press; 1962.

94. Rogers EM, Shoemaker FF: *Communication of Innovations: A Cross Cultural Approach*. New York: Free Press; 1971.

95. Katz E: **Communication research and the image of society: Convergence of two traditions**. *Am J Sociol* 1960, **65**:435-504.

96. Katz E, Levin ML, Hamilton H: **Traditions of research on the diffusion of innovation**. *Am Sociol Rev* 1963, **28**:237-252.

97. Coleman J, Katz E, Menzel H: **The diffusion of an innovation among physicians**. *Sociometry* 1957, **20**:253-270.

98. Coleman JS, Katz E, Menzel H: *Medical Innovation: A Diffusion Study*. Indianapolis: Bobbs-Merrill; 1966.

99. Mansfield E: **The speed of response of firms to new techniques**. *Q J Econ* 1963, **77**:290-311.

100. Mansfield E: **Intrafirm rates of diffusion of an innovation**. *Rev Econ Stat* 1963, **45**:348-359.

101. Mansfield E: **Size of firm, market structure, and innovation**. *J Polit Econ* 1963, **71**:556-576.

102. Griliches Z: **Hybrid corn: An exploration in the economics of technological change**. *Econometrica* 1957, **25**:501-522.

103. Allen TJ, Cohen SI: **Information flow in research and development laboratories**. *Adm Sci Q* 1969, **14**:12-19.

104. Sarter B: **Some critical philosophical issues in the science of unitary human beings**. *Nurs Sci Q* 1989, **2**:74-78.

105. Cottrill CA, Rogers EM, Mills T: **Co-citation analysis of the scientific literature of innovation research traditions: Diffusion of innovations and technology transfer**. *Sci Commun* 1989, **11**:181-208.

106. Hägerstrand T: *The Propogation of Innovation Waves*. Lund, Sweden: University of Lund; 1952.

107. Hägerstrand T: *Innovation Diffusion As a Spatial Process*. Chicago: Chicago University Press; 1967.

108. Brown LA: *Diffusion of Processes and Location: A Conceptual Framework and Bibliography*. Philadelphia: Regional Science Research Institute; 1968.

109. Hägerstrand T: **Aspects of the spatial structure of social communication and the diffusion of information**. *Pap Reg Sci* 1966, **16**:27-42.

110. Hagerstrand T: **A Monte-Carlo approach to diffusion**. *Archives Europeennes De Sociologie* 1965, **6**:43-67.

111. Gouldner AW : **Cosmopolitans and locals: Toward an analysis of latent social roles - I**. *Adm Sci Q* 1957, **2**:444-480.

112. Duncan JW: **Transferring management theory to practice**. *Acad Manage J* 1974, **17**:724-738.

113. Churchman CW: **Managerial acceptance of scientific recommendations**. *Calif Manage Rev* 1964, **7**:31-38.

114. Churchman CW: **The researcher and the manager: A dialectic of implementation (with A.H. Schainblatt)**. *Manage Sci* 1965, **11**:B69-B87.

115. Salton G, et al.: *Information Storage and Retrieval (Reports ISR-7, ISR-8, and ISR-9)*. Cambridge: National Science Foundation, Harvard Computation Lab; 1964.

116. Salton G: **Information dissemination and automatic information systems**. *Proc IEEE* 1966, **54**:1663-1678.

117. Caplan NS, Morrison AS, Stambaugh RJ: *The Use of Social Science Knowledge in Public Policy Decisions at the National Level*. Ann Arbor: Institute for Social Research; 1975.

118. Havelock RG: *Planning for Innovation Through Dissemination and Utilization of Knowledge*. Ann Arbor: Center for Research on Utilization of Scientific Knowledge: University of Michigan; 1969.

119. Havelock RG: *Planning for Innovation Through Dissemination and Utilization of Knowledge*. Ann Arbor: Center for Research on Utilization of Scientific Knowledge, University of Michigan; 1971.

120. Yin RK: *Changing Urban Bureaucracies : How New Practices Become Routinized*. Santa Monica: Rand Corp; 1978.

121. Yin RK, Gwaltney MK: **Knowledge utilization as a networking process**. *Sci Commun* 1981, **2**:555-580.

122. Van de Vall M: **Utilization and methodology of applied social research: Four complementary models**. *J Appl Behav Sci* 1975, **11**:14-38.

123. Van de Vall M, Bolas C, Kang TS: **Applied social research in industrial organizations: An evaluation of functions, theory, and methods**. *J Appl Behav Sci* 1976, **12**:158-177.

124. Merton RK: **The Matthew Effect in science. The reward and communication systems of science are considered**. *Science* 1968, **159**:56-63.

125. Merton RK: *Social Theory and Social Structure*. New York: Free Press; 1957.

126. Merton RK: *Social Theory and Social Structure*. Glencoe: Free Press; 1968.

127. Merton RK, Fiske M, Kendall PL: *The Focused Interview: A Manual of Problems and Procedures*. New York: Free Press; 1990.

128. Merton RK, Reader GG, Kendall PL: *The Student Physician: Introductory Studies in the Sociology of Medical Education*. Cambridge: Commonwealth Fund/Harvard University Press; 1957.

129. Mitroff II: *The Subjective Side of Science: A Philosophical Inquiry into the Psychology of the Apollo Moon Scientists*. New York: Elsevier; 1974.

130. Mansfield E: **Technical change and the rate of imitation**. *Econometrica* 1961, **29**:741-766.

131. Mansfield E: *Industrial Research and Technological Innovation: An Econometric Analysis*. New York: W.W. Norton; 1968.

132. Mansfield E: *The Economics of Technological Change*. New York: W. W. Norton; 1968.

133. Allen TJ: *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R & D Organization* . Cambridge: MIT Press; 1977.

134. Allen TJ, Cohen SI: **Information flow in research and development laboratories**. *Adm Sci Q* 1969, **14**:12-19.

135. Cooney S, Allen TJ: **The technological gatekeeper and policies for national and international transfer of information**. *R&D Management* 1974, **5**:29-33.

136. Vernon R: **International investment and international trade in the product cycle**. *Q J Econ* 1966, **180**:190-207.

137. Utterback JM: **The process of technological innovation within the firm**. *Acad Manage J* 1971, **14**:75-88.

138. Aiken M: **Organizational structure, work process, and proposal making in administrative bureaucracies**. *Acad Manage J* 1980, **23**:631-652.

139. Evidence-Based Medicine Working Group: **Evidence-based medicine. A new approach to teaching the practice of medicine.** *JAMA* 1992, **268**:2420-2425.

140. Sackett DL: **Clinical epidemiology: What, who, and whither**. *J Clin Epidemiol* 2002, **55**:1161-1166.

141. Guyatt GH, Haynes RB, Jaeschke RZ, Cook DJ, Green L, Naylor CD, Wilson MC, Richardson WS: **Users' guides to the medical literature - Xxv. Evidence-based medicine: Principles for applying the users' guides to patient care**. *JAMA* 2000, **284**:1290-1296.

142. Guyatt GH, Meade MO, Jaeschke RZ, Cook DJ, Haynes RB: **Practitioners of evidence based care - Not all clinicians need to appraise evidence from scratch but all need some skills**. *BMJ* 2000, **320**:954-955.

143. Haynes RB: **What kind of evidence is it that evidence-based medicine advocates want health care providers and consumers to pay attention to**. *BMC Health Serv Res* 2002, **2**:7 pages.

144. Grol R: **Improving the quality of medical care: building bridges among professional pride, payer profit, and patient satisfaction**. *JAMA* 2001, **286**:2578-85.

145. Nowotny H, Scott P, Gibbons M: **Mode 2 revisited: The new production of knowledge**. *Minerva* 2003, **41**:179-194.

146. Orszag PR, Ellis P: **Addressing rising health care costs--a view from the Congressional Budget Office**. *N Engl J Med* 2007, **357**:1885-7.

147. Fitzgerald L, Ferlie E, Hawkins C: **Innovation in healthcare: How does credible evidence influence professionals?** *Health Soc Care Community* 2003, **11**:219-228.

148. Van den Bulte C, Lilien GL: **Medical innovation revisited: Social contagion versus marketing effort.** *Am J Sociol* 2001, **106**:1409-1436.

149. West E, Barron DN, Dowsett J, Newton JN: **Hierarchies and cliques in the social networks of health care professionals: implications for the design of dissemination strategies**. *Soc Sci Med* 1999, **48**:633-646.

150. Hart WB: **Everett M. Rogers: His role in intercultural communication study**. *Int J Intercult Relat* 2005, **29**:491-495.

151. Haider M, Kreps GL: **Forty years of diffusion of innovations: Utility and value in public health**. *J Health Commun* 2004, **9**:3-11.

152. Rogers EM: *Diffusion of Innovations*. New York: The Free Press; 1983.

153. Rogers EM, Shoemaker FF: *Communication of Innovations: A Cross Cultural Approach*. New York: Free Press; 1971.

154. Rogers E: *Diffusion of Innovations*. New York: The Free Press; 1995.

155. Zaltman G, Duncan R, Holbek J : *Innovations and Organizations*. Toronto: John Wiley & Sons; 1973.

156. Zaltman G: *Strategies for Planned Change*. New York: Wiley; 1977.

157. Coleman JS, Katz E, Menzel H: *Medical Innovation: A Diffusion Study*. Indianapolis: Bobbs-Merrill; 1966.

158. Weiss CH: *Using Social Research in Public Policy Making*. Lexington: Lexington Books; 1977.

159. Gandhi AG, Murphy-Graham E, Petrosino A, Chrismer SS, Weiss CH: **The devil is in the details - Examining the evidence for "proven" school-based drug abuse prevention programs**. *Eval Rev* 2007, **31**:43-74.

160. Mark M, Weiss CH: **The oral history of evaluation, part 4 - The professional evolution of Carol H Weiss**. *American Journal of Evaluation* 2006, **27**:475-484.

161. Kothari A, Birch S, Charles C: **"Interaction" and research utilisation in health policies and programs: Does it work?** *Health Policy* 2005, **71**:117-125.

162. Weiss CH: **Have we learned anything new about the use of evaluation**. *American Journal of Evaluation* 1998, **19**:21-33.

163. Weiss C: **The many meanings of research utilization**. *Public Adm Rev* 1979, **39**:426-431.

164. Mansfield E: **Technical change and the rate of imitation**. *Econometrica* 1961, **29**:741-766.

165. Mansfield E: *Industrial Research and Technological Innovation: An Econometric Analysis*. New York: W.W. Norton; 1968.

166. Allen TJ, Hyman DB, Pinckney DL: **Transferring technology to the small manufacturing firm: A study of technology transfer in three countries**. *Research Policy* 1983, **12**:199-211.

167. Blackman AW : **The market dynamics of technological substitutions**. *Technol Forecast Soc Change* 1974, **6**:41-63.

168. Mahajan V, Peterson RA: *Models for Innovation Diffusion*. Beverly Hills: Sage; 1985.

169. Mahajan V, Peterson RA: **Integrating time and space in technological substitution models**. *Technol Forecast Soc Change* 1979, **14**:231-241.

170. Kuhn T: *The Structure of Scientific Communities*. Chicago: University of Chicago Press; 1962.

171. Kuhn T: *The Structure of Scientific Communities*. Chicago: University of Chicago Press; 1962.

172. Ryan B, Gross NC: **The diffusion of hybrid corn seed in two Iowa communities**. *Rural Sociology* 1943, **8**:15-24.

173. Backer TE, Dearing J, Singhal A, Valente T: **Writing with Ev-- Words to transform science into action**. *J Health Commun* 2005, **10**:289-302.

174. Rogers EM, Medina UE, Rivera MA, Wiley CJ: **Complex adaptive systems and the diffusion of innovations**. *The Innovation Journal* 2005, **10**:article 29.

175. Rogers EM: **A prospective and retrospective look at the diffusion model**. *J Health Commun* 2004, **9**:13-19.

176. Farley G, Geison GL: **Science politics and spontaneous generation in nineteenth-century France: The Pasteur-Pouchet debate**. *Bull Hist Med* 1974, **48**:161-198.

177. Shapin S: *The Social History of Truth*. Chicago: Chicago University Press; 1996.

178. Knorr Cetina K: *Epistemic Cultures*. Cambridge: Harvard University Press; 1999.

179. Cronin B: **Bibliometrics and beyond: Some thoughts on web-based citation analysis**. *Journal of Information Science* 2001, **27**:1-7.

180. Beall J, Kafadar K: **Measuring typographical errors' impact on retrieval in bibliographic databases**. *Cataloging & Classification Quarterly* 2007, **44**:197-211.

181. Gibbons M, Limoges C, Nowotny H, et al.: *The New Production of Knowledge*. London: Sage; 1994.

182. Schuster M, McGlynn E, Brook R: **How good is the quality of health care in the United States?** *Milbank Q* 1998, **76**:517-563.

183. Garfield E: **Citation indexing: Its theory and application in science, technology and humanities.** In *Mapping the structure of science (Chapter 8)*: John Wiley & Sons; 1979:98-147.

Competing Interests

None declared

Authors' Contributions

CE: conceived the study and its design, secured funding, provided leadership and coordination participated in data analysis and interpretation, drafted the final manuscript and approved the final submitted manuscript.

LD: conducted data analysis and made major contributions to interpretation of findings, writing, and provided critical commentary

JL: participated in designing the study, securing grant funding, participated in all team meetings providing critical and substantive commentary to both process and final products

CW: coordinated and conducted all searches, ran all analyses, produced all maps, figures and tables and contributed to writing the final manuscript.

LW, SS, JPM: participated in study design, all team meetings and data interpretation; provided input into the writing of the manuscript.

All authors read and approved the final manuscript.

Acknowledgements

This work was supported by grants-in-aid from the Canadian Institutes of Health Research (CIHR) (MOP #67228) and the Social Sciences & Humanities Research Council (grant #410-2004-0592). Drs Estabrooks and Lavis receive career support from the CIHR. Dr Wallin received post doctoral fellowship funding and Dr Scott received doctoral and post doctoral funding from CIHR and AHFMR during the conduct of this study.

Iva Seto served as a research assistant, completed searches and did data cleaning under the direction of CW. She was supported by the CIHR grant-in-aid MOP #67228.

Richard Thornley assisted with final formatting and preparation of the manuscript. He is supported by Dr Estabrooks' Canada Research Chair.

Dr Olle Perrson, Sociology Institute, Umea University, Umea, Sweden was a consultant on the project and advised on methods, software training and use, and reviewed the final work for technical and methodological accuracy. His work was supported by the CIHR grant-in-aid MOP #67228.

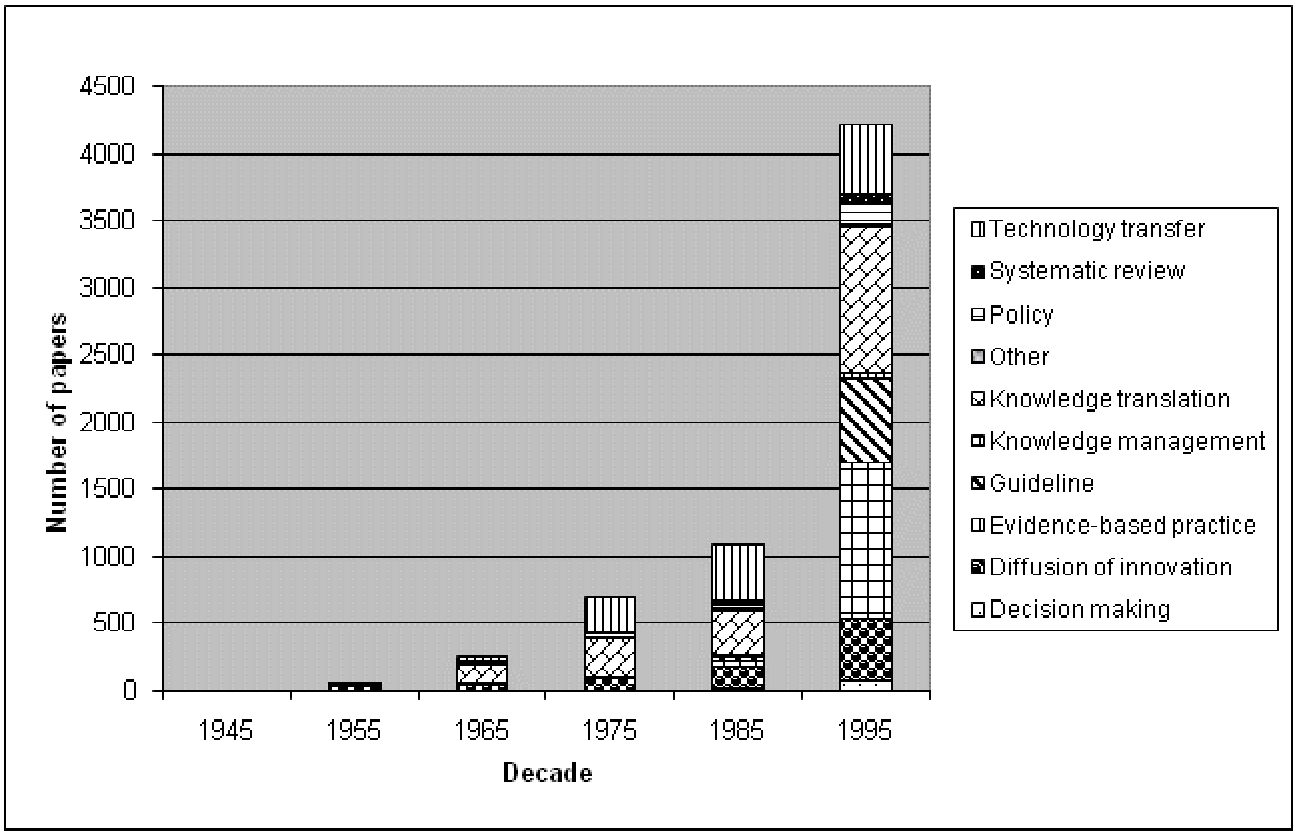
Appendix A. Search strategy

knowledge use OR knowledge utili*ation OR knowledge uptake OR knowledge transfer OR knowledge mobili*ation OR (knowledge AND (disseminat* OR exchange OR implement OR translat* OR adopt)).ti OR knowledge diffusion
OR research utili*ation OR (research AND (uptake OR use)).ti
OR research transfer OR research translat* OR research disseminat* OR research implement*
OR evidence based medicine OR evidence based practice OR
(evidence based).ti OR evidence uptake OR evidence disseminat* OR (evidence AND implement*).ti
OR diffusion of innovation
OR guideline implement* OR guideline use OR guideline utili*ation OR guideline uptake OR guideline exchange OR guideline translat* OR guideline disseminat* OR guideline adopt* OR guideline mobili*ation OR (guideline AND (transfer OR diffusion).ti
OR (idea* AND (diffusion OR disseminat*OR mobili*ation OR transfer OR exchange OR translat*).ti
OR Science utili*ation OR (science AND (adopt* OR diffusion OR disseminat* OR mobili*ation OR transfer* OR translat*).ti
OR Health technology assessment AND (implement OR polic*)
OR Systematic review and (use OR utili*ation OR uptake OR implement* OR transfer* OR mobili*ation OR exchange OR translat* OR disseminat* OR adopt* OR diffusion)
OR (Innovat* use.)ti OR innovat* implement* OR innovat* exchange OR innovat* translat*OR innovat* mobili*ation OR innovat* adopt* OR innovat* diffusion OR
(innovat* AND (transfer OR uptake OR utili*ation OR disseminat*).ti
OR Technolog* mobili*ation OR **technology transfer** OR technolog* adopt* OR technolog* AND (uptake OR implement* OR disseminat*).ti
OR information utili*ation OR information implementat* OR information uptake OR information adopt* OR information mobili*ation OR information translat*
OR (information AND (disseminat* OR exchange OR transfer OR use).ti
OR theor* use OR theor* utili*ation OR theor* uptake OR theor* implement* OR theor* transfer **OR** OR theor* mobili*ation OR **theor*** adopt* OR theor* diffusion OR
theor* AND (disseminat*).ti

Simple Boolean searching of all the terms of interest (knowledge, research, evidence, guideline, ideas, science, innovation, technology, information, theory AND use, utilization, uptake, implementation, transfer, mobilization, exchange, translation, dissemination, adopt, diffusion; technology transfer; diffusion of innovation; health technology assessment; systematic review; evidence based practice)resulted in over 100,000 hits (WoS has a limit of 100,000 hits). In order to begin to limit the number of hits and increase precision of the search, the search strategy was developed and tested by scanning each combination of the terms & phrases of interest for relevance. Some terms were combined using AND, some were used as phrases and some were limited to title. Some combination of terms were not included in the search strategy as the results were not relevant to our study. For example, the phrase Research adopt was excluded as this search resulted in citations about research into adoption, and Evidence transfer was also excluded as the citations related to forensics.*

Figure 1

Table 1. Knowledge utilization domains by decade



Note: the 'number of papers' is inflated in this table, as the domain categories are not mutually exclusive (a paper may have more than one domain)
Note: the last decade is annualized from October 27, 2004

Table 2. Most prolific publishers of knowledge utilization articles (1955 to 2004)

# of articles	Journal Title
76	Knowledge – Creation Diffusion Utilization*
66	Technovation
60	Journal of Advanced Nursing
59	International Journal of Technology Management
53	British Medical Journal
51	Journal of Evaluation in Clinical Practice
48	Technological Forecasting and Social Change
43	IEEE Transactions on Engineering Management
42	JAMA-Journal of the American Medical Association
41	Research Policy
39	Medical Journal of Australia
32	International Journal of Technology Assessment in Health Care
32	Journal of the American Medical Informatics Association
28	R & D Management
28	Management Science
27	Medical Care
24	Social Science & Medicine
24	Science Communication*
23	Family Practice
23	Journal of General Internal Medicine

*In September 1994 *Knowledge –Creation Diffusion Utilization* became *Science Communication*

Table 3. Most prolific journals by decade

Decade	# of articles	Journal title
1955–1964	11	Rural Sociology
	3	Library Quarterly
	3	Sociometry
	2	Social Forces ; Personnel Psychology; Review of Economics and Statistics; Human Organization; American Sociological Review; American Documentation; Administrative Science Quarterly
1965–1974	8	Nauchno – Tekhnicheskaya Informatsiya Seriya 1 – Organizatsiya I Metodika Informatsionnoi Raboty
	6	Administrative Science Quarterly
	5	Human Relations
	5	Special Libraries
	5	American Behavioral Scientist
1975–1984	35	Knowledge – Creation Diffusion Utilization
	16	Proceedings of the American Society for Information Science
	14	R & D Management
	9	Administrative Science Quarterly
	9	Rehabilitation Counseling Bulletin
1985–1994	41	Knowledge – Creation Diffusion Utilization
	23	Technological Forecasting and Social Change
	23	Technovation
	15	Journal of Scientific & Industrial Research
	12	JAMA- Journal of the American Medical Association
1995–2004	55	International Journal of Technology Management
	52	Journal of Advanced Nursing
	51	Journal of Evaluation in Clinical Practice
	48	British Medical Journal
	41	Technovation

Table 4. Most cited authors by decade

Decades	# cites	Author name	Domain	Institution	Country
1945-1954	7	Seinwerth, H.W.	Other		USA
1955-1964	40	Wilkening, E.A.	Diffusion of innovation, Agriculture, rural sociology	University of Chicago	USA
1965-1974	67	Rogers, E.M.	Diffusion of innovation	Ohio State University	USA
1975-1984	155	Rogers, E.M.	Diffusion of innovation	Stanford University	USA
1985-1994	198	Rogers, E.M.	Diffusion of innovation	University of Southern California	USA
1995-2004	627	Rogers, E.M.	Diffusion of innovation	University of New Mexico	USA

Table 5. Most cited publications by decade

Decades	**# cites**	**Paper**	**Domain**	**Institution**	**Country**
1945-1954	-	All cited articles only cited once	-	-	-
1955-1964	9	Wilkening, E. A. (1952, May). "Acceptance of improved farm practices in three coastal plains countries." *Technical Bulletin 98. North Carolina Agricultural Experiment Station.*	Diffusion of innovation	University of Chicago	USA
1965-1974	36	Rogers, E.M. (1962). *Diffusion of Innovations*. 1st Edition. New York: The Free Press.	Diffusion of innovation	Ohio State University, United States	USA
1975-1984	70	Rogers, E.M. & Shoemaker, F.F. (1971). *Communication of Innovations: A Cross Cultural Approach.*[1]New York: The Free Press	Diffusion of innovation	Stanford University/University of Denver	USA
1985-1994	89	Rogers, E.M. (1983). *Diffusion of Innovations.* 3rd Edition. New York: The Free Press.	Diffusion of innovation	University of Southern California	USA
1995-2004	229	Evidence Based Medicine Working Group (1992). "Evidence based medicine. A new approach to teaching the practice of medicine." *JAMA,* 268(17), 2420-2425.	EBM	McMaster University	Canada

[1] Note: The 2nd edition of Everett Rogers' *Diffusion of Innovations* was co-authored with F. Shoemaker and published under the title of *Communication of Innovations*. Subsequent editions were authored by Rogers only, and published under the name *Diffusion of Innovations.*

Table 6. Core-set authors by decade by domain

	1975-1984	1985-1994	1995-2004
Knowledge utilization	Caplan Glaser Havelock Merton Mitroff Rich Vandevall Weiss Yin	Bozeman Backer Caplan Dunn Glaser Havelock Rich Weiss	Backer Caplan Havelock Weiss
Diffusion of innovations	Aiken Brown Coleman Downs Feller Hage March Rogers Utterback Zaltman	Kimberly March Rogers Zaltman	Brown Coleman Katz Rogers Zaltman
Technology transfer	Allen Federal Insurance Corporation Mahajan Mansfield Vernon	Allen Bass Jensen Mahajan Mansfield Nelson Reinganum Rosenberg Sharif Teece	Allen Mansfield Mahajan Nelson Rosenberg
Evidence-based medicine		Eddy Haynes Lomas	Chalmers Davis Eddy Grimshaw Guyatt Haynes Lomas Oxman Sackett UK Dept Health Woolf
Other	Burt		

Figure 1. First author co-citation map 1965-1974

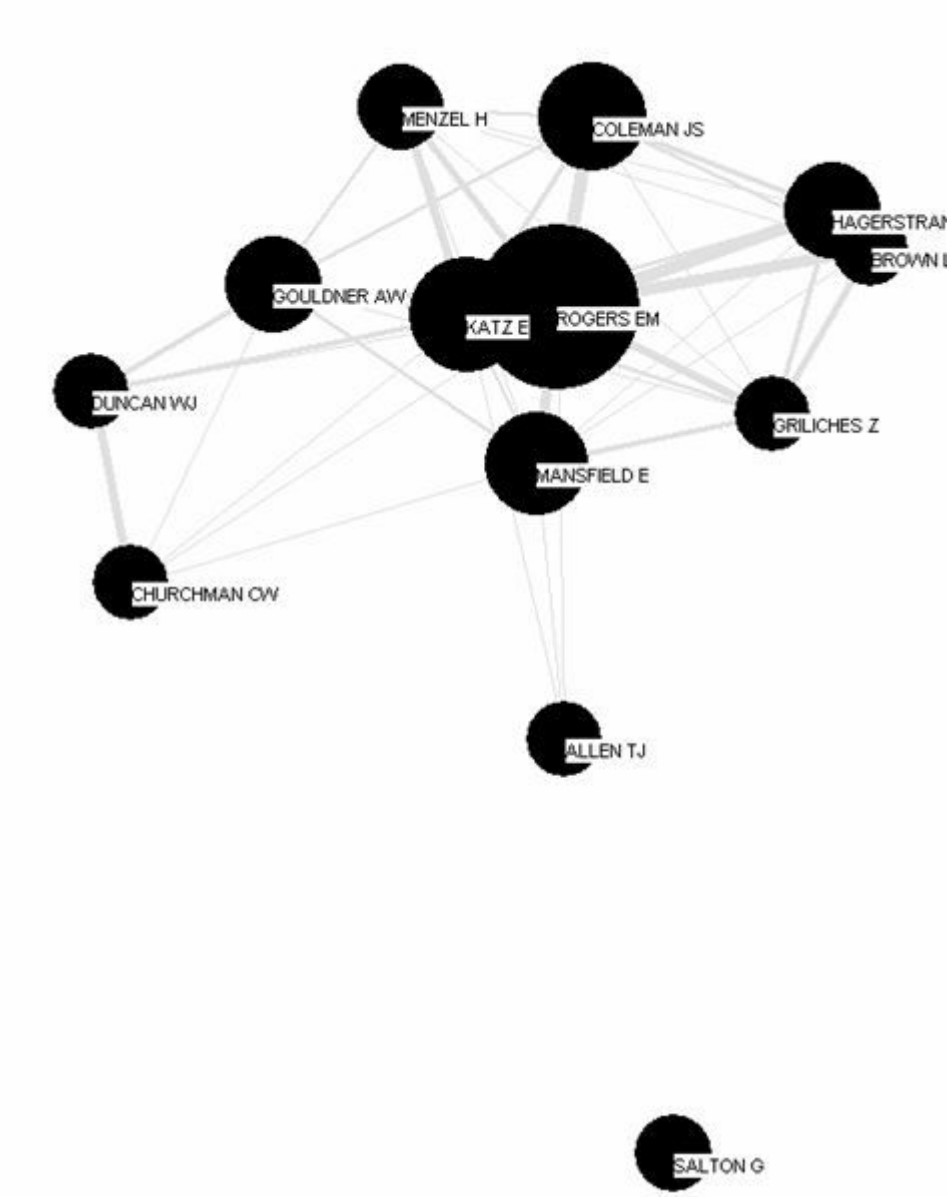


Figure 2. First author co-citation map 1975-1984

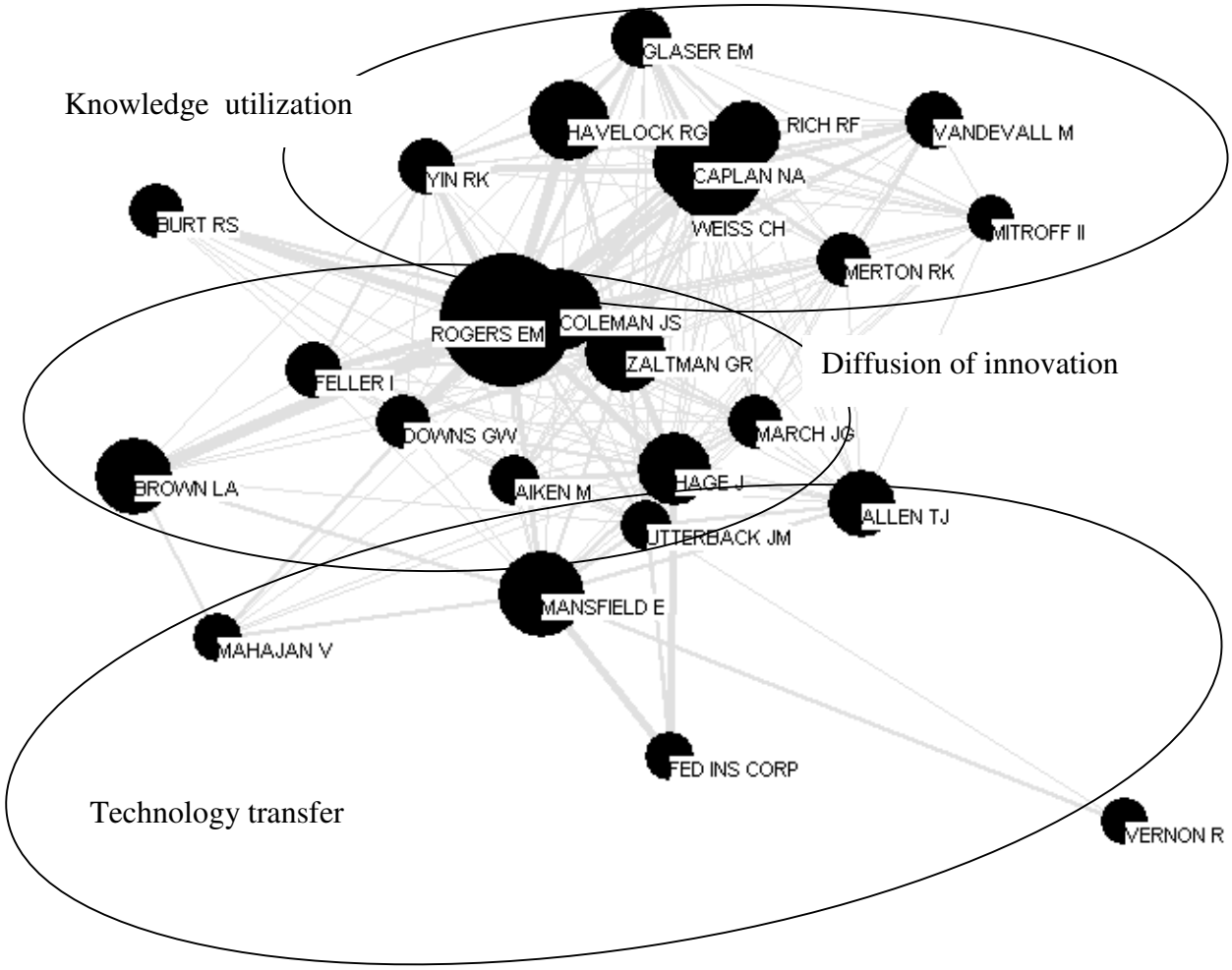


Figure 3. First author co-citation map 1985-1994

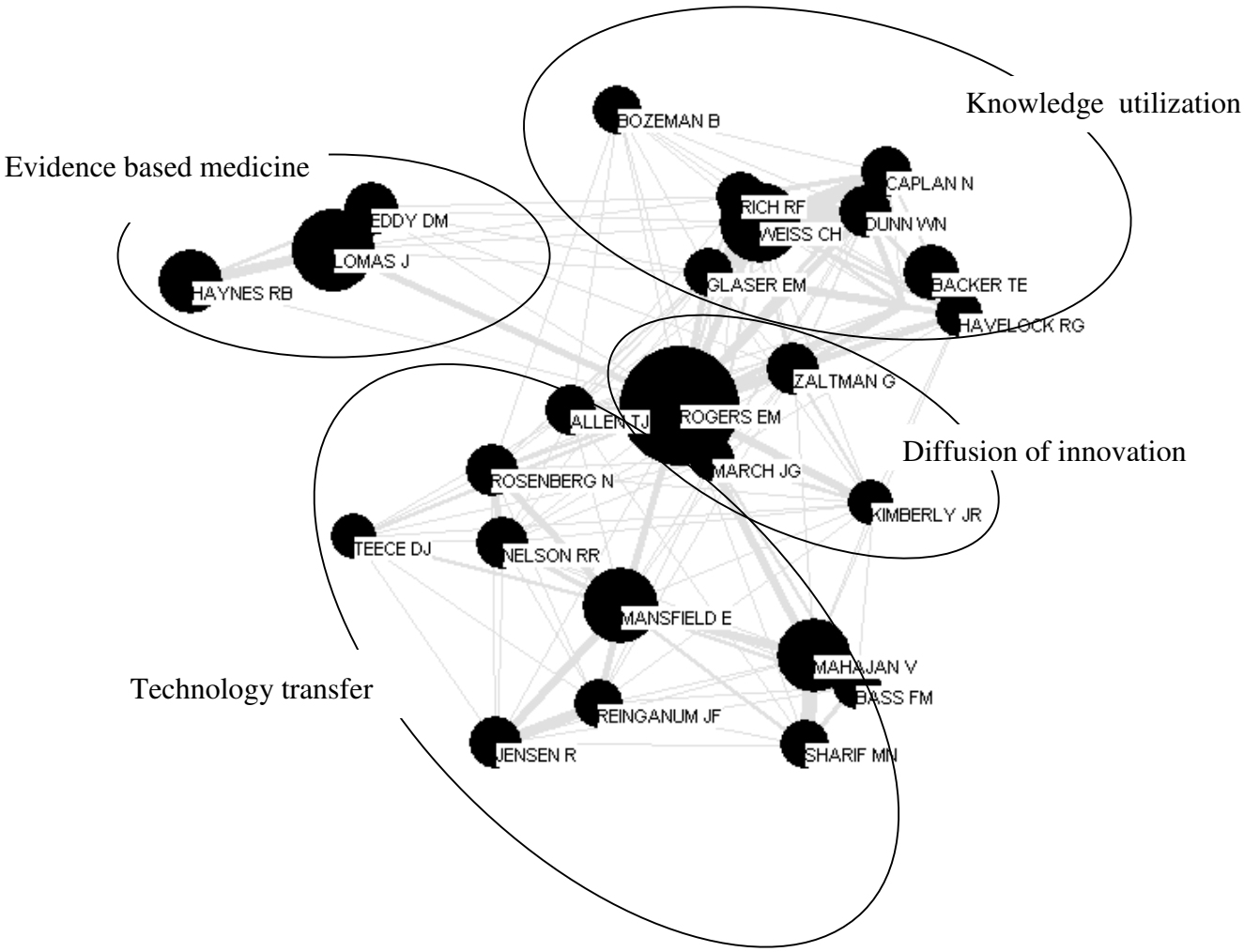
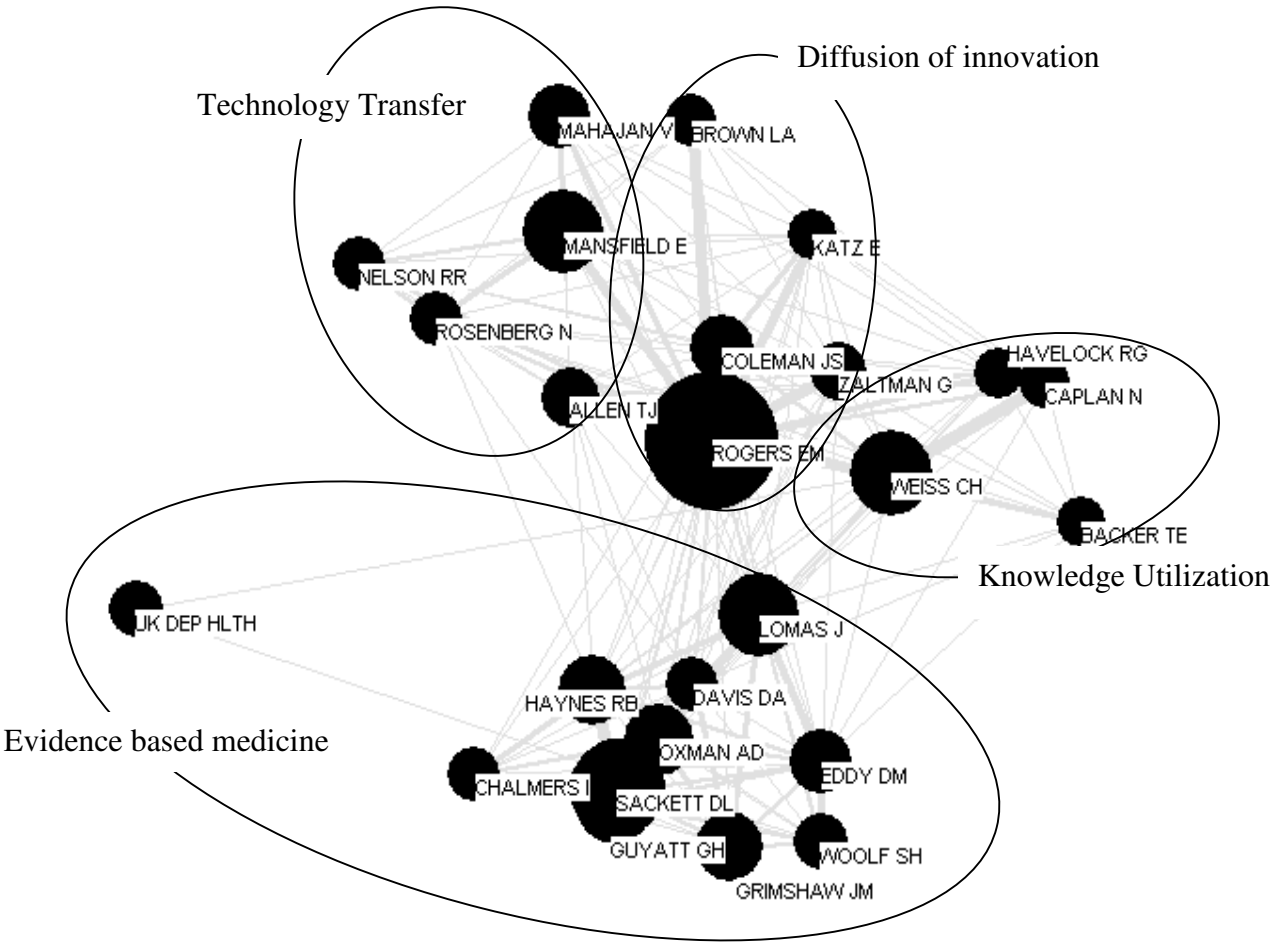


Figure 4. First author co-citation map 1995-2004



Additional files provided with this submission:

Additional file 1: letter implementation science submission 19 december 2007_ce.doc, 52K
http://www.implementationscience.com/imedia/1183286461175057/supp1.doc