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Macro-level Diffusion of a Methodological Knowledge Innovation: Research Synthesis Methods, 1972-2011

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Macro-level diffusion of a methodological knowledge innovation: Research Synthesis Methods, 1972-2011

Abstract

Use of research synthesis methods has contributed to changes in research practices. In disciplinary literatures, authors indicate motivations to use the methods include needs to (a) translate research-based knowledge to inform practice and policy decisions, and (b) integrate relatively large and diverse knowledge bases to increase the generality of results and yield novel insights or explanations. This review presents two histories of the diffusion of research synthesis methods: a narrative history based primarily in the health and social sciences; and a bibliometric overview across science broadly. Engagement with research synthesis was strongly correlated with evidence-based practice (EBP), and moderately with review prevalence. The social sciences were most diverse in terms of when research synthesis was adopted. Technology, physical sciences, and math appear to be relatively resistant though fields such as physics may be considered to have used similar methods long ago. Additional research is needed to assess the consequences of adoption within fields, including changes in how researchers engage with knowledge resources. This review demonstrates that particularistic histories of science and technology may be fruitfully augmented with informetrics to examine how disciplinary diffusion narratives coincide with patterns across science more broadly, thereby opening up disciplinary knowledge to inform future research.

Introduction

Following the development of contemporary research synthesis methods in the 1970s by psychology and education researchers, such methods, under the labels “systematic review” and “meta-analysis” became an integral component of the evidence-based practice (EBP) movement that revolutionized research use in health and medicine and research practices in education. In psychology, research synthesis is credited with providing empirical procedures that enable quantitative cumulation of knowledge (Hedges, 1987). Diffusion of the methods has been driven in part by the EBP movement, and in part by beliefs in the benefits of the accumulation of scientific knowledge and consensus formation. Receptivity across science fields has varied.

Skeptics suggest limitations in how research synthesis methods are applied; restrictions associated with the characteristics of studies that can be synthesized; and exclusion of experiential knowledge and professional expertise limit the integrative capacity of the methods. In fields in which research synthesis is the preferred method of research review, it may be argued that knowledge, evidence, and understandings gained through methods or processes that are not congruent with prevalent approaches to research synthesis are at best, ignored; at worst, delegitimized. The politics of knowledge notwithstanding, research synthesis has changed research integration within and at the boundaries of many science fields.

To date, there has been little empirical research to examine trends in the diffusion of

research methods across science broadly. This gap is addressed with this study through an investigation of the macro-level diffusion of research synthesis methods from 1972 to 2011. It is hoped that this work will help connect and contextualize predominantly field-specific studies of engagement with research synthesis methods performed by others, generally from within their own fields (e.g., Barrios, Guilera, & Gomez-Benito, 2013; Cadotte, Mehrkens, & Menge, 2012; DeGeest & Schmidt, 2011); and sketch the landscape against which more detailed examinations of the development and diffusion of the methods (e.g., Shadish & Lecy, 2015) can be viewed. Fields sometimes neglected by other studies, those that do not engage with the methods, are also described. From an information science perspective, this review demonstrates that particularistic histories of science and technology may be fruitfully augmented with informetric approaches to examine how disciplinary narratives of diffusion coincide with patterns across science more broadly. Through this approach, themes discussed in disciplinary narratives have the potential to inform future research. Such analyses can help us better determine the nature of scholarly work, and in this particular case, better understand diffusion of research methods across science fields.

Research synthesis methods

Research synthesis is an empirical research method in which data and findings from primary research studies are analyzed with the goal of generating new knowledge or interpretations. Research synthesis involves formulating a research problem, retrieving relevant literature, evaluating, analyzing, and synthesizing data, and interpreting the results. The importance of presenting and disseminating findings is often emphasized in research synthesis, and therefore this is often identified as the concluding step (Cooper & Hedges, 1994). Generally, researchers engaging in research synthesis strive to adhere to transparent and systematic procedures (c.f., Noblit & Hare, 1988; Pawson, 2006). As with other research methods, study characteristics vary with the nature of the research questions, the goal of the study, and the epistemological and ontological orientations of those conducting the study. As a documentary method in which reports of previous research studies form the basis of evidence, the characteristics of a synthesis will be determined in part by the nature and extent of previous research; and the availability and documentation of studies in reports.

Prior studies of the impact and diffusion of research synthesis methods

In work focused on the impact of research synthesis, Murphy (2003) and DeGeest and Schmidt (2010) examined developments in the field of industrial and organizational psychology following adoption of psychometric validity generalization meta-analysis beginning in the late 1970s[1]; Miller and Pollock (1994) analyzed the challenges and potential benefits of meta-analysis as an innovation in social psychology; and Boyle (2012) examined the transformation of research methods and research culture in complementary and alternative medicine (CAM) during the period in which the Office of Alternative Medicine (OAM)[2] and funding for complementary and alternative medicine were initiated at the National Institutes of Health (NIH). Cadotte, Mehrkens, and Menge (2012) found that in ecology, the number of papers, datasets, species, and range of reference publication dates has increased in meta-analytic studies over time; and that

meta-analyses, when compared to papers in the same issue of the same journal, are written by larger groups of authors. About 15% of these authors were associated with a synthesis center (e.g., the National Center for Ecological Analysis and Synthesis, NCEAS).

Recently, a few comparative studies have been performed: Researchers in criminal justice (Wells, 2009) and social work (Lundahl & Yaffe, 2007) examined trends in the use of meta-analysis in their own fields versus that of others. Wells found adoption of meta-analysis in criminal justice was lagging that in psychology and sociology; and Lundahl and Yaffe found production of and commentary on meta-analyses in social work lagged that of psychiatry, psychology, and nursing; but was similar to family studies. Meanwhile, in the medical and health sciences, systematic reviews of systematic reviews (umbrella reviews or overviews; Smith, Devane, Begley, & Clarke, 2011) have arrived, though there continue to be questions about the scalability of the systematic review approach as it is currently implemented (Bastian, Glasziou, & Chalmers, 2010), as well as whether different types of reviews and research syntheses are better for different purposes (Dijkers, 2009; Gurevitch, Curtis, & Jones, 2001).

Research synthesis methods can be considered an innovation amenable to a diffusion analysis as described by Rogers (2003) and extended by scholars from a broad array of research traditions (Greenhalgh, Robert, Macfarlane, et al., 2005). This framing focuses on the processes and characteristics associated with how innovations, which may be ideas, technologies, methods, conventions, behaviors, or other definable entities, are communicated and spread from person to person across social systems over time (Rogers, 2003). Innovations diffuse along cognitive, social, organizational, geographical, and institutional dimensions (Boschma, 2005). At boundaries, innovations may be transferred, or translated and transformed, based on the degree of difference, dependence, and novelty between contexts and associated with the innovation (Carlile, 2004).

This review presents an examination of the diffusion of research synthesis methods in two complementary parts: a selective, historical review of the development and diffusion of the methods based on disciplinary narratives, primarily in the health and social sciences; and drawing on this narrative review, an illustrated systematic bibliometric overview across science. Through this dual approach, this review demonstrates that particularistic histories of science and technology may be fruitfully augmented with informetrics to examine how disciplinary diffusion narratives coincide with and diverge from patterns of diffusion across science more broadly, thereby opening up disciplinary knowledge to inform future research.

Historical overview of the diffusion of research synthesis methods

Historical accounts identify the 1960s and 1970s as critical to the development of research synthesis (e.g., Glass, McGaw & Smith, 1981). A turning point was reached when Gene Glass described the statistical analysis of findings from a large number of independent studies in a presidential address to the American Educational Research Association (AERA; Kulik & Kulik, 1988) and subsequently published two landmark papers. In the first, Glass (1976)

discussed the difference between primary data analysis, secondary data analysis, and "meta-analysis", a term he coined to describe the use of statistical methods to examine the results of multiple compatible primary studies in combination and synthesize the data. The second paper, by Smith and Glass (1977), used meta-analytic techniques to adjudicate between conflicting opinions expressed in reviews about the relative efficacy of drug treatments alone versus drug treatments with psychotherapy for psychological disorders. In combination, these publications served to heighten awareness of meta-analysis (Kulik & Kulik, 1988). While Glass notes (Glass, McGaw & Smith, 1981) that others, including Robert Rosenthal and Light and Smith (1971), had been working with similar methods at the time, most prior work might be described as the "pre-history" of research synthesis though this might be due more to a lack of continuity, connection, and widespread awareness of other work rather than large conceptual differences between meta-analytic approaches and prior statistical analyses of primary research reports (see, e.g., Cochran, 1937; Leitch, 1958).

Two important types of early (pre-history) works that are frequently identified in histories of research synthesis include methodological advances – especially from statistics – and early reviews that used systematic approaches to literature review and integration. More recently, Bastian, Glasziou, and Chalmers (2010) provided a broader perspective of the history of "the development of trials and the science of reviewing trials" (p. 2) in medicine, which includes the development of information indexes and systems (e.g., *Index Medicus*, MEDLINE, trial registries), organizations (e.g., the Office of Technology Assessment (OTA), the Cochrane Collaboration, the Agency for Healthcare Research Quality Evidence-based Practice Centers (AHRQ - EPC)), regulations (e.g., Food and Drug Administration Amendments Act of 2007), and guidelines such as evidence hierarchies, practice guidelines, publication guidelines (e.g., MARS[4], JARS[5], MAER-Net[6]), and reporting standards (e.g., PRISMA[7], MOOSE[8], QUORUM[9]), in addition to landmark studies and publications.

Within science, diffusion of enabling technologies and techniques (Altman, 2000; Altman & Goodman, 1994) and reconciliation of epistemic beliefs with approaches to synthesis (Strike & Posner, 1983) influence the nature of research syntheses, and may influence the extent to which research synthesis methods are used and the importance of synthesis publications across fields. A secondary thread in the history of research synthesis is the impact these methods and the structures that support them do or ought to have on science practice. This is clearest in the context of publication guidelines. For example, one goal of the recent revisions to the *American Psychological Association* research reporting guidelines was to accommodate secondary analyses of aggregate findings documented in research reports (APA Publications & Communications Board Working Group, 2008). It has been suggested that wide-spread use of evidence hierarchies that identify meta-analyses and randomized control trials as the "highest" level of evidence (based on internal validity) influence citation patterns directly and through influence on article submission guidelines (Dijkers, 2009). Finally, Clarke, Chalmers, and others have repeatedly called for guidelines necessitating pre- and post-study systematic reviews to assess the contributions of each study (e.g., Clarke, Hopewell, & Chalmers, 2010).

Research synthesis is framed as having been developed in response to the failings of traditional literature reviews, and in some cases, rather than as an extension of them (c.f., Dickersin & Chalmers, 2010; Dijkers, 2009; Garfield, 1987; Mulrow, 1987). At least three themes recur in discussions of the emergence of systematic approaches to reviewing literature: (1) Pressures associated with increasing numbers of primary research publications (Chalmers, Hedges & Cooper, 2002; Glass, McGaw & Smith, 1981); (2) the roles of reputation and prestige (or "experience and expertise," Huth, 2009) versus more egalitarian or "fair" evaluations of research findings; and (3) episodic and systemic failures to achieve unbiased estimates of consensus, including for the purpose of communicating "the state of science" to inform policy and practice decisions (Chalmers, Hedges & Cooper, 2002; Glass, McGaw & Smith, 1981; Light & Pillemer, 1984).

A number of influential works were published in the 1980s (e.g., Hedges & Olkin, 1985; Rosenthal, 1984; "Statistics in Medicine," 1987; Yusuf, Peto, Lewis, Collins, & Sleight, 1985). Jointly, these publications contributed to the stature of quantitative research synthesis among statisticians (Chalmers, Hedges, & Cooper, 2002). Interest in use of research synthesis for policy decisions continued during the 1980s as well. In 1982, the Office of Technology Assessment (OTA) published a report that discussed the potential uses of meta-analysis and systematic reviews in assessments of health technologies. In 1983, the National Institute of Education published a collection of commissioned essays that explored the potential of secondary research studies to contribute to knowledge in education research, policy, and practice (Ward & Reed, 1983). Notable differences between Ward and Reed (1983) and the 1982 OTA publication include a stronger emphasis on the implications of diverse epistemologies and approaches to research in the context of integrative syntheses of primary studies, and a more integrated discussion of meta-analysis and research synthesis in education. Issues related to divergent research orientations would become important to the diffusion of research synthesis in other fields such as nursing and complementary and alternative medicine (Boyle, 2012).

Through the 1970s, 1980s and early 1990s, important developments occurred in the medical and health sciences that culminated in what was to become known as the evidence-based practice (EBP) movement. Archibald ("Archie") Cochrane is recognized for providing a vision for EBP inseparable from the methods used in medical research, first with his emphasis on RCTs,[10] and second, on systematic review of RCT findings[11] (Alvarez-Dardet & Ruiz, 1993; Chalmers, 2006). Just prior to the establishment of the Cochrane Collaboration, and the declaration of the evidence-based practice (and later, policy) movement (Evidence-Based Medicine Working Group, 1992), publications from two important high-profile lines of research were released, the *Effective Care in Pregnancy and Childbirth (ECPC)*[12] project (Fox, 2011; Mosteller, 1993) and a study on treatments for myocardial infarction (Antman, Lau, Kupelnick, Mosteller, & Chalmers, 1992). *ECPC* effectively advocated for and demonstrated the benefit of a systematic approach to review. The *ECPC* project, which was led by Iain Chalmers at Oxford, resulted in the two volume work, *Effective Care in Pregnancy and Childbirth* (1989), which

contained “syntheses provided by scores of meta-analyses of randomized and quasi-randomized trials…” (Mosteller, 1993 p. 524); a companion guide to practice recommendations, and the Oxford Data Base of Perinatal Trials. In the myocardial infarction study, the authors were able to demonstrate the need for research syntheses through a comparison of textbook advice on treatment for myocardial infarction with results from systematic research syntheses (Chalmers et al., 2002). This research showed that “valid advice on some lifesaving treatments had been delayed for more than a decade, and other forms of care had been promoted long after they had been shown to be harmful” (Chalmers et al., p. 21), with the implication that, for some patients, the cost of not performing clear and valid syntheses was premature death.

EBP catalyzed the diffusion of research synthesis methods. The rapid increase in use of research synthesis in most medical and health sciences is readily apparent from a simple review of search results retrieved by queries for meta-analyses and systematic reviews in databases such as *PubMed* and the *Web of Science* (*WOS*). The high visibility and apparent success of EBP fostered the development of evidence-based movements in other practice disciplines, including nursing, social work, and librarianship (Trinder & Reynolds, 2000). More than two decades later, it appears that the message of EBP still engenders initiatives in a widening spectrum of fields including, for example, Conservation Biology (Pullin & Stewart, 2006).

Publications that introduced research synthesis to wider audiences began to appear more frequently beginning in the 1990s. These included Lipsey and Wilson’s (1993) critical assessment of over 300 quantitative syntheses on the efficacy of psychological, educational, and behavioral treatments; and Cooper and Hedges’s (1994) *Handbook of Research Synthesis. Meta-Ethnography* by Noblit and Hare (1988) is generally recognized as the work that translated the concept of synthetic research methods to an approach congruent with an interpretive perspective.

Despite the apparent success of early studies, reports of research synthesis studies were not immediately recognized as important research contributions on par with primary research. In 2002, Chalmers, Hedges, and Cooper described the acceptance of research synthesis in academia as follows:

> Over recent decades, research synthesis has been widely seen within academia as second class, scientifically derivative work, unworthy of mention in reports and documents intended to confirm the scientific credentials of individuals and institutions. Indeed, systematic reviews are sometimes characterized as “parasitic recycling” of the work of those engaged in the real business of science... (pp. 21-22)

More recent studies suggest that this is no longer the case in at least some medical and health science fields (Bastian, Glasziou & Chalmers, 2010; Dijkers, 2009; Patsopoulos, Analatos & Ioannidis, 2005). Acceptance and use of research synthesis in other fields appear to vary greatly, though may be greater in practice-oriented fields due to the association between research synthesis and EBP (Trinder & Reynolds, 2000) and the efforts of influential individuals and

highly visible boundary organizations[13] (Guston, 1999) that have been pivotal to the evidence-based movement. Other factors that may contribute to the growing number of studies that use research synthesis include the perception that syntheses can integrate relatively large or diverse bodies of knowledge; the identification of approaches that can be used to synthesize research across and within groups of studies aligned with different philosophical perspectives; and publications that examine or promote the potential of research synthesis methods within disciplinary contexts (e.g., Rousseau, Manning, & Denyer, 2008).

Bibliometric overview of the diffusion of research synthesis methods

This historical overview suggests that whether researchers in a field adopt research synthesis methods may depend on several factors, including the extent to which researchers draw on past research, interest and engagement with evidence-based practice or policy, and whether research in a field is more directly applicable in a practice or policy context. Therefore, after describing patterns of the diffusion of research synthesis methods across science fields broadly, data were analyzed to assess associations between adoption of research synthesis methods and (a) engagement with past research, (b) engagement with EBP, and (c) more 'pure' versus more 'applied' research orientations. Additionally, commentary and development of novel forms of research synthesis methods suggests that it is possible that some fields might have tried to adapt the methods to research in the field. Such efforts could be a reflection of the perceived importance of research-based synthesis, and, in the event of successful adaptations, could facilitate broader use of the methods. Therefore, the prevalence of diverse forms of research synthesis was examined.

Methods

Bibliometric methods are employed to describe engagement[3] with research synthesis methods across science fields over time. In bibliometric studies, characteristics and content of publication, patent, or other research-related communications are analyzed to examine patterns in scholarly communications. Key assumptions of bibliometric analyses include that it is possible to extract data from research-related communications to represent knowledge produced in scientific research and to characterize social, cognitive, temporal, and other dimensions of groups that contribute to the production of knowledge. Development of conceptual and operational definitions, data identification and extraction, and descriptive statistical analyses are key components of bibliometric studies. Definitions, and data collection and analysis used in this study are discussed below.

Conceptual and operational definitions

Science fields are dynamic culture-bound socio-cognitive spaces (Whitley, 2000) held together by cohesive forces reflected in values, norms, beliefs, and practices (Bourdieu, 1988). Multiple, overlapping field boundaries can be identified at different scales based on field interactions and attributes, including those associated with collaboration and competition for resources, job markets, publication, and communications (Chubin, 1976). *WOS* categories are used to operationalize science fields: The broader Research Areas (SC) were used to aggregate data for the majority of analyses. When summarizing field-level data, Research Areas were

grouped into seven broad topical areas. For analysis of the diversity of fields that have engaged with research synthesis, the narrower *WOS* Categories (WC) were chosen to enable use of existing data and tools (Chavarro, 2011). The categorization schema, which divide science into overlapping categories based on journals, have been used extensively in bibliometric research, and provide access to socially meaningful divisions amenable to larger scale representations.

Research synthesis methods are research methods in which primary research findings are analyzed in a transparent and, generally, systematic manner, with the goal of generating new knowledge or interpretations. "Sub-types" of research synthesis methods include systematic review, integrative research review, qualitative research synthesis; meta-ethnography (Noblit & Hare, 1988); systematic research synthesis (Gough, 2004); and realist synthesis (Pawson, 2006). Research synthesis was operationalized via a set of query phrases (supplement 1) and seed publications (supplement 2) used to search the *Science* and *Social Science Citation Indexes* (*S/SCI*). Though as defined by Glass (1976), meta-analysis refers to statistical techniques used to combine quantitative data across studies, meta-analysis has often been used to denote the composite process of research synthesis, and therefore is included.

Diffusion, in the tradition of the diffusion of innovations, is described by identifying when and to what extent science fields have used research synthesis using visual and quantitative techniques. Three measures are used: When continuous engagement with research synthesis methods began in each field; the extent of engagement over time within fields; and the diversity of fields that engaged with the methods over time. When fields (SC's) began to engage with research synthesis is indicated by the publication year of the first RSM publication that is followed by other RSM publications in each subsequent year. The extent of RSM engagement is a count of RSM publications; and the proportion of RSM publications to all publications from 1972 or the first continuous year, whichever is more recent, to 2011. Three diversity measures were used: variety, balance, and dissimilarity (Rafols and Meyer, 2010). Variety is a count of science fields (WC's); balance, the distribution of publications across fields, measured by Shannon evenness; and similarity, the extent to which fields are cognitively similar, using Rao-Stirling diversity, with field distances determined by category-level citation patterns. Raw and normalized count data were used to calculate balance.

Review publications critically assess prior research in a given area. Reviews include research syntheses such as systematic reviews and other types of reviews such as narrative or historical reviews. Publications with records labeled "Review" in the *S/SCI* Document Type field are considered reviews. Given that whether there are 100 or more references in a publication is one criteria used to define reviews in the *WOS*, in some fields, it might be more likely that research syntheses are not categorized as reviews because studies included in a synthesis may not be included in the publication's reference list (Payne et al, 2012). Accordingly, it may be more correct to interpret this measure as the extent to which a field engages with past research.

The *evidence based practice and policy (EBP)* movement (Pope, 2003) is a scientific-

intellectual movement (Frickel & Gross, 2005) with research, practice, political, social, and other dimensions, but which is primarily focused on mobilizing resources to translate and transform research-based knowledge to inform practice. EBP engagement is operationalized through a topic index search in *S/SCI* with the query phrase, "("evidence based") NOT ("evidence based on") NOT ("evidence based upon")". Results were limited to publication years 1992[1]-2011. Prevalence of EBP is the proportion of EBP publications to all publications (1992-2011).

Diversity of research synthesis methods is conceptualized as engagement with a wide range of research synthesis methods. Diverse forms of research synthesis include those that incorporate qualitative research, and also those that approach research synthesis from an interpretivist or realist stance. Diverse research synthesis methods publications were identified with a subset of the research synthesis methods searches (see supplements 1 and 2).

Pure and applied research fields: Scholars within a field may view that field as more pure or applied based on its relationship to practical problems (Biglan, 1973a). Applied fields focus more on research of more direct and immediate use outside the research context. Findings from prior studies that categorized fields with Biglan's three-dimensional[2] taxonomy (Biglan, 1973b; Malaney, 1986; Stoecker, 1993) were used to categorize fields as pure, mixed, or applied.

Data collection

Data were collected from the *WOS Expanded Science Citation Index* (*SCI*) and *Social Sciences Citation Index* (*SSCI*) using a combination of keyword (supplement 1) and cited reference (supplement 2) searches. The indexes were last updated 6 July 2012 at the time of the keyword search; cited reference indexes were searched on July 10, 16, 17, and August 1, 2012. RSM engagement and diversity data consist of bibliographic records identified with the searches; EBP, review prevalence, and norming data were collected via the *WOS* "Analyze" feature.

Data analysis

Data were organized by year of publication and *SCI/SSCI* Subject Category to determine, report, and present frequency data by year and field. Descriptive statistical analyses and correlations were calculated using SPSS v. 20 (IBM Corp., 2011) and R v. 2.15.1 (R Core Team, 2012). Spearman rank correlations were selected to analyze associations. Descriptive functional data analysis (FDA; Ramsay and Silverman 2005) was used to describe the increase in use of research synthesis methods in fields over time. Functional data analysis is similar to discrete data analysis except that series of data points are transformed into functions, which are treated as data objects. FDA was chosen to visualize the rates of publication of research synthesis methods papers, and to calculate the first derivative of the data objects, which represents the velocity, or change in rate and direction, of use of research synthesis over time. The R package fda (Ramsay, Wickham, Graves, & Hooker, 2012) was used for analysis.

The diversity of fields that engaged with research synthesis methods over time was examined using the variety, balance, and similarity measures previously discussed. A base network of cosine-normalized citation patterns from the 2010 *Journal Citation Reports* (*JCR*)

was used to indicate cognitive dissimilarity of fields. Changes in diversity over time were visualized with overlay maps created in Pajek (Batagelj & Mrvar, 1998) following Rafols, Porter, and Leydesdorff (2010). Ten-year time slices are used to conserve space.

Results

The extent of engagement with research synthesis methods has increased following the development of contemporary forms of the methods in the 1970s in education and psychology. Beginning in the 1990s, a greater number of fields engaged with the methods. Across all years (1972-2011), 123,881 records provide evidence of engagement with research synthesis. The number of publications has increased over time and varies across research fields. Education and Education Research was the first to publish research synthesis methods papers continuously, beginning in 1975. Two other social sciences, Psychology (1976) and Business and Economics (1979) followed shortly after. In the early eighties, several other fields, including the first in the health sciences (Geriatrics and Gerontology; Rehabilitation; and Sports Sciences, all in 1980), and the general social science category (Social Sciences Other Topics, 1980) began to engage regularly with research synthesis. As of 2011, only Microscopy included no RSM publications.

Though adoption occurred first in social science fields, across all social sciences, there is a high level of variation (mean=1990.1, s.d.=10.4 years). Clinical medicine (1988.4, s.d=2.7) and other fields in health and medicine (Other Health and Medicine, mean=1988.3, s.d.=7.5) were the first to adopt the methods *en masse*; and physical science and math fields the last (mean=2000.0, s.d.=7.6 years). Field groups with the least variability include clinical medicine, the relatively small agriculture group (N=6), and the life sciences (Table 1).

Table 1. *Year continuous RSM publication began by field groups*

Field Group	Field Ct	Miss	Mean	SD	Min	1st Qtr	Median	3rd Qtr	Max
All	136	18	1992.3	8.0	1975	1987	1990	1998	2010
Social Science	23	2	1990.1	10.4	1975	1982	1988	2000	2010
Other Health & Medicine	19	0	1988.3	7.5	1980	1982	1988	1990	2008
Clinical Medicine	25	0	1988.4	2.7	1983	1986	1989	1990	1994
Physical Science & Math	17	7	2000	7.6	1985	2000	2001	2004	2010
Technology	21	9	1997.8	9.1	1985	1989.5	1997.5	2006	2010
Life Science	25	0	1994.8	5.6	1986	1991	1994	1998	2006
Agriculture	6	0	1995.2	3.1	1990	1993	1996.5	1997	1998

Extent of engagement with research synthesis methods

The number of research synthesis methods papers published in each field ranges greatly, from 0 in Microscopy to 15,521 in General Internal Medicine and 15,044 in Psychology. Across all fields, the mean number of research synthesis publications is 1,295.06 (s.d.=2,530; median=342.5). Generally, clinical medicine fields had the greatest number of research synthesis

publications, followed by other fields in health and medicine (Other Health and Medicine) and the social sciences (Table 2). In contrast, the twenty fields with the fewest number of RSM publications include nine fields from the physical sciences and math; nine technology fields, and two from the social sciences.

Table 2. Research fields with the greatest number of RSM publications

Rank RSM	Field	Group	RSM Ct	Rank prop	First year	Size rank
1	Gen Int Med	CM	15521	14	1984	6
2	Psychology	SS	15044	12	1976	9
3	Card Syst Cardiol	CM	9502	22	1986	12
4	Neurosci Neur	CM	9016	40	1983	5
5	Psychiatry	HMO	8434	7	1981	27
6	Pub Env Occ Hlth	HMO	7875	8	1982	29
7	Oncology	CM	7077	26	1986	18
8	Surgery	CM	6452	20	1986	13
9	Pharma Pharmacy	CM	5793	42	1985	8
10	Gastroent Hepa	CM	5339	20	1987	30
11	Business Econ	SS	4451	43	1979	18
12	Hlth Care Sci Serv	HMO	3970	4	1988	69
13	Ob Gyn	CM	3902	13	1988	48
14	Endocr Metab	CM	3336	35	1990	24
15	Pediatrics	CM	2735	37	1986	33
16	Hematology	CM	2631	50	1989	21
17	Urol Nephr	CM	2440	32	1990	45
18	Educ, Educ Res	SS	2431	39	1975	44
19	Resp System	CM	2320	24	1989	59
20	Env Sci Ecol	LS	2204	64	1986	15

Note. Rank RSM: based on counts of RSM publications; RSM Ct: RSM publications counts; Group: field groups (CM: Clinical Medicine; SS: Social Sciences; HMO: Other Health & Medicine; LS: Life Sciences); Rank Prop: proportion of RSM publications to all publications; First year: first year of continuous RSM publications; Size rank: based on document counts.

When the number of research synthesis publications is considered as a proportion of all publications, the relative homogeneity across non-clinical health and medicine fields becomes evident; as does the heterogeneity across clinical medicine fields (Table 2). The social and life sciences engaged with RSM to a lesser extent though variation within the social sciences is much

lower when the size of fields is considered. Overall, trends in the number and proportion of research synthesis publications across fields support the conventional narrative of the importance of the methods in health and medicine and related to the evidence-based practice movement. Though the importance of the methods often has been discussed in psychology and education, fewer publications might be expected because social science researchers typically integrate results over a large number of studies, sometimes hundreds (Shadish & Lecy, 2015). In comparison, only six to sixteen studies are typically included in at least some health and medical science fields (Mallett & Clarke, 2002; Moher, Tetzlaff, Tricco, Sampson, & Altman, 2007).

Table 3. *RSM Publications per 10,000 publications from the year of continuous RSM use*

Field Group	Mean	SD	Min	1st Qtr	Median	3rd Qtr	Max
All	**52.1**	**63.6**	**0**	**7.3**	**23.3**	**77.6**	**313.4**
Social Science	56.4	51.3	5.4	19.2	34.1	76.2	225.8
Other Health & Medicine	126.5	80.7	11.8	55.9	124.1	165.2	302.5
Clinical Medicine	82.9	146.5	22.2	58.4	78.6	112.2	146.5
Life Science	42.1	61.4	6.0	14.2	22.3	51.7	313.4
Agriculture	14.6	4.8	8.1	11.2	14.1	17.7	22.0
Technology	5.2	5.8	0	1.1	3.4	6.9	15.5
Physical Science &Math	4.2	5.4	0	0	1.1	5.5	21.4

A complex, dynamic view of increasing engagement with research synthesis emerges when counts of publications by field are viewed over time. In Figure 1 the slopes and shapes of the publication rate functions depict a range of growth trajectories, from steeply increasing to long gentle slopes. The dense matt in the lower right corner indicates some fields have engaged with the methods only recently or not at all.

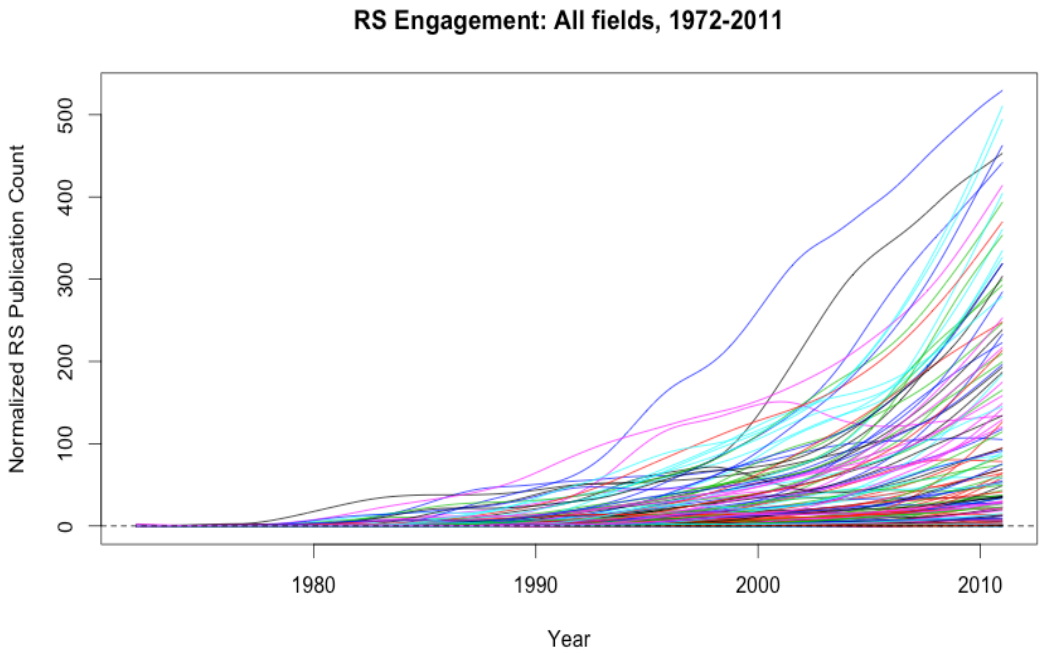

Figure 1. **Rate of research synthesis publication differs across science fields**

Note: RSM publications per 10,000 publications by research field and year. B-splines were fitted to smooth data.

Dramatic differences are evident in the plot of the first derivative of the functional slopes (Figure 2). The first derivative corresponds with research synthesis engagement as a function of the "velocity", or change in rate and direction of publication over time. The data suggest that engagement with research synthesis has fluctuated to differing extents across fields. It is possible that some fields are more affected by "fads" and "fashions" in research practices (Abrahamson, 1991), which may be induced externally (fashions), such as by funding agencies, or internally (fads) as a result of group dynamics. If so, this would impact rates of increase and variation. In addition to overall publication trends, there may be a periodicity in publication trends, and in some fields, events such as conferences, special journal issues, or controversies may trigger increased engagement for limited periods.

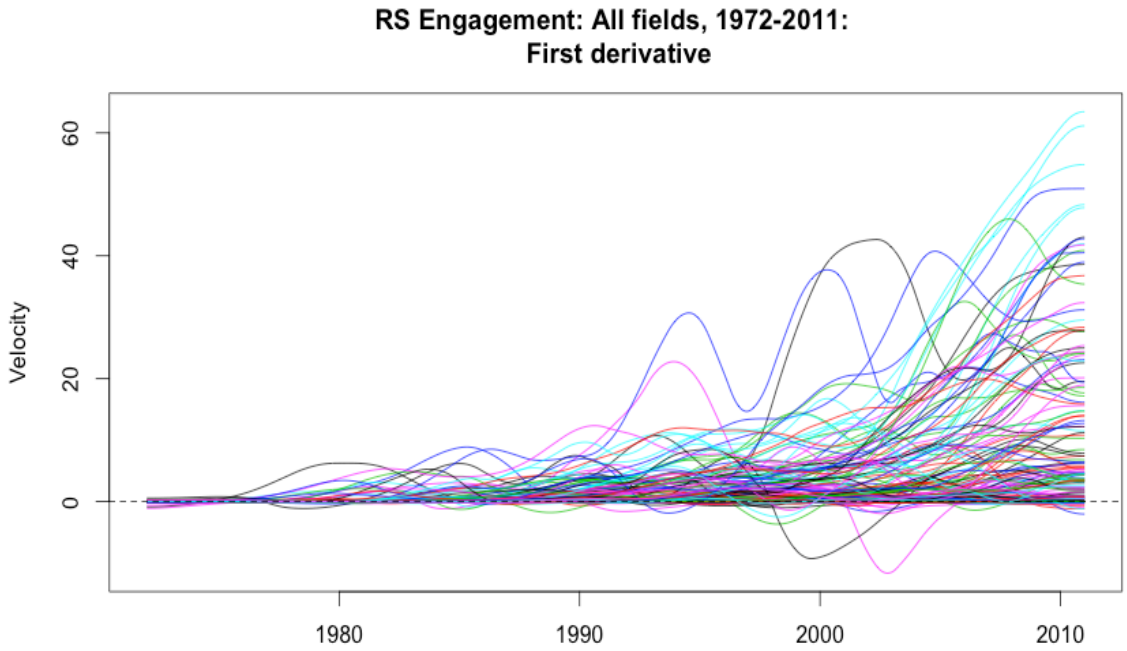

Figure 2. **Velocity of research synthesis publications in science fields**

Diversity of fields that engaged with RSM over time

Adopter diversity is another important aspect of diffusion. The variety and cognitive dissimilarity of fields that have engaged with research synthesis over time has increased, though at uneven rates (Table 4). As the number of categories has neared the maximum, 223, the rate at which variety has increased has slowed. The largest increase occurred in the first half of the 1990s, which corresponds with the rise of the evidence-based practice and policy movements. Figure 3 depicts the number of fields (nodes) that have engaged with the methods over time. Dissimilarity increased over time, which indicates that the set of fields that have engaged with research synthesis methods has become increasingly diverse cognitively. The increase in dissimilarity is evident in the overlay maps: more cognitively dissimilar fields are spatially distant and connected by fewer links.

Table 4. *Diversity of science fields engaged with RSM over time.*

Time period	Variety	Shannon Evenness (Balance)		Dissimilarity
		Count data	Normalized	
1972-1976	16	0.976	0.867	0.873
1977-1981	54	0.801	0.806	0.856
1982-1986	84	0.782	0.795	0.872
1987-1991	131	0.818	0.805	0.890
1992-1996	170	0.820	0.828	0.904
1997-2001	189	0.806	0.845	0.906
2002-2006	203	0.792	0.855	0.911
2007-2011	211	0.789	0.867	0.911

Balance, based on raw count data indicates there is an increasing difference in the proportions of research synthesis publications across fields. Though the number of fields that engage with research synthesis has increased (variety), the number of publications in each field has grown increasingly disparate. Normalized count data, compared to the raw count data, depicts greater balance across fields: When field size is taken into account, the proportion of research synthesis publications to all publications is more even. This view adds another dimension to diversity, however, because the range in the size of fields that engage with RSM and the increasing numbers of publications produced by some large fields in later years in a sense skews field-level comparisons. In addition to the magnitude of difference in balance for raw versus normalized data, the trends differ, especially 1997-2011. During this time, raw data indicates a decrease in balance, and normalized data, an increase.

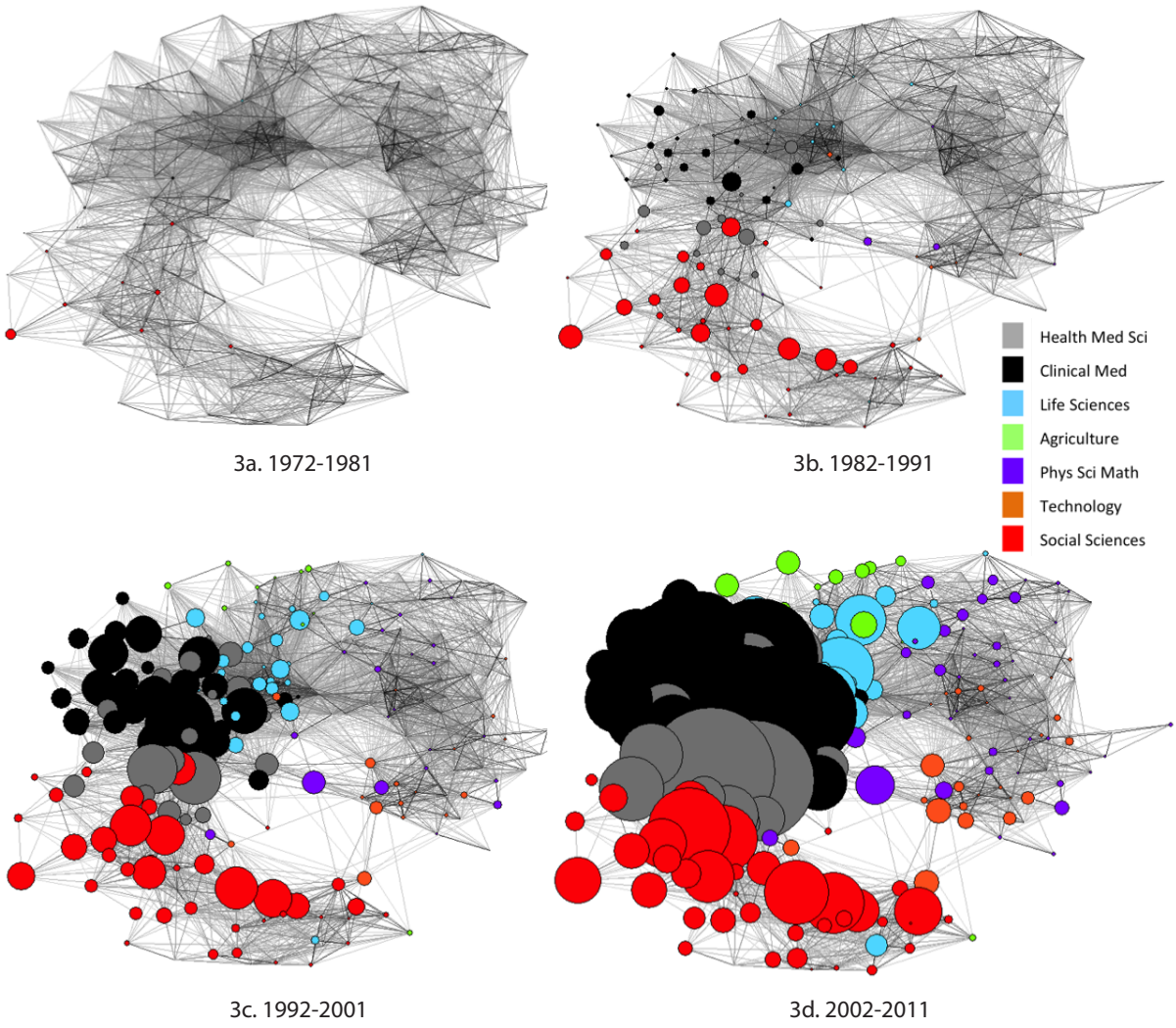

Figure 3 **RSM diffusion over on a base map of science, 1992-2011.** Nodes represent fields; node size, number of papers; edges (lines), referencing patterns; and relative node size, balance.

Characteristics associated with research synthesis methods diffusion

Relationships between engagement with research synthesis methods and factors identified as important to adoption in disciplinary literatures included the proportion of reviews in research fields; the extent to which authors have engaged with evidence-based practice and policy (EBP); the extent of interest in diverse approaches to research synthesis; and whether a field is more pure or applied. While sixteen of twenty-one correlations were significant, only associations between three variables were strongly correlated (Table 5).

Strong correlations were observed in all bivariate analyses between (a) the number of years RSM have been used in a field, (b) the proportion of RSM publications compared to all publications within fields, and (c) the extent of engagement with EBP. The relationship between the number of years RSM publications were produced and the proportion of RSM publications

(ρ=0.706, p< 0.001) is not surprising given that it takes time for publications on any topic to accumulate, but also suggests continuity of engagement with the methods. Once a field began to engage with RSM, the methods were unlikely to be rejected during the period examined (1972-2011). Strong correlations between EBP and both the proportion of RSM publications (ρ=0.893, p< 0.001) and the number of years RSM use (ρ=0.712, p< 0.001) underscore the historical relationship between EBP and RSM.

Table 5. *Bivariate Spearman's rho (ρ) correlations*

Measure	N	2.	3.	4.	5.	6.	7.
1. RSM/all pubs	136	.706 (.000)	-.060 (.244)	.403 (.000)	.893 (.000)	.072 (0.203)	.279 (.011)
2. Yrs RSM used	136		.385 (.000)	.289 (.000)	.712 (.000)	.166 (0.027)	.331 (.003)
3. Field size	136			.187 (.015)	-.055 (.264)	-.164 (0.029)	.091 (.231)
4. Reviews/all pubs	136				.351 (.000)	-.258 (0.001)	-.213 (.042)
5. EBP/all pubs	136					.144 (0.048)	.424 (.000)
6. Diverse/all RS	135						.048 (.351)
7. Biglan class	67						

Note. Correlations reported as ρ (significance). RSM/all pubs: proportion of RSM publications; Yrs RSM used: the number of years of continuous RSM use; Field Size: number of publications (1992-2011); Reviews/all pubs: proportion of reviews (1972-2011); EBP/all pubs: proportion of EBP publications (1992-2011); Diverse/all RS: proportion of diverse RSM to all RSM; and Biglan Class: an ordinal measure (1="Pure", 2="Mixed", and 3="Applied").

Correlations between diffusion variables and other characteristics were small to moderate. Moderate correlations were observed between the proportion of reviews and proportion of RSM (ρ=0.403, p< 0.001); and between Biglan class and years of RSM use (ρ=0.331, p= 0.003). Among factors identified through the historical review, the strongest correlations were between the proportion of EBP publications and Biglan class (ρ=0.424, p< 0.001), and reviews and EBP (ρ=0.351, p< 0.001). Small negative correlations were observed between the proportion of reviews and diverse RSM (ρ=-0.258, p< 0.001) and Biglan class (ρ=-0.213, p= 0.042).

Engagement with evidence-based practice

The extent to which a field engages with evidence-based practice and policy may be an indicator of a greater interest in research synthesis methods, especially since RSM has often been identified as a method used to translate and transform research-based knowledge to inform professional practices. The quintessential effort at the nexus of EBP and RSM comes from medicine and the health sciences: the Cochrane Collaboration. A number of leaders in the evidence-based medicine movement (Smith & Rennie, 2014) are well represented in the RSM dataset. For example, a search across the RSM dataset indicates there are approximately 34 publications by Iain Chalmers, 96 by Thomas Chalmers, 28 by Kay Dickersin, 101 by Paul Glasziou, 217 by Gordon Guyatt, 36 by Drummond Rennie, and 18 by David Sackett.

Engagement with EBP varies across and within fields (Figure 4). Fields in health and medicine have engaged with EBP to the greatest extent; and clinical medicine, social science, and a few others have also engaged with EBP. The relatively high proportion of EBP publications identified in some fields, such as Computer Science; and relative lack of EBP in others, such as Veterinary Sciences is surprising. Additional evidence would be necessary to understand the relationship between EBP and these fields.

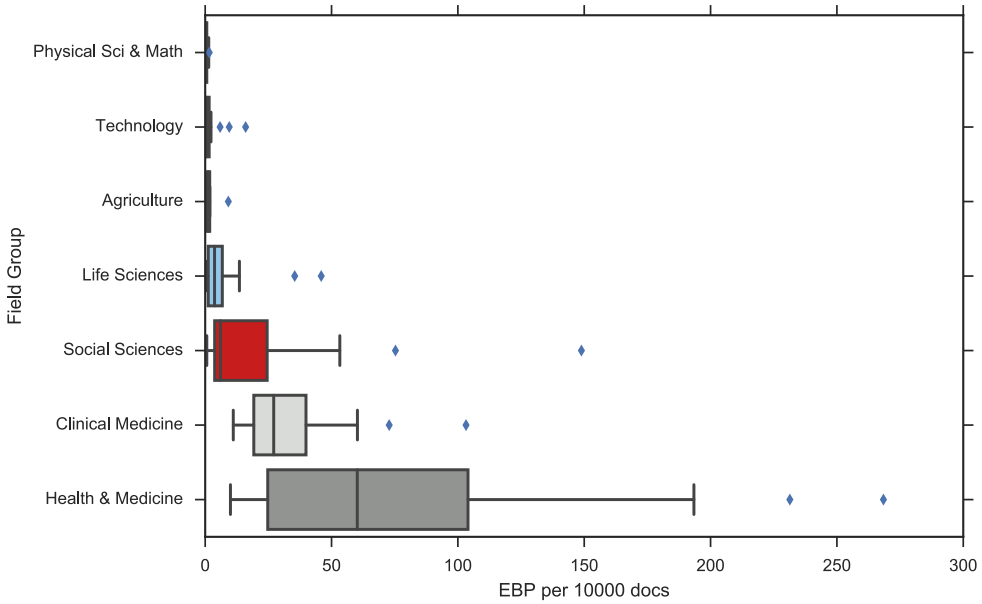

***Figure 4*. Number of EBP publications per 10,000 publications**

Though the genesis of the EBP movement was not until the 1990s, earlier work suggests concerns associated with the ability to draw on research findings to support practice and policy decisions in the professions was a compelling reason for researchers in many fields to focus on the development of research synthesis methods. This is evident in Frank L. Schmidt's work with psychometric meta-analysis, developed in the context of validity generalization research in industrial-organizational psychology (DeGeest & Schmidt, 2011). Anecdotally, evidence of interest in using RSM to inform practice and policy decisions predates known usage of the phrase "evidence-based practice" by at least twenty years in the social sciences. For example, Light and Smith (1971) quote then-Senator Walter Mondale's address to the American Educational Research Association (AERA) as a motivating example of the need for the "cluster approach,… a means of combining the data of studies from which conflicting conclusions have been drawn" (p. 430). Mondale, discussing the relationship between research and school integration policy states:

> What I have not learned is what we should do about these problems. I had hoped to find research to support or to conclusively oppose my belief that quality integrated education is the most promising approach. But I have found very little conclusive evidence. For every study, statistical or theoretical, that contains a

> proposed solution or recommendation, there is always another, equally well documented, challenging the assumptions or conclusions of the first. No one seems to agree with anyone else's approach. But more distressing: no one seems to know what works. As a result I must confess, I stand with my colleagues confused and often disheartened (Mondale, in Light & Smith, 1971, p. 431).

Though Mondale's quote may be posited as motivation to use research synthesis methods and implies that the methods may solve long-standing research problems, critiques of systematic review approaches (e.g., Boell & Cecez-Kecmanovic, 2015), how the methods are implemented, and issues associated with research and publication systems (e.g., Ioannidis, 2016) suggests such optimism should be measured. Just as topical knowledge evolves, so too does procedural or methodological knowledge, as is indicated, for example, by adaptations to research methods (Sheble, 2014). Further, as discussed in the diffusion literature, it is possible for innovations that would be effective to fail; and for others that are not especially effective to be widely adopted (Abrahamson, 1991). Contagion effects and false perceptions of the "goodness" or suitability of an innovation to a context may, in some cases, contribute to diffusion (Strang & Macy, 2001).

Reviews: Resources dedicated to past research

Traditional literature reviews are one way that researchers bring past research to bear on contemporary problems. Reviews vary in the extent to which they are comprehensive, explicitly or implicitly include expert opinion, and breadth and depth of coverage. Reviewed literature may be selected based on expert judgment, through sampling procedures, or systematic collection using defined search strategies (as suggested by Bates, 1992). Researchers in fields that devote a greater proportion of resources to reviews may be interested in novel approaches to research integration. Conversely, if traditional review practices are viewed as a good fit for a field, researchers may be more reticent to adopt novel approaches, especially those as resource-intensive as systematic research synthesis methods. Low levels of review in a field may indicate that researchers in a field place less value on formal integration of past research compared to alternative initiatives that result in other types of documents such as reports of primary research studies or theory papers.

There has been a great deal of variation in the number of review papers published across and within fields over time (Figure 5). By field groups, there is a general upward trend in the proportion of reviews, with the exception of the social sciences in recent years. The recent decrease in the proportion of reviews in a number of social science fields begins in 2010 after relative highs from around 2000 until about 2009. Whether this reflects a change in publication practices, a change in the citation indexes, or something else is unclear. Two possibilities include that, with the advent of the *Book Citation Index* in 2011, a proportion of social science review publications were removed from the *SSCI* to be offered exclusively through the new index, or, if research synthesis was becoming the predominant form of review in some social science fields, the language used to describe such work (e.g., "meta-analysis", "research synthesis", etc. versus "review") and changes in referencing practices may have resulted in fewer "Review" items.

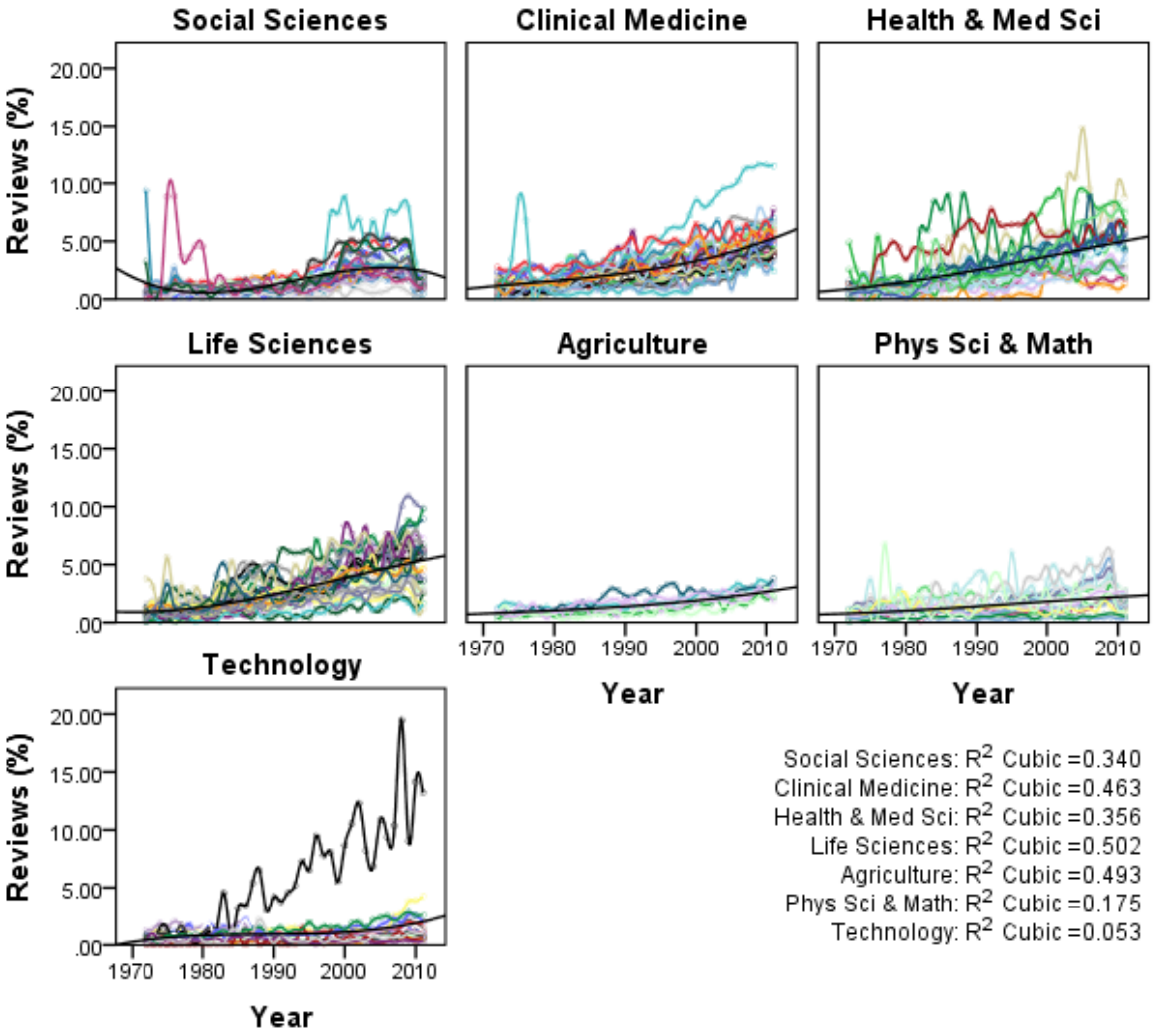

***Figure 5*. Proportion of reviews by field and field group**

Note: Cubic interpolation lines were fit to identify group-level trends.

Review prevalence was moderately correlated with RSM engagement (ρ=0.403, p<0.001) and EBP engagement (ρ=0.351, p<0.001), but only modestly correlated with other factors, including years of RSM use (ρ=0.289, p<0.001), field size (ρ=0.187, p=0.015), proportion of Diverse RSM (ρ=-0.258, p=0.001), and Biglan Class (ρ=-0.213, p=0.042). These associations suggest that the relationship between reviewing practices and RSM engagement is not direct. Given the changes in the proportion of reviews over time, it is possible that measurement of reviews en masse from 1972-2011 has masked the relationship between reviews, RSM engagement, and other factors. Negative correlations between Biglan Class and EBP suggest that it may be beneficial to look more closely at associations between review prevalence and RSM in the context of more pure fields and those that engage with EBP.

Diversity of research synthesis methods

Diverse approaches to research synthesis could influence whether and to what extent researchers adopt the methods. A diverse form could be imported from another field, or

developed by researchers in the field. If the field was receptive to the diverse, adapted form of RSM, this might facilitate adoption of RSM. Though this is possible, the data suggest engagement with diverse forms of research synthesis was negligible in most fields. Only 3,136 instances of diverse RSM publication were found. Fields with the greatest proportions of diverse research synthesis were primarily, but not exclusively, social sciences (Table 6). Fields with more than 100 diverse RSM publications were: Psychology (302 publications), Public Environmental and Occupational Health (264), Health Care Sciences Services (217), Nursing (204), General Internal Medicine (189), Education and Education Research (172), and Business Economics (105).

Table 6. *Diverse Research Synthesis Methods*

Prop. Rank	Count Rank	Field	RSM pub counts Diverse	RSM pub counts All	RSM pub prop Diverse	RSM pub prop All	Years of RSM
1	52	Geography	11	58	18.966	0.232	8
2	25	Public Administration	30	219	13.699	0.233	21
3	72	Energy Fuels	5	37	13.514	0.142	6
4	64	Urban Studies	7	53	13.208	1.117	12
5	18	Sociology	40	329	12.158	0.183	30
6	50	Operations Res Mgmt Sci	12	112	10.714	0.041	18
7	16	Biomedical Social Sciences	47	466	10.086	0.856	22
8	4	Nursing	204	2,148	9.497	1.901	30
9	11	Computer Science	65	717	9.066	0.096	26
10	48	Transportation	13	152	8.553	0.568	18
11	20	Information Sci Library Sci	34	408	8.333	1.465	21
12	40	Linguistics	17	209	8.134	0.312	23

The proportion of Diverse RSM was correlated with the number of years of RSM use (ρ*=0.166, p=0.027)*, field size (ρ*=-0.164, p=0.029)*, proportion of reviews (ρ*=-0.258, p=0.001)*, and EBP engagement (ρ*=0.144, p= 0.048)*. The magnitudes of the correlations were modest, and no association was found with overall proportions of RSM. These preliminary findings may be influenced by how diverse RSM were defined and the search strategy used to identify diverse forms of research synthesis.

Conceptually, diverse forms of research synthesis were defined based on the overall process of synthesis, and the data collection strategy was devised accordingly. Assumptions about the language researchers would use to describe methods, reflected in the data collection strategy were likely appropriate for some fields more than others. Diverse forms of research synthesis that draw on more traditional terms likely were missed, as were incremental introductions of novelty that contribute to the development of diverse approaches. For example, in Evolutionary biology, the development of phylogenetic meta-analysis has been important. Whether this should be considered a diverse form of RSM is open to interpretation. It is also possible that when the overall landscape of the diffusion of research synthesis is considered,

diverse forms of research synthesis have been important in smaller or niche research communities; or that these diverse alternatives have yet to be shaped in a form that solves a broad range of extant synthesis problems as well as other forms of systematic review and meta-analysis.

Limitations

This study, like other bibliometric studies, is limited by uneven availability of data. Selection of journal titles for inclusion in the *S/SCI* provides an unbalanced view of research in fields (Meho & Yang, 2007). The extent to which selection distorts research fields varies by field and is not well documented across fields. It would have been preferable to include a number of journals not indexed in the *S/SCI*, including *Evidence Based Library and Information Practice* (*EBLIP*), *Environmental Evidence*, *Research Synthesis Methods,* and *Systematic Reviews*; and early volumes of *Educational Research Review*.

Dramatic increases in the levels of engagement with research synthesis methods in latter years in part may reflect expectations that authors identify research synthesis studies as such - or, more specifically, as "systematic review" or "meta-analysis" - in titles since *WOS* topic searches query the Keywords Plus™ field as well as publication title, abstract, and author-provided keywords. Identification of whether a paper reports a research synthesis is recommended by research reporting guidelines in the medical, health, and psychological sciences (e.g., APA, 2008); and may appeal to researchers in fields in which hierarchies of evidence are recognized since research synthesis studies are rated highly in such hierarchies.

Given that the EBP measure is relatively coarse, the relationship between EBP and RSM may be underestimated. For example, the phrase 'empirically supported treatment', which was not included in the EBP search, is commonly used in psychological sciences, and so the prevalence of EBP engagement in these fields is somewhat underestimated. Additionally, in some contexts, "evidence-based" phrases may be used less frequently as other phrases such as "research-informed practice" become more prevalent. Hjørland (2011), for example, argues that "research-based practice" is preferable to EBP because it "is open to more fruitful epistemologies and provides a broader understanding of evidence" (p. 1301). However, identification of many publications authored by EBP thought leaders and searches for other phrases in the *S/SCI* suggest the measure is generally on target.

Discussion and future directions

Research synthesis methods have contributed to changes in the practice and use of research in diverse fields across science. Past studies have described increased use of research synthesis methods in specific fields (e.g., DeGeest & Schmidt, 2011); and methods books often illustrate increased prevalence of research synthesis methods over time (e.g., Koricheva, Gurevitch, & Mengersen, 2013). This study described engagement with research synthesis methods over four decades across science broadly, and identified factors that appear important to its adoption. These factors included engagement with evidence-based practice and policy, and

the relative importance of literature review activities. A further factor seems to be research orientation, with differences noted between pure versus applied fields. Additionally, the prevalence of diverse forms of research synthesis methods, which could signal an attempt to adapt the methods to the needs of the field, was examined but found to be inconclusive.

Relatively modest engagement with research synthesis methods in the 1970s and 1980s was followed by expansion in both the extent of engagement and diversity of fields that engaged with the methods in the 1990s. This period coincides with the popularization of the evidence-based practice movement first, in medical and health science fields (Evidence Based Medicine Group, 1992), and later, in other fields. Engagement with the methods continued to increase and spread across fields through the first decade of the 2000s. While the social sciences were the first to engage with the methods, engagement varied greatly across social science fields. In contrast, there was less variation across clinical medicine. Overall, physical science and math, and technology fields were later adopters, engaging with the methods only in more recent years and to a lesser extent. In technologically oriented fields, the lack of engagement may be due to difficulties in coherently synthesizing research across relatively rapidly changing technologies. Some fields likely rely on other approaches and use other language to describe synthesis across research studies. For example, the Particle Data Group (1957-2014) integrates findings across particle physics studies and publishes results in the *Review of Particle Physics*.

The extent of engagement with research synthesis methods was strongly associated with the number of years the methods have been used ($\rho=0.706$, $p<0.001$) and with engagement with EBP ($\rho=0.893$, $p<0.001$). Though a correlation between the length of time the methods have been used and the extent of use is not surprising, the strength of the association is notable, and suggests fields that adopted research synthesis were likely to continue using them. Additional research would be needed to determine whether fields that adopted research synthesis more recently were likely to continue using the methods since there are likely relevant differences between fields that engaged with the methods earlier versus later. The strength of association observed between engagement with EBP and use of research synthesis methods is likely influenced by the great quantity of medical and health sciences research. Examination of fields at a more granular level (Sheble, 2014) suggested that the use of systematic reviews to support research translation in the health sciences has been emulated in other fields, including fields as different as Social Work and Conservation Biology.

Though the great quantity of research and interest in integrating past studies frequently have been identified as motivations to use research synthesis methods (e.g., Bastian, Glasziou, & Chalmers, 2010), prevalence of review publications, and adoption of research synthesis methods were moderately correlated ($\rho=0.403$, $p<0.001$). This finding indicates these factors are not the sole drivers for the adoption of research synthesis methods. Future research should analyze relationships between engagement with past research and RSM longitudinally; and examine fields that devote greater resources to review activities but do not use RSM to ascertain whether the methods are not used because of lack of awareness, social traditions, failure of the methods to

address important needs, or other reasons.

A relatively weak association between engagement with the methods and whether a field is more "pure" or "applied" in nature presents an interesting contrast to the strong correlation between engagement with EBP and research synthesis. The difference in levels of association in part may be explained by a lack of engagement with the methods in technology-focused fields, which engaged with research synthesis to a lesser extent. The extent to which the data used for this measure, originally captured in studies with faculty participants at select universities from the early 1970s through the early 1990s, is representative of the fields throughout the time period examined is unclear.

The findings suggest that as conceptualized here, diverse methods of research synthesis were seldom used and were only modestly correlated with factors believed to be important to diffusion of the methods. While diverse forms of research synthesis may be developed and adopted infrequently, or only in smaller or niche communities, true diversity in application of the methods across science may occur at more granular levels, and may not be reflected in the language used to define diversity here. Future studies should examine adaptation to research synthesis methods at more granular levels. Additionally, a data-driven approach to identification of diverse forms of research synthesis methods might be used to expose gradual adaptations in how the methods are conceptualized.

Conclusion

This study has presented two histories of the diffusion of research synthesis methods: one a selective, descriptive textual presentation of important facets of diffusion based on disciplinary narratives, primarily from the health and social sciences; and the second, an illustrated systematic bibliometric overview broadly across science that examines themes that emerged from the historical review: that research synthesis methods were developed at least in part as a response to large quantities of literature; the centrality of EBP to diffusion of the methods; and that research synthesis is especially relevant in more applied fields. This dual approach provides an opportunity to examine and build on ideas and questions encapsulated in past claims to open up the perspectival expertise of disciplinary researchers and examine their knowledge and views across a broader context.

Research methods can be considered usefully as innovations that are meaningfully treated within the theoretical framework of diffusion as presented by Rogers. Widespread adoption of systematic approaches to research synthesis has had a profound impact on how researchers interact with prior research in the medical and health sciences, and psychology. The methods were adopted in a wide range of other fields, and likely have affected research practices and use in these fields, including collaboration patterns and how researchers interact with literature, data, and information infrastructures. More subtle changes may relate to what is included in reference lists, and how research is evaluated and used to support subsequent research. Research synthesis methods, like collaboration and interdisciplinary scholarship, promote integration of research-

based knowledge, an important counter-balance to specialization. Future research should investigate relationships between different approaches to research integration; and outcomes of programs designed to promote integration of science knowledge. A better understanding of how these approaches complement each other and differ would lead to a better understanding of integration, or synthesis, in science overall; and could inform design of research policy programs. Additionally, though not considered directly here, analysis of innovation in research methods could yield insights into how to design data tools to support synthesis methods.

Endnotes

1. Psychometric validity generalization (VG) meta-analysis is used to assess whether and to what extent a psychological construct, test, or measure is a valid predictor across a variety of contexts (DeGeest & Schmidt, 2010).

2. OAM is now the National Center for Complementary and Alternative Medicine (NCCAM).

3. 'Engagement' is used to recognize that identified publications may relate to RSM in a variety of ways. Publications may implement, develop, discuss, or in some other way relate to research synthesis methods.

4. MARS: Meta-analysis Reporting Standards (APA, 2008).

5. JARS: Journal Article Reporting Standards (APA, 2008).

6. MAER-Net: Meta-analysis of Economics Research Reporting Guidelines (Stanley et al., 2013).

7. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Moher, Liberati, Tetzlaff, & Altman, 2009).

8. MOOSE: Meta-analyses Of Observational Studies in Epidemiology (Stroup et al., 2000).

9. QUOROM: QUality Of Reporting Of Meta-analysis (Moher et al., 1999), replaced by PRISMA in 2009.

10. Cochrane, A. L. (1972). *Effectiveness and efficiency: Random reflections on health services.* London: Nuffield Provincial Hospitals Trust. Note: Cochrane explicitly recognized that the RCT approach was not universally suitable for research.

11. Cochrane, A. L. (1979). 1931-1971: a critical review with particular reference to the medical profession. In: *Medicines for the year 2000* (pp. 1-11). London: Office of Health Economics.

12. Chalmers, I., Enkin, M., & Keirse, M. J. (1989). *Effective care in pregnancy and childbirth*. Oxford: Oxford Medical Publications.

13. Such boundary organizations include the Cochrane and Campbell Collaborations, the EPPI-Centre (UK), and health science programs in Australia, Canada, and more recently, the United States (Fox, 2011).

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