STRATEGIC ORTHODOXY AND INNOVATION INCENTIVES IN SCIENCE STUDIES

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Kyle Sean Siler

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Kyle Sean Siler, Ph.D.
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This dissertation examines the invisible and visible colleges of contemporary Science Studies; a nascent, diffusing Social/Intellectual Movement largely contained within modern universities. Three main empirical studies underpin this examination. Firstly, network analysis of bibliography works in Social Studies of Science. Based on measures for article orthodoxy and closeness centrality, results show that orthodox contributions were more cited in nascent, foundational periods, while interstitial ideas were more valued in later time periods. Secondly, the various institutional niches Science Studies scholars have carved out are examined. Drawing on the newness and unique malleability of their field, professional advantages have been derived from enacting varying degrees of intellectual closure and quasi-disciplinary organizational forms. Thirdly, to examine the factors underpinning success, citation analysis is conducted of a seminal Science Studies book, *Laboratory Life*. Prominence and orthodoxy of a scholar positive influence the likelihood of citing the book, but these trends decline over time. This suggests that books and ideas can have very different meanings and life-cycles in different communities.

BIOGRAPHICAL SKETCH

Kyle Siler received a Bachelor of Arts degree in Sociology with First Class Honors from the University of Calgary in 2002. Then, he moved to McMaster University, where he received a Master of Arts degree in Sociology in 2003. At Cornell University, Kyle conducted research on intellectual strategy and diffusion, as well as scientific peer review and decision-making challenges in online poker. After completing a Ph.D. degree from the Department of Sociology at Cornell University, Kyle will hold a Banting Postdoctoral Fellowship at McMaster University, commencing in 2012.

ACKNOWLEDGMENTS

The adage that “it takes a village to raise a child” is also applicable to dissertations and scholars. I was extremely fortunate to have conducted my doctoral work at Cornell University, which was a fertile and supportive environment, facilitating my development as both a scholar and a person. While the dissertation entailed an enormous amount of work on my part, I would not have had the skills or motivation to complete without the constant and unconditional support of others.

David Strang was kind (or foolhardy?) enough to chair my dissertation, even when I was not initially sure what I was doing. David granted me a long leash to explore with, but was always able to deftly untangle me whenever I accidentally wrapped that leash around my neck with my sometimes naïve frolicking. David was incredibly generous with his time and patient with me whenever I was clumsily scrambling up steep learning curves. While I cannot purport to possess David’s patience and even-tempered wit, in addition to molding me as a scholar, David also provided me with a role model to at least attempt to emulate when mentoring others. I do not know how good I am (or ever will be) as a sociologist, but I do know that thanks to David, I am a good deal better than I probably should have been!

Reflective of the breadth and depth of quality at Cornell University, I was also lucky to have been guided by thoroughly brilliant dissertation committee members. Pamela Tolbert is more responsible for this dissertation than anyone, as she honed in on a large presentation I gave as a fairly green student in her class, and pointed out that the small part on STS was an idea worth pursuing. Further, through her enthusiastic and learned pedagogy, Pam compelled me to pursue organizational theory and research as a focal part of my intellectual identity and career. Pam's ability to filter through sometimes arcane and meandering issues, and succinctly clarify the relevant issues or problems was particularly useful, given the challenges of encountering new and sometimes bewildering challenges as a young researcher. While Sarah Soule was greatly missed after she departed for sunnier pastures, she still went above and beyond what a graduate student would normally expect in Ithaca, let alone three time zones away. Sarah is a uniquely talented scholar, in that she is just as adept with dealing with grand, theoretical ideas, as she is about minute details. Sarah was enormously helpful in framing my work theoretically, but also was willing able to scrutinize my prose, and brought to my attention things that I had never been conscious of, such as my tendency to not keep my tenses consistent. Stephen Hilgartner offered an insider's perspective on STS, which was particularly important for an outsider like myself. Steve was also able to understand where I was coming from as a sociologist, which made the link he provided to STS even more invaluable. I hope I was able to do his field justice!

Beyond my dissertation committee, this work was also enabled by the generosity of Kate McCain at Drexel University, who in response to an email merely asking for a review of relevant articles in her field, volunteered three days of her time to mentor me in citation analysis. Doing this work would have been bewildering without that foundation. Further, the faculty and graduate students as a whole at Cornell underpin a vibrant and nurturing intellectual and professional culture, which was a fertile and inspiring environment to work in. There may have been adversities and even the occasional villain along the way, but I still would not want to have completed my

doctorate anywhere else. From Calgary to Hamilton to Ithaca, countless people have directly or indirectly helped me improve as a scholar and a person. In turn, while my name may be on the title page of this dissertation, any credit this work receives should not wholly be my own.

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INTRODUCTION

Sociologists and philosophers of science have long identified a continuum between natural and social explanations of science (Cole, 1992). The content of scientific ideas and research can be influenced by the social qualities and connections of their progenitors, as well as by the inherent quality of the work. Additionally, the potential for an idea to diffuse or a scientist to gain prominence can be influenced by both its inherent quality, as well as the intellectual and social diffusion channels it can travel through. Baldi's (1999) citation analysis of sociology suggests that articles are cited primarily for their inherent content and quality, as opposed to social reasons. However, extensive research also suggests that scientists and ideas coming from advantaged origins (e.g., from male scientists, or from elite universities) receive greater deference and exposure (Reskin, 1978; Burris, 2004). Beyond scientific contexts, people in general tend to defer to what are perceived as leading ideas, or to overestimate the quality of contributions from high-status people and institutions (Leahey, 2003; Ceci and Williams, 1983). In turn, analyses of science and idea diffusion need to account for both scientific and social factors that determine which ideas become popular and influential. While some contexts and case studies may be more conducive to scientific or non-scientific influences than others, the potential for influence from both sides of the continuum exists.

Cole (1983) argues that science is defined by its inherent uncertainty, particularly at the elite research frontier which tends to lead science and make important discoveries. Scientists are charged with the challenge of developing new and cutting-edge ideas and research projects. If something is clearly true, then the appeal of research on that topic is of little interest to scientists. Thus, working with some degree of uncertainty is an inherent risk – perhaps an occupational hazard – of being a scientist. As people are generally risk-averse and uncomfortable with uncertainty, they tend to takes measure to avoid or mitigate the uncertainty, or to adopt arbitrary heuristics to use as criteria to resolve difficult decisions (Kahneman and Tversky, 1979). In turn, identifying quality is a challenge, particularly in the early stages of an innovation, where people have few social referents to mine for information. People tend to gravitate towards contributions that have been identified by others as being meritorious (Merton, 1968), to the point that status signals can drive the popularity of an innovation more than quality (Salganik, 2004). Further, the dustbin of history is filled with many failed ideas and innovators, some of whom which were offering contributions of higher quality than the rivals or incumbents that vanquished them.

Whitley (1984) specifically identified *task uncertainty* and *mutual dependence* as the main factors underpinning scientific uncertainty. Task uncertainty refers to the limitations scientists face when conducting experiments and analyses based on often imperfect data and methods. Mutual dependence involves the degree to which scientists in a given field agree upon the normative values, priorities and ideas that define a scientific field. While scientific disciplines possess task uncertainty and mutual dependence to varying degrees, scientific work is influenced by the challenge of creating quality in contexts where what quality is, is uncertain or not entirely agreed upon. Paraphrasing Pirsig (1974), Moody (2005) argues that “quality exists, even if it is difficult to define.” As quality can be difficult and contentious to define, scientists must make choices regarding the intellectual and social influences they will base their work upon. As knowledge communities develop via repeated interaction and cumulative knowledge, this increases the heterogeneity and complexity of the network (Carley, 1991). This entails a division of labor within the knowledge community, requiring some degree of specialization on the part of actors within the field. In turn, this raises the question of if and how scientists choose their niches in complex fields, and what the intellectual and career-related consequences of such decisions are. As Newton famously quipped, scientists “stand on the shoulders of giants” to make scientific progress. However, the choices scientists make in choosing “where to stand”, influences their intellectual vantage points and career trajectories. This thesis uses the case study of Science and Technology Studies (STS; also referred to as Science Studies) to analyze how the choices of scholars in intellectual and institutional contexts influence the content and reception of their ideas, and in turn their scientific careers.

This dissertation examines scientific decision-making and outcomes in STS on a variety of levels: institutional, disciplinary, individual and article-level choices, as expressed through citations. In particular, the research endeavors to uncover and analyze the factors that result in successful outcomes in science, which may occur at the departmental, individual or paper level. Three different studies are reported in the following three chapters. The first chapter examines STS from historical and qualitative perspectives. Academia tends to be very inertial and organized through entrenched disciplinary enclaves (Abbott, 2005), so carving out a new niche in this environment is a significant challenge. Through historical archives from central STS institutions, interviews with founders of STS departments and keyword analysis, the first chapter identifies the varying tactics STS actors employed to successfully establish and defend their professional and intellectual turfs. The second chapter moves the locus of decision making from the institutional level to the individual level. The intellectual influences underpinning scientific articles are operationalized through the bibliographic networks of STS papers. In turn, network metrics are analyzed to determine which bibliographic network positions are most conducive to an article being highly cited. The third chapter examines an influential, highly-cited work in Science Studies – *Laboratory Life* – and endeavors to reveal how and why the book became so influential, and its unique intellectual and professional diffusion trajectory.

Chapter 1: Establishing STS in the Academic Hinterland

Abbott (2005) distinguished between Heartland and Hinterland disciplines in the contemporary ecology of higher education. Heartland disciplines – such as philosophy, political science and mathematics – are staples of the modern university; few post-secondary institutions could be seen as entirely legitimate without having such departments. In contrast, Hinterland disciplines are less common and lack the cachet of most Heartland Disciplines. While Hinterland disciplines may be prized and differentiating assets for some universities, they are seldom seen as vital.[1] As formal institutionalization of STS did not occur until the mid-1970's, and STS departments have been formally established in relatively few universities, STS is an example of a successful and diffusing Hinterland discipline. Since Hinterland disciplines tend to lack legitimacy and resources, this raises the question of how such knowledge institutions survive.

[1] It is worth noting that "Heartland" and "Hinterland" are ideal types, and some disciplines occupy space on the continuum between the two extremes. For example, while most universities have sociology departments (which suggests it is a Heartland discipline), the 14th and 35th ranked colleges in the 2012 U*.S. News and World Reports* rankings – Washington University in St. Louis and University of Rochester – do not have sociology departments, presumably with little harm to their legitimacy.

This challenge is exacerbated for nascent organizations that also lack visibility and coordinating institutions, such as professional associations and a unifying intellectual canon.

In addition to the academic challenge of creating new knowledge, STS scholars also often were faced with the challenge of navigating professional and institutional environments in order to support and establish their new discipline. To explain how and why STS has managed to succeed despite the inherent disadvantages of being a Hinterland discipline in a competitive, inertial field, such as academia, interviews were conducted with scholars who played a role in founding an STS institution. By asking scholars how they overcame the aforementioned challenges of new academic endeavors, this can reveal the strategies and tactics scholars use to establish niches in often crowded and competitive academic contexts. Further, interviews can reveal possible advantages and benefits of STS and its social/intellectual positioning that drew scholars to STS can also be revealed. STS was founded with a primary emphasis on interdisciplinarity (Hackett et al., 2008: ch.1). In turn, numerous scholars voluntarily 'left' intellectually and/or professional their home disciplines to various degrees to pursue STS work. Interviews provide a means of revealing the risks and/or rewards scholars perceive, and the influences that underpin their intellectual vantage points and scientific work.

The challenge and struggle to establish and diffuse STS is linked to intellectual and professional changes in the field as a whole. Hilgartner (2003) argues that since its initial founding as an interdisciplinary endeavor, STS has developed an intellectual canon and professional niche of its own, and in turn, has begun to develop into an autonomous discipline of its own. Winner (1996) suggests that tensions exists between dueling factions of STS, involving those that want to retain its interdisciplinary ethos, and others that desire stronger academic and professional boundaries around a well-demarcated intellectual core. Cole (1996) argues that professionalization and increased intellectual coordination of STS came at the expense of jettisoning its mainstream sociological roots. Interviews with prominent STS members provide a means of accessing some of the "inside baseball" behind these conflicts within the field, as well as revealing a variety of philosophies regarding where they want their careers, departments and the discipline of STS to proceed next. Compared to older and more established disciplines, STS is a relatively small and young field. As STS has the potential for expansion to numerous new arenas (i.e. universities and institutions that have yet to found STS departments), coupled with its generally eclectic intellectual culture, this makes it a particularly malleable field with an uncertain future. Thus, this raises the stakes around intellectual and institutional decisions and dilemmas that STS scholars face. Interviews can reveal how leaders heavily invested in STS have handled, and are attempting to successfully negotiate these challenges in the future.

Ch. 2 – Intellectual Positioning and Good Ideas

As mentioned, scholars "stand on the shoulders of giants" to further science and accumulate knowledge. Scholars have diverse intellectual biographies and personal aptitudes, and assume varied viewpoints and niches in their fields. Intellectual and professional identities may be adopted or cultivated by scholars for personal and/or blatantly "careerist" reasons. Given that scientific knowledge is complex, this is conducive to generating intricate, heterogeneous fields (Abbott, 2002). In turn, a scholar's position in these complex fields may impact their intellectual and professional standing. Burt (2004) adopts a very strong position, suggesting that most "geniuses" are not necessarily distinguished by exceptional individual intelligence. Instead, genius is more often explained by unique life experiences and network ties that – often unintentionally – resulted in a new and valued innovation. Relatedly, to explain creative processes in individuals, Lévi-Strauss (1966) proffered the concept of *bricolage*; the mixing and combination of different ideas to create a new product. This raises the question of which combinations of ideas and social relationships are most conducive to innovation and professional advantages for actors working within a complex, complex field, such as a burgeoning academic institution like STS. Further, to borrow Podolny's (1993) analogy of networks pipes and prisms; intellectual choices in a scientific article represent information flows, while simultaneously emitting social signals regarding the preferences and social positioning of the author.

Social scientists have long debated which social positions are most conducive to innovation and personal advantage in networks and institutions. Perry-Smith and Shalley (2003) theorize that core, peripheral and semi-peripheral positions all have the potential to be the optimal position for innovation. Context is important in determining the incentives and resources available to actors in different network positions, and as a result, many network positions have the potential to be optimal. Focusing on scientific contexts, research has generally focused on the innovative and professional advantages from being located in central intellectual, institutional and social networks. Merton's (1968) Matthew Effect posited that central scholars in a discipline are able to use those advantages into additional privileges in the future. Stinchcombe (1994) and Cole (1983) argue that most healthy sciences operate with a division of labor where peripheral scholars take cues and directions from central, elite leaders in their field. This division of labor is believed to often contribute to intellectual conservativism in science (Kuhn, 1962; Klamer and Colander, 1990). Regardless, the division of labor of a knowledge organization underpins its intellectual and professional cultures (Whitley, 1984), while setting incentives for scholars working in the context of their chosen field(s).

Whether scholars accurately perceive incentive and field structures, or if and to what degree their professional and intellectual choices are motivated by such concerns are also open questions, that in part were answered by interviews reported in Chapter 1. Even if authors do not perceive or care about field incentive structures based on social connections, they still may exist. Thus, this chapter focuses on the central question of whether particular network positions are conducive to an article being highly cited. The focus on which articles become highly cited is rooted in Burt's (2004) concept of "good ideas"; which argues that ideas which receive the most attention garner the most benefits for its progenitors, regardless of their actual inherent quality. Intellectual networks are constructed via citation networks, which are used to empirically map the choices of STS scholars, as well as the changing macro-level structure of the entire field over time.

Chapter 3: Understanding a Scientific Success Story: The Case of Laboratory Life

Chapter 2 focuses on the issue of successful innovation at a relatively broad, macro level. Citation analysis is used to explain what the general bibliographic network properties are which make an article more conducive to receiving citations and exposure. Chapter 3 is much more specific, analyzing the factors that helped a seminal book in STS emerge and diffuse through the field with significant influence. *Laboratory Life*, by Bruno Latour and Steve Woolgar, was released in 1979 and is widely seen as a foundational work exemplifying the social constructivist perspective that would become a large (if not focal) part of the intellectual identity of STS. Chapter 3 examines how *Laboratory Life* diffused so widely in STS and in other academic fields, as well as its unique diffusion history. Diffusion research (e.g., Rogers, 1995) is often underpinned by the notion that adopters at various times of an innovation's life-cycle tend to have different personal qualities, as well as possessing different interests in adopting that innovation. Applied to a scientific context, this raises the question of how academic ideas are changed – if at all – over the course of an article's life-cycle.

The experimental design of Chapter 3 is modeled after McCain and Salvucci's (2006) work, analyzing the citation history of a popular management book. McCain and Salvucci found that amongst academic citers, there was a broad array of varying – and sometimes contradictory – interpretations and uses of the book. The main axes of variation amongst citers were time and disciplinary affiliation. Early citers were found to use the book for one purpose, which faded over time with later citers. Further, scholars from the relatively large array of disciplines that the book was relevant to, also tended to cite the book for different reasons and purposes. The potential for multiple interpretations of a book is pertinent in an interdisciplinary field like STS, as adopters are generally less homogeneous in nature, contributing to lower degrees of consensus. In turn, not only can qualitatively analyzing the citation history of an important book shed light on the intellectual history of a field, it also speaks to the question of what makes a scholar more or less likely to cite a given work. As is a recurring theme throughout this thesis, the processes by which citations are given and received – and by extension credit and information are productively exchanged in science – is influenced not only by a scholar's personal quirks, but also by the institutional and social connections they harbor.

CHAPTER 1

NASCENT INSTITUTIONAL STRATEGY IN DYNAMIC FIELDS: THE DIFFUSION OF SCIENCE AND TECHNOLOGY STUDIES

Overview

This paper examines the case study of Science and Technology Studies (STS) to uncover and analyze issues of professionalism, institutionalization and social movement development. These issues pertain to an increasingly variegated higher education political economy which is challenging, if not changing, the nature of academic and professional organizations. As new academic endeavors challenge and often aim to strategically amend the traditional disciplinary organizational and professional model for knowledge work in universities, this gives rise to new issues and contradictions. Partially institutionalized as an interdiscipline and a discipline in various contexts throughout the world, STS is a Social/Intellectual Movement at a unique juncture in its history and development, characterized by an amalgam of different intellectual, professional and organizational logics. Frickel and Gross (2005: 206) defined a Scientific/Intellectual Movement (SIM) as “collective efforts to pursue research programs…in the face of resistance from others in the scientific or intellectual community.” Analogously, the history of STS has entailed struggles for survival and to justify its existence and knowledge claims in both institutional and intellectual realms. Influenced by its success, STS is currently being influenced by contradictory logics with some desiring greater intellectual and professional closure, and others arguing that such moves would be entail betrayal of the founding ideals of STS. Accordingly, strategy is contentious, and success in a Scientific/Intellectual Movement can be a double-edged sword.

The Ecology of Higher Education

Abbott (2005: 265) argued that modern universities are characterized by roughly thirty *heartland* disciplines (e.g., physics, English, economics) which are present in all (or almost all) legitimate institutions of higher education and engage in the full complement of scholarly and teaching duties. However, the ecology of higher education and professions within it, are changing. Brint (2005) observed that modern universities are becoming increasingly variegated, as they strategically create and market idiosyncratic niches and identities. This is achieved via the creation of academic programs which fall outside of the traditional liberal arts. Such academic programs are built upon the repudiation, modification or boundary-spanning of traditional liberal arts, and are often framed under the rubric of “interdisciplinarity.” In contrast to the professional and academic ideals of Abbott’s heartland, this new *hinterland* has provided the turf for new ideas about scholarly and professional structures in higher education. To underscore the potential richness of the hinterland in academia, Dogan and Pahre (1989) chronicled that peripheral and new contexts are often sources of innovation, while Burt (2004) showed that actors who manage to span relationships via occupying structural holes tend to be more conducive to “good ideas.”

STS epitomizes scholarly exploration and organizational *bricolage* (Douglas, 1987), and appears indicative of this new organization of knowledge and professionalism in higher education. By maintaining, utilizing and reinventing intellectual and institutional links to the humanities, social sciences and sciences alike, STS is an archetypal interdiscipline.

Interdisciplinarity confers both advantages and disadvantages upon STS, in addition to creating a number of new challenges and issues regarding the organization of knowledge and work in contemporary universities. By challenging the turf and organizational structures of traditional liberal arts, the case of STS exposes three main themes in the organization of knowledge and higher education: *reinvention, accounting* and *professionalism*. Many STS scholars seek to *reinvent* the distribution and organization of knowledge turfs, which often involve idiosyncratic, symbiotic and/or competitive[2] relationships with sciences, social sciences and humanities. Successful reinvention opens a new professional and intellectual niche for a scholar to credibly work within. Linked ecologies between fields (Abbott, 2005; Bourdieu; 1969) are common in the dynamic and competitive overarching system of professions (Abbott, 1988). These relationships are particularly important to STS, given that they are diffuse, multiplex and often do not precisely correspond to how work and organizations have traditionally been organized in research universities. For example, STS harbors both co-operative and competitive relationships with sociology, where it shares scholarly content and can share topics and cross-appointments, but also can infringe on scholarly and professional turfs, in addition to competing for faculty lines.[3] While there may be professional and intellectual advantages to boundary spanning and forging unique relationships, they also create problems with how to *account* for labor, work, merit and credit. This raises the question of how channels of communication, hierarchies of values and standards of merit can be reconciled amongst disparate groups, philosophies and interests. The answer(s) to this question are particularly weighty, when one considers that control over merit and credentialing underpin the strength and identity of a *profession* and its turf

[2] Note that competition and symbiosis are not necessarily mutually exclusive.
[3] Put differently, STS is both a *substitute* and a *complement* to sociology, and many other liberal arts. As will be discussed, the ability to frame these relationships in different manners has implications for the scholarly and institutional strategies of STS scholars and institutions.

(Abbott, 1988; Freidson, 2001; Brint, 1994). Since STS programs and scholars are generally quite aware of the intellectual and professional challenges associated with a new institutional form of knowledge, identifying and dealing with these dilemmas pertaining to professionalism is very relevant.

Using keywords culled from Sociological Abstracts, and a lengthy list of institutional affiliations of authors copied directly from every issue of *Social Studies of Science* (or its earlier incarnate as *Science Studies*), the professional structure of STS and its changes over time can be more clearly illustrated and understood. Further, these data and analyses also reveal details about disciplines and fields similar to STS, such as sociology, in addition to the relationships STS harbors with ideas and fields throughout higher education and beyond. Next, STS will be analyzed discursively via qualitative and historical data. From interviews with institutional entrepreneurs and intellectual leaders in STS, these data are fleshed out, and theories are offered to describe and analyze the unique professional niche(s) of STS.

Analysis of* Social Studies of Science*: The flagship institution of STS

To analyze the institutional affiliations of scholars in the science studies community over time, records were transcribed from *Social Studies of Science* , a major science studies journal, from 1971-2006. Scholars affiliated with an academic entity with no clear disciplinary or field allegiance (e.g., Environmental Policy Studies, Liberal Studies) were categorized as a General Academic affiliation. History and philosophy also comprise a notable portion of the intellectual and institutional base of science studies. To distinguish between scholars located in history departments, and “history of science” departments, categories were created for “pure” departments, and “qualified” history and philosophy departments with other modifiers in their name (e.g., “of science”, “environmental”). Beyond that, disciplinary affiliations were self-explanatory. In the event of co-authorship, partial credit for the article was distributed equally amongst all authors. Book reviews and minor contributions were not tallied. The above graph includes the most prevalent affiliations. In total, 1271 authors in 910 articles (233 from '71-'85, 312 from '86-'96 and 365 from '97-'07) were collected (See Appendix 1 for the full list)

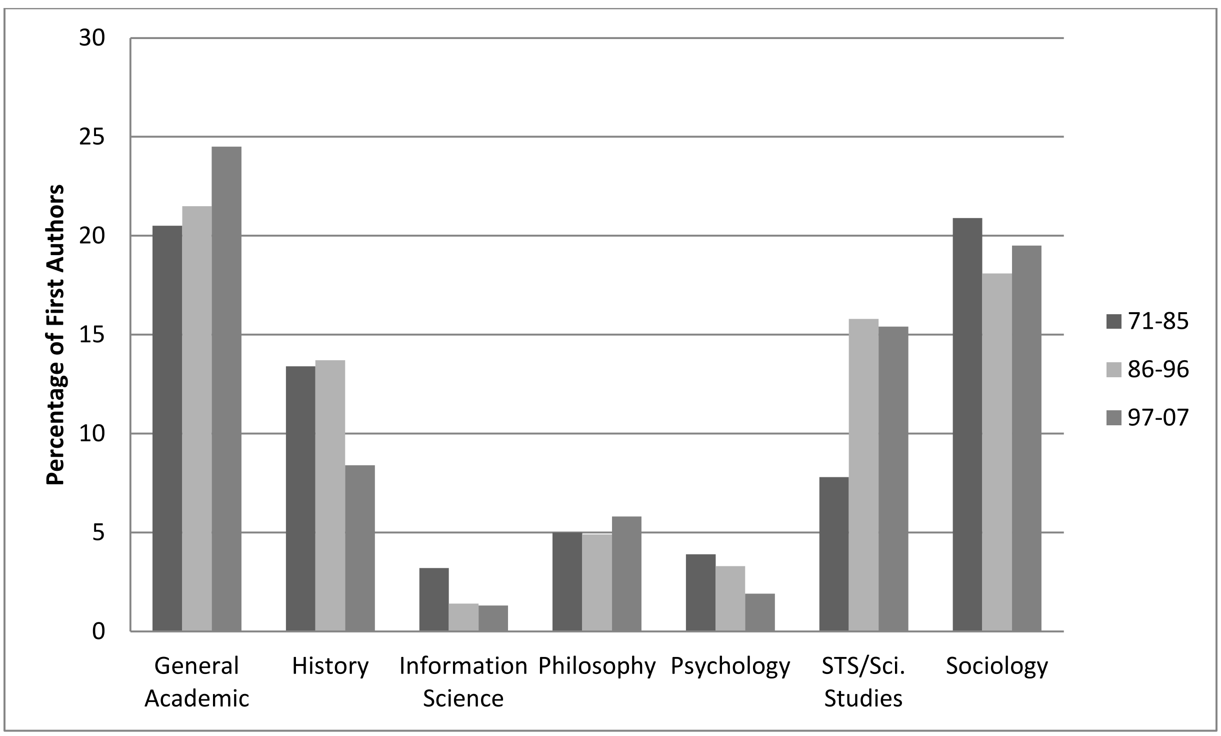

FIG. 1.1 - DEPARTMENT AFFILIATIONS OF *SOCIAL STUDIES OF SCIENCE* AUTHORS, 1971-2007.

Figure 1.1 illustrates changes in institutional affiliations in *SSS* over three time periods, which roughly correspond to what Hackett et al. (2007) dubbed the “birth”, “adolescence” and “maturation” periods of STS. The first important trend conveyed in the Figure 1.1 is the doubling of STS/Science Studies affiliations between the first two time periods. This reflects the institutionalization of formal STS departments (often out of entities that would have been classified as General Academic in an earlier time period) in the late 1980's and early 1990's. However, the proportion of STS/Science Studies contributors remained constant over the second and third time periods. This suggests that there may be some sort of a glass ceiling hovering over the institutionalization of science studies. In this sense, the anti-field and academic institutionalization sentiment and logic that STS was founded on remains *imprinted* (Stinchcombe, 1965) in the culture of STS in its later years, when different values and logics may be needed to continue strengthening and proliferating the SIM.[4]

The steady increase in contributors from the General Academic category is worth noting as well, especially since it is the most frequent affiliation in the two latter time periods. As the proportion of contributors from STS departments stagnates, general contributions have continued to increase. This may reveal more about the structure of the field. While STS has managed to achieve many *forms* of institutionalization (e.g., journals, conferences, departments), their *content* remains mixed in many ways, whether it be via its partially-open labor markets, or by non-STS contributors prominent in its major journals. Regardless, it seems apparent that the *SSS* demographic is still more populated by academic and institutional misfits and vagabonds than it is with STS members, which is notable that while STS departments continued to form and burgeon during the final time period, intellectual contributions in its major journal remained relatively constant. As mentioned, this pastiche of various academics and institutions could entail a source of intellectual innovation, organizational uniqueness, or self-defeating professional

[4] It is also worth mentioning that contributions from history departments decreased over the last time period. This may be due in part to STS successfully demarcating itself from History of Science departments, and its general move away from heartland disciplinary sources in general.

weakness. Whether this organization and professional structure is inherent, a virtue or a vice for STS remains an open, and normative question.

While the preceding data and analyses focused on the institutional links which define the intellectual core of the science studies community, they reveal little about the intellectual content of the field. To analyze content, keyword analysis was employed. As *Sociological Abstracts* indexes *SSS*, and has assigned descriptive keywords to every article in the journal, keywords could be culled from throughout the history of the journal.[5] In total, 4777 keywords were collected (909 from 1975-85, 1438 from 1986-96 and 2430 from 1997-2007. The biggest challenge these data present is the obvious subjectivity involved in the coding process, as shown by the steady increase in the number of keywords assigned to articles. In 1975-85, each article averaged 3.9 keywords assigned to it, which rose to 4.6 in 1986-96, then 6.7 in the 1997-2007 time period. To deal with this, amounts of recurring keywords were divided by the total number of keywords in the time period, to reveal the proportional prominence of the keyword. Of note that this yielded some relatively small proportions, due to the ubiquity of vacuous keywords (e.g., Scientific, Analyze, Social) of little to no theoretical interest assigned to articles, which were filtered out of the analyses. Thus, relative positions and changes over time are the most relevant things to consider. Figure 1.2 graphs the changes in the most prominent keywords indexed in *SSS* over time (See Appendix 2 for the full list of keywords).

[5] Unfortunately, the indexing was superficial and incomplete during the journal's early incarnation as *Science Studies* from 1971-74. Accordingly, the analyses begin in 1975 as the journal debuted as *Social Studies of Science*.

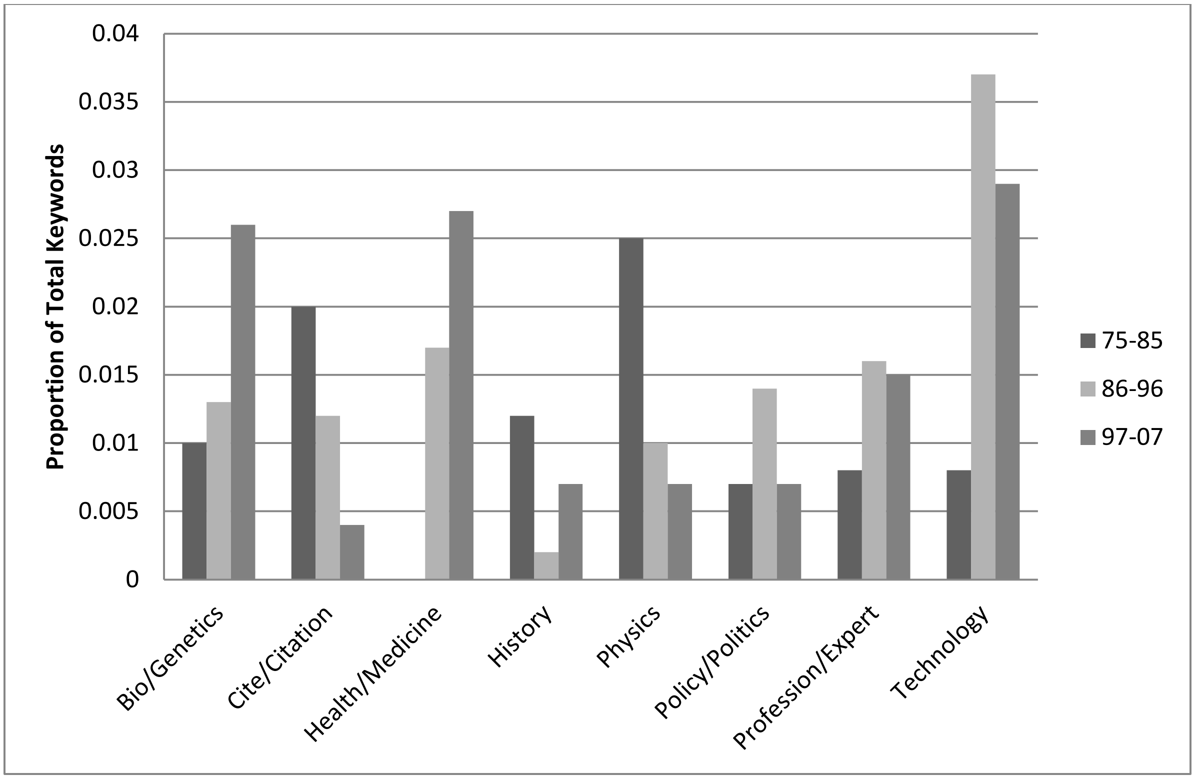

FIG. 1.2- PROPORTIONS OF KEYWORDS IN *SOCIAL STUDIES OF SCIENCE*, 1975-2007.

A cursory glance at Figure 1.2 reveals steady declines in the proportional relevance of physics and citation analysis, with precipitous increases in biology/genetics, health/medicine and technology. The fact that physics in particular was important and prominent in the early days of science studies is important, given that young and new institutions often attempt to attach themselves to high-status actors and entities for resources and legitimacy (Podolny, 2005). Of note is that over time, since the founding of *SSS*, some of the prestige and resources attached to physics moved to the life sciences in later time periods, which also likely explains the shift of attention in STS to those areas in later time periods. The decline in citation analysis is particularly interesting, given its prominence in early years, and that it entailed a considerable constituency of scholars in the social and library sciences.[6] These scholars not only contributed to the critical mass of scholars needed to make STS viable as a SIM, particularly in its incipient years, but also involved links to established disciplines, departments (mainstream sociology, information science) and theories (Mertonian social studies of science). While the decline in citation analysis can be correlated with the appointment of virulent anti-citationist David Edge (see Edge, 1981) as editor of *SSS*, discussions with citationists and Mertonians initially associated with 4S claimed that their withdrawal was precipitated by the overall shift of the culture and demographic of the society towards constructivist and anti-positivistic viewpoints, which they deemed inimical to their work. This raises the question of why STS (as a SIM and a nascent organization) would willingly alienate or purge such a constituency, despite the theoretical benefits of keeping membership higher, and maintaining more diverse potential diffusion networks, while maintaining legitimacy-conferring links to scholars in more established fields. This question will be returned to shortly.

In contrast to the declines in physics and citation analysis, studies in health/medicine, biology/genetics and technology all made large increases over the time periods. Given the recent shift of research funding and prestige towards the biological, medical and other life sciences, this is not terribly surprising. However, it does reveal a degree of resource dependency (Pfeffer and Salancik, 1978) on the prestige and funding of mainstream science, and the recurring philosophical orientation of STS towards topical malleability over disciplinary or professional closure. The increase in technology articles, first precipitated by Pinch and Bijker (1984)

[6] Figure 2 understates the degree to which citation analysis declined in the 1986-96 time period, as the majority of articles with “Cite-” keywords between 1986-96 were very critical of citation analysis (e.g., MacRoberts and MacRoberts, 1986). Accordingly these articles were not undertaking any sort of empirical study using citations, as was common in the first time period, where citation analysis was prominent.

increased the scope of the turf of STS. Of note is that Pinch and Bijker framed the subject matter as "technology", as opposed to engineering, physics, industry, or in relation to already established categories or entities. This allowed STS and science studies to gain a foothold into such matters, without infringing on the turf of scientists and experts in technological fields. Analogously, the purging of mainstream sociology and citation analysis represented a move (and arguably, a step towards increased institutionalization and autonomy) in science studies towards a strategy of non-field-specific generality, as opposed to linking or borrowing from established fields. Similarly, Hilgartner (2004) suggests that "knowledge" should be the turf that an institutionalized STS should claim for itself in the ecology of higher education. This generality allows for professional and intellectual malleability and the framing of a unique turf, which allows STS to study many of the same topics and phenomena other scholars do, without infringing on their professional jurisdiction. This balance is particularly important, because despite all of the research and rhetoric from STS scholars which has been critical of mainstream science (see Cole, 1996), it is still dependent on science for intellectual legitimacy, inspiration, and often access for ethnographic laboratory studies.

Finally, these data and analyses pertaining to science studies are pertinent to sociology as well. As shown in Figure 1.1, scholars from sociology departments are prominent in the science studies community. However, when one looks more closely at the institutional affiliations of the contributors, it becomes apparent that most of the contributions are not coming from mainstream departments. Table 1.1 shows the proportion of *SSS* contributors from Top 30 sociology departments, as listed by the *U.S. News and World Report* sociology rankings, published in 2005.

TABLE 1.1 – PROPORTION OF SOCIOLOGISTS AFFILIATED WITH TOP 30 SOCIOLOGY DEPARTMENTS IN *SOCIAL STUDIES OF SCIENCE*, 1971-2007.

	1971-85	1986-96	1997-2007
Percentage of Top 30 – Affiliated Sociologists	20.2%	5.6%	8.3%
N (Total Sociologists)[7]	78.03	58.16	72.16

These percentages likely overstate the presence of elite influence, because a number of contributors from top thirty sociology departments were non-tenure track faculty (e.g., graduate students, visiting scholars) at the time of the publication. Regardless, these data support Ben-David's (1978) observation that the institutional, if not also intellectual content of STS is very different than mainstream sociology. The relative prevalence of Top 30 sociologists departments in the first time period is largely reflective of the inclusion of sociologists associated with Robert Merton. As discussed, most of these scholars left the science studies community in the 1980's. In the place of elite sociological influence, a large amount of British sociologists and related scholars are prominent. The institutional weakness (Fuller, 2000; McLaughlin, 2005) and peripherality in disciplinary co-citation networks (Moody, 2006) of British sociology has long been perceived, as has its proclivities towards interdisciplinary endeavors such as media and cultural studies. When considered in the context of relatively abundant government funding for the social study of science in the United Kingdom (Edge, 1995), it makes sense that the malleable, institutionally flexible discipline of sociology (at least, relative to its mainstream counterpart) could occupy this niche in Britain. In a sense, the line between sociology and

[7] Note that N values may not be whole numbers due to partial credit being assigned for co-authorship and explicitly listed joint appointments.

science studies has become blurred in many departments. This may be a factor inhibiting the further diffusion and institutionalization of formally dubbed STS departments, and may also be a Trojan horse modifying, if not eroding the periphery of sociology. In turn, the ecologies of STS and sociology remain particularly intertwined, as both entities can function as flexible, institutionally weak social sciences. Thus, all that separates sociology and STS can often be merely a name. Whether this is ideal for a given academic discipline is a normative question.

Theorizing Professionalism in Science and Technology Studies

Informed by approximately formal semi-structured interviews with twelve scholars who were involved with founding Science Studies institutions, Society for the Social Studies of Science conference observation, archival work pertaining to the STS departments at Cornell University and the Massachusetts Institute of Technology and numerous informal discussions with STS scholars, this paper will explore these issues. As academic work is being re-organized in new, but increasingly entrenched institutions such as STS, this has implications for the larger ecology, or system of professions (Abbott, 1988) in knowledge work. More generally, the status of STS as a successful SIM also can inform theories and research, pertaining to institutional entrepreneurship, social movements, organizational growth, strategy and legitimacy. Next, the strategies and struggles of STS in light of the aforementioned professional, accounting and reinvention issues will be explored. Finally, institutional affiliations and keyword assignments in *Social Studies of Science*, the longest-serving major science studies journal will be analyzed to better illustrate the properties of the *invisible college* (Crane, 1972) of science studies. Data and ideas from the interviews and archival work will be interspersed throughout discussions of professionalism, accounting and reinvention, and will set the context for the keyword and institutional affiliation analyses later in the paper.

Professionalism

The modern research university, adapted from the German model in the 19th Century (Camic and Xie, 1994: 778; S. Turner, 2000) entails devolving professional authority over credentialing and research to departments, where institutionalized groups of academics make professional decisions regarding merit, hiring and other normative matters. Heartland disciplines have strongly demarcated intellectual and social boundaries within which their labor market enclave is couched. The proliferation and increasing institutionalization of interdisciplines such as STS, contrasts with such structures. In charting out the various forms of STS programs scattered throughout the world, Hilgartner (2004: 205) distinguishes between *interdisciplinary* and *new discipline* organizational models. The new discipline model, characterized by the STS program at Cornell University is more institutionally and professionally ambitious. However, the interdisciplinary model, best exemplified by the STS program at UC-San Diego, where all professors and students have cross-appointments in traditional disciplines also has apparent advantages. An interviewee noted that the model allows students to have two forms of intellectual capital with their Ph.D. – STS and a traditional discipline. This is particularly important for new students, as many interviewees report and bemoan their perceptions that the STS labor market remains small and precarious for new STS Ph.D's. The interdisciplinary model also entails some degree of subordination of STS to traditional disciplines, which Abbott (1988: 69) notes is a way to settle potential jurisdictional conflicts and allows matters of practical jurisdiction to be shared more widely. However, for all of its advantages, by ratcheting STS to traditional, and usually superordinate disciplines, the interdisciplinary model of organization may entail expenses of losing homogeneity, frame clarity, professional strength and paradigmatic militancy. Table 1.2 lists the professional closure of all STS programs in the United States listed on stswiki.org. Departments were coded as being ‘disciplinary’, in that most or all scholars had their primary affiliation to the science studies department; interdisciplinary, if they were mainly cross-appointed; or mixed, if the department was comprised of a mix of STS and cross-appointed faculty.[8]

TABLE 1.2 – PROFESSIONAL ORGANIZATIONAL FORMS OF STS DEPARTMENTS (SOURCES: STS WIKI AND UNIVERSITY WEBPAGES)

Disciplinary	6
Interdisciplinary	11
Mixed	24

Abbott (1988: 82-83) argues that in contests between professions over turf and jurisdiction, the profession with the more extensive organization usually wins. Further, in order to continue growing, a SIM needs to institutionalize in order to attempt to build legitimacy, framing and visibility. In the 1970’s, an unofficial journal, *Science Studies* (soon re-named *Social Studies of Science*), a professional association (Society for the Social Study of Science, or 4S), an annual meeting and in the 1980’s, an official journal (*Science, Technology and Human*

[8] Of note is that the six listed United Kingdom STS departments all offered PhD programs, and half (three) had an orthodox orientation. This may have to do with the fact that STS originated in the United Kingdom, and sociology has a much weaker presence in the country vis-à-vis the United States (Fuller, 2000).

Values) and even a students' association (6S) were all founded. In the late 1980's and early 1990's, aided by National Science Foundation grants, formerly diffuse science studies programs at Cornell, MIT and UC–San Diego were institutionalized into formal, Ph.D-granting departments. This institutionalization – and in particular, byline funding at universities, as opposed to resources attached to transitory grants or funds – helped entrench STS in universities, while endowing STS scholars with the ability to further shape their field by claiming jurisdiction over the discipline. In many cases (RPI, Georgia Tech, MIT, Virginia Tech), STS programs allow technical schools to offer social science classes, even though they may not have the resources or interests in founding separate departments.[9] Table 1.3 shows the distribution of institution and Carnegie university institutional classifications associated with science studies departments in the United States, according to the STS Wiki.

TABLE 1.3 – TYPES OF UNIVERSITIES WITH STS DEPARTMENTS IN THE UNITED STATES

Research 1 (Very High Research Activity)	26
Research 2 (High Research Activity)	4
Master's University (Some Research)	3
Liberal Arts College/Teaching Emphasis	8

Also indicative of the institutional and strategic variability of STS departments, Table 1.4 shows the highest degree offered by various programs; note that only a fraction of the population of research universities actually award doctorates in STS or related disciplines.

[9] For example, at Georgia Tech, "Economic Sociology" was listed as an STS course. Presumably, the lack of a sociology department at the university contributes to this situation.

TABLE 1.4 – HIGHEST DEGREE OFFERED IN UNITED STATES STS DEPARTMENTS

None/Concentration/Minor	13
Bachelor's Degree	11
Master's Degree	0
PhD	9
No Degree Offered	4

Optimal professional and intellectual tradeoffs between breadth and depth vary between contexts and histories. While professional organization and cohesion generally tends to entail strength and rent accrual, Abbott (1988: 83) also acknowledges that less organized professions have certain advantages, as they are more able to move between available tasks. Intellectual and professional malleability can be a competitive advantage, especially as many universities move their priorities away from the liberal arts in the 21st Century (Brint, 2005; Abbott, 2002). Further, Cyert and March (1963) argue that organizations with flexibility often enjoy innovation advantages. Numerous interviewees mentioned finding fruitful niches in their universities, as administrators looked for research dealing with "real" or "contemporary" problems. Critics expressed concern that by shifting resources to sometimes weakly organized and institutionalized science studies endeavors, this potentially can offer university administrators greater control over the framing, while limiting the professional and intellectual autonomy of their STS department. One interviewee was concerned that the science studies community was being overrun by "contract researchers" and non-academic interests, as the flexibility (and generally, low institutionalization) of STS makes it particularly attractive for government and university administration interests, as researchers are less beholden to disciplinary training, priorities and interests. In turn, Fuller (2000) argues that some of the strength and success STS has enjoyed in the higher education ecology in the past two decades may have come from a “strength from weakness” position. Note that if the demographic of science studies is dominated by those coming from weakly institutionalized contexts, this will influence and define the political, strategic, institutional and intellectual content of the field. While flexibility and malleability may have short-term tactical advantages, they may come at the cost of long-term survival interests. The payoffs, costs and equilibria between flexibility, institutionalization, heterogeneity and autonomy for STS are varied, complex and situationally-bound to the numerous contexts and institutional environments it is couched in. Further, these complex forces are operating within an increasingly heterogeneous and differentiating array of universities in the ecology of higher education.

A recurring, if not universal, issue that continues to arise from both interviews and institutional archives is that hiring and tenure have been problematic in STS, in part due to the youth of the field, low institutionalization and idiosyncratic organization. A number of respondents remarked that they ended in science studies because of their unusual and variegated academic background. While these interstitial scholars derived intellectual inspiration and uniqueness from their background, finding a space to work in often remained a challenge. Such challenges are not surprising, given Zuckerman’s (1998) research, which emphasized the perils of lacking a clear identity which conforms to a well-known category. The interviewees emphasized the importance of locating, or creating spaces in which to frame and market themselves for resources, attention and legitimacy. A number of interviewees found their work, and STS as an institution, to be most saleable in organizational structures that offer departments a lot of slack. Notably, this often occurs outside of faculties of Social Science, which tend to house more strongly enclosed heartland disciplines. Other times, outside funding sources from government agencies, granting councils or university initiatives provide the support and space for work and scholars working outside of or in the interstices of traditional disciplines. However, such provisions do not necessarily entrench the scholar or position in the university, or grant the department automatic annual byline funds in the university budget. The flexibility of funding scholars and research outside of disciplinary enclaves is often part of the attraction of interdisciplinary funding initiatives. Further, getting hired and finding some sort of institutional space is often only part of the challenge. For example, at MIT, Keegan (2006: 24) chronicles the case of Sherry Turkle, a sociologist who was hired in the 1970's without departmental affiliation ran into problems receiving tenure, despite a prolific publishing record, in part because it was not her science studies peers who judged the merits of her work and had the power to award tenure.

Perhaps the biggest issue regarding hiring and tenure is the continuing practice of STS hiring new scholars without degrees in STS. While there are a number of philosophy of science and history of science programs similar to STS in topical, if not also epistemological interests, STS also hires scholars from traditional disciplines, particularly from the sciences and social sciences. Further, in some of the interdisciplinary and mixed professional-nice departments mentioned in Table 1.2, undergraduate classes listed in STS are taught by non-STS faculty. From a professional standpoint, this entails having a *partially-open labor market*, which stands in contrast to the ideal of professional control over credentialing (Abbott, 1988; Brint, 1994) and the ideal academic discipline, which enacts labor market closure with its teaching and hiring

(Stinchcombe, 1994) and is thus able to reproduce itself (Bourdieu, 1988). Accordingly, operating a partially-open labor market should result in some loss of professional strength. A couple of interviewees mentioned that in order for STS to remain viable as a long-term academic discipline, it needs to start establishing a stronger professional and intellectual core and ensure there are academic jobs for Ph.D. students. While the first generation of STS scholars were "refugees", who wanted to escape the "field-ness" of their home disciplines, many subsequent STS scholars, who were trained and socialized in STS institutions are more inclined to want to strengthen boundaries around their own field.

Despite the potential liabilities associated with labor market openness, there also may be advantages associated with porous intellectual and/or professional boundaries. In general, there are three main reasons why STS engages in, and may benefit from partially-open labor markets, at least at this juncture in its development:

1. As a young field with relatively low legitimacy, STS benefits from importing cultural, social and intellectual capital from established disciplines.[10]

2. STS is indicative of a "new organization" of knowledge in higher education, and derives its vitality from, and occupies a valuable niche, by occupying structural holes and interstitial spaces between established disciplines.

[10] Quoting Spiegel-Rosing's initial concerns about STS, (1977), Hackett et al. (2007) acknowledge that STS has a tendency to focus on "harder, bigger sciences", which lends support to that STS imports cultural and social capital from prestigious actors and departments in order to enhance legitimacy. Indicative of its diffuse nature of the field, the relationship between STS and mainstream science spans the entire continuum from subservient complementarity (Winner, 2001: 245) and luddism (Keegan, 2006: 8). As is the case with the social sciences, STS has varied and complicated relationships with its counterparts and partners in the natural sciences that range from commensalistic, to symbiotic to predatory.

3. Since there are only a handful of Ph.D.-granting STS departments around the world, and even fewer that have existed for more than a decade, there is a limited pool of applicants with Ph.D.'s in STS. Consequently, STS departments may find hiring quality applicants from other academic fields attractive.

These factors raise the question of whether and how the partially-open labor market will ever be closed. Particularly to the extent that the second reason is relevant, closing the labor market would be contrary to the ideals, and possibly interests, of STS. If STS is built upon the importation of scholars from other disciplines in universities (in addition to links to non-disciplinary entities in and outside of universities), then professional weakness and surplus Ph.D.s may be necessary evils for maintaining this unique and possibly fruitful professional organizational structure. However, maintaining these links and gaps over time may be difficult, given that both institutionalization (Zucker, 1977) and social interaction (Carley, 1991; Mark, 1998) induce fact complexity, group homogeneity and in turn, boundaries (Gieryn, 1983). In turn, as successful organizations develop and age, this generally promotes intellectual and social homogeneity. While there are benefits associated with increased solidarity and heterogeneity, for a field rooted in eclectic philosophies such as STS, this may also present challenges.

As institutionalization and disciplinary closure are contrary to the initial ideas and inspiration behind 4S, perhaps some sort of compromise between professionalism and openness will occur. This is analogous to the pressures of co-optation that institutionalization and growth often impose upon successful heterodox organizations and social movements (e.g., see Selznick, 1949). For example, one interviewee was incensed at long-standing editorial direction as *SSS* that compelled authors to cite texts in science studies deemed “foundational”, as a means of inducing an appearance of scholarly consensus and field-ness, at the very least. This respondent emphasized the abject hypocrisy of a community largely based on being critical of mainstream, institutionalized science “engaging in its absolute worst behaviors.” However, not all professional dilemmas regarding growth and institutionalization are quite as incendiary. Paths between moments of increasing institutionalization (Barley and Tolbert, 1997; Katz and Gartner, 1988) are not necessarily linear, and different types of institutionalization may inhibit development of other forms (e.g., an interdisciplinary model may be inimical to the eventual development of a more strongly institutionalized new discipline model), even if most institutionalized academic entities have gradually emerged out of ‘parent’ disciplines (Kohler, 1982; Abbott, 2001; Khurana, 2007). Whether, and to what degree, STS’s increasingly institutionalized form of professional organization is sustainable or conducive to success is probably context-dependent[11] to some degree, and remains to be seen for STS.

Accounting

As has been discussed, academic disciplines entail labor-market enclaves in which merit, hiring, promotion and career progress decisions are largely contained. However, when non-traditional or interdisciplinary groups and institutions develop in universities, this entails a mixing of enclaves and values, which are not always easily commensurable. Thus, accounting for labor, merit and quality can be a particularly knotty issue for hinterland fields like STS. For example, one interviewee talked about the challenges and downfalls of one STS department

[11] Of course, a profession whose fate depends on contextual situations is probably also indicative of lacking strength.

based on the interdisciplinary model in assigning credit for work done in their home departments, *vis-à-vis* their STS appointment. The respondent claimed that while the program has been successful in some senses, it is still plagued with co-ordination and free-rider problems and arguments regarding how to trade students and credit for educating them. In general, it was argued that it is still difficult to create incentive structures to persuade faculty to do something that is good for STS, without also being good for their home departments.

Another interviewee mentioned that acknowledgment of non-traditional forms of merit was vital to founding his department and aligning it with the changing mission of his university, which was strategically shifting its foci to public service and practical research. As elite science increasingly concentrates in a small cluster of "top tier" universities (Abbott, 2002) and endowment inequalities increase exponentially (Ehrenberg, 2002), many non-elite universities have embarked upon strategic plans and initiatives which led to increasing heterogeneity of academic programs and organizations, most commonly residing outside of the liberal arts (Brint, 2005). By opening the floodgates between professional and disciplinary boundaries, this may allow for innovation, uniqueness and niche marketing, but also entails the de-institutionalization or amendment of professional logics, structures and interests traditionally associated with academia.

A recurrent issue faced by nascent STS departments within their universities is how to claim turf without antagonizing existing departments and interests, all of which possess more legitimacy and seniority. For example, when formulating institutional strategies, Carl Kaysen at MIT emphasized a strategy of not antagonizing or threatening the turfs of the existing social science departments and scholars (May 20, 1981). One interviewee suggested that potential conflicts over resources and turf can be defused if faculty lines and other resources were framed in a less-narrow manner, as opposed to thinking of things from an "accountant's perspective." The implication is that through careful hiring and brokerage, faculty appointments can be made in joint, or shared contexts, where "the whole is greater than the sum of its parts", if not mutually beneficial. Put differently, STS exhibiting characteristics of an interdiscipline and a discipline simultaneously is not necessarily seen a contradiction. Another respondent argued that "while faculty lines are limited, they are not finite."[12] In other words, while resources may be limited, they can be stretched between various academic fields in non-zero-sum manners. The archipelago of Indonesia was suggested as an analogy, as it consists of numerous islands of varying shapes and sizes. Similarly, the respondent argued that STS would be best off with an island (note that this connotes a claim of autonomy and turf) of its own, with its idiosyncratic shapes and quirks, as opposed to being forced to survive in an ecology where "one size fits all." As much of the history of STS and the scholars trying to perpetuate it, has been defined by the struggle for recognition and optimal framing arguments, there may be an element of political rhetoric and framing ensconced in these responses and opinions. These responses also reflect reinvention in how knowledge and professionalism can be re-organized in contemporary higher education.

[12] In contrast, an informal discussion with the chair of a young, but successful and rapidly growing STS department at a middle-status public research university conceded that some of the gains his department has achieved, has come at the expense of other heartland disciplines, particularly in the humanities. The ability to mold the mission of the department to the new "strategic plan" of the university administration was cited as a key reason for the success of the department. This is relevant, given the previous discussion of benefits that can be derived from professional and disciplinary openness.

Reinvention

In order to account for this fusion of institutional strategizing and intellectual bricolage that underpinned the formation and propagation of STS, the concept of *institutional entrepreneurship*, which entails the combination and synthesis of various cultural and institutional entities (DiMaggio, 1991) is relevant. STS has been bolstered by leaders managing to convince administrators and funding agencies to support and sometimes institutionalize the SIM. Such activity is highly strategic, risky and often requires *social skill* (Fligstein, 1997; Rojas, 2007) to recognize and capitalize on opportunities in cultural and institutional environments in higher education. Social skill incorporates both personal (charisma, persuasiveness) and relational (social networks) characteristics of individuals. Hambrick and Chen (2008: 42) also chronicled the difficulty of a new academic entity of convincing administrators to grant resources, and to create demand for the new endeavor amongst markets of students and benefactors. Similarly, Aldrich (1999: 231) states that pioneering founders must concentrate on framing the unknown in such a way that it becomes believable. Much like with any social movement, leaders need to identify potential targets and niches, appropriately frame their vision, and convince targets to support or join their endeavor, in order for their movement to survive and proliferate.

Preliminary interviews with founders and chairs of STS departments have revealed a recurring theme of needing to maneuver within the institutional opportunity structure of their universities to cultivate a new department. The preceding term is a modified version of Tarrow's (1994: 85) political opportunity structure, which is defined as "consistent…dimensions of the political environment that provide incentives for people to undertake collective action by affecting their expectations of success or failure." Constrained or enabled by institutional/political opportunity structures, individual scholars attempt to best situate their work and careers. This is done at both N individual/strategic level and at broader levels, such as disciplinary, invisible college and institutional/organizational realms. As one interviewee noted, there needs to be some sort of a perceived lacuna in a university (or, at least one that an institutional entrepreneur can frame and market) in order for a new academic endeavor to be successful. Respondents mentioned that when taking programs that were dying and reviving them, grantsmanship and brokering social relationships as key factors in getting the attention of administrators. Thus, institutional entrepreneurs must be able to *identify* potential spaces and opportunities, *strategize* how best to procure them and then be able to *execute* their plan with guile and social skill.

Also of note is that in addition to space, and institutionalization, *priority* is a potential reward for institutional entrepreneurs. Accordingly, institutional entrepreneurs have to weigh the costs of what Stinchcombe (1965) dubbed "liabilities of newness" versus the potential rewards of boundary spanning and first-mover advantage. While new paradigms, institutions, ideas and papers bear the risks of lacking legitimacy, they also may carry the potential rewards of innovation and first-mover advantage, which is particularly important in science, where *priority* claims over intellectual turfs are highly valued (Merton, 1973; Dasgupta and David, 2002). To capture priority, and other academic rewards, scholars in SIMs can be strategic actors at the individual and/or institutional level (Mullins, 1973).

As is the case with most social movements (Snow et al. 1988), *framing* is another important activity STS engages in. One interviewee claimed that throughout his graduate training and career, which had landed him in a number of disparate settings throughout the sciences, social sciences and STS, he always figured that needed a marketable "mission statement" for STS. The need for such frames may be particularly strong when in the early years of STS, it was almost inevitable that a scholar would need to work in or with a non-STS department. However, STS also engages in framing internally as well. Hackett et al. (2008: 4-8) attempt to frame the development of STS itself, by arguing that, as a quasi-official programmatic handbook, it now covers a "maturing" discipline, as opposed to the "adolescent", and "birth-level" handbooks of 1995 and 1977 respectively. Of note is the sanguine assessment of progress, while subtly conceding that development has not completed.

A major paradox and professional challenge associated with STS, is that as a young academic field in need of a clear identity and justification, despite the fact that it was founded on the notion of transgressing such boundaries. One interviewee mentioned the peculiar practice in 4S to prohibit the "sectioning" of the membership into specialty areas as a way of inducing homogeneity and unity amongst its membership. Of course, this loss of heterogeneity also entails a loss of fact complexity gained via specialization (Blau, 1970; Carley, 1991; Mark, 1998).[13] Sacrificing scholarly depth may also be worthwhile for 4S because increased complexity would impede the ease of adoption from new recruits, casual interloper or collaborators in the natural sciences. A couple of interviewees claimed that the constructivist and Latourian theories which dominate STS gained traction because they were simple enough to facilitate easy adoption from

[13] Ironically, Turner (2006) and Stinchcombe (1994) that sociology suffers from the opposite problem, namely pervasive heterogeneity, but little unification.

non-STS members, yet remained vague enough to allow for deeper scrutiny from more entrenched academics (also see Lamont (1987), on the rise of Jacques Derrida in philosophy).

While establishing links with desired actors and ecologies has been central in the development of STS, so has its more antagonistic relationships. One respondent argued that STS was founded more out of the notion of "common enemies" (namely, positivistic and disciplinary-bound conceptions of science) than out of shared intellectual backgrounds, beyond a common topical interest in science and technology. Leydesdorff (1995: 22) argues "[t]he sociological perspective has taught us – with a wealth of historical evidence – that science and its progress are heavily dependent on material and social conditions. However, the claim of "the social construction of knowledge" made by authors in the new [Social Studies of Knowledge (SSK)] is *epistemological*, and at best valid as a heuristic device in empirical research" (italics added). SSK was a British rejoinder to the quantitative, analytic and arguably conservative perspectives on science offered by Robert K. Merton and others. Zuckerman (1988: 513) argued that structural sociology of knowledge was at odds with SSK, in part due to the latter's proclivity towards Constructivism, discourse analysis, relativism, structural analysis, functional analysis and conflict theory. Ben-David (1978) adds Americans typically educated in elite departments oriented towards graduate training. British sociologists came to SSK from different fields, and academic structures, often heavily involved with undergraduate education.

While early STS conferences involved both Mertonian and British sociologists of science (see http://www.4sonline.org/past_meetings.htm), this did not last long. Several, interviewees mentioned that Mertonians and other positivist-leaning scholars largely "withdrew" from the

4S.[14] Collins (1983: 271) characterized the relationship between SSK (the theoretical position and group that would most strongly influence STS) and mainstream sociology as one of "cognitive tangentiality, with an admixture of academic antagonism." Another interviewee remarked that any claims that STS is distinct epistemologically had more to do with academic-disciplinary politics, than using the best tools to answer questions. Differentiating itself from mainstream sociology (intentionally or otherwise) may have been a strategic move, as it increases heterogeneity, distinctiveness, and moves STS into a less-crowded niche space. Generally speaking, it is notable that even in its incipience and with its stated aversion to disciplinary structure and boundaries, STS managed to carve a niche and create heterogeneity *vis-à-vis* other disciplines, and thus homogeneity, within its own boundaries.

Conclusion

STS is notable in that it occupies varied professional niches, spanning the continuum between nascence and full development. While it possesses many relics of institutionalization, such as departments, journals and conferences, the data and interviews conducted suggest that the content within these boundaries is much fuzzier than in established heartland disciplines, or most strong professions, for that matter. STS shares its departmental and institutional niches with a diverse array of scholars and interests, which is both a source of its intellectual identity and inspiration, but also contributes to lower autonomy and control over those institutions. The intellectual core of STS, as defined by its major journal, is far more populated by non-STS scholars than by those affiliated with STS. Although the relative youth of STS is a contributor to this, data showing that contributions from STS departments over the past decade suggests have

[14] Mertonian sociologist Stephen Cole (1996) would later characterize this as a regrettable surrender.

remained stagnant that institutionalization has stalled in the intellectual core, and may have reached its carrying capacity. Thus, this state of professional openness may not just be indicative of a transitory and developing field, and may instead define STS for a long time. This openness has perpetuated a scenario where scholars, departments and institutions with diverse backgrounds and interests with relatively little in common. This is both a blessing and/or a curse for STS (depending on one's viewpoint), but it does appear to be placing a glass ceiling over the future institutionalization of the discipline. How labor and merit can be objectively accounted for in such a fuzzy field with disparate logics, ideas, values and standards remains an unresolved issue. However, this issue is increasingly prevalent in contemporary universities, as more and more intellectual and/or professional endeavors do not conform to the traditional heartland disciplinary professional/organizational model.

As it has continued to develop over the past three decades, STS finds itself faced with a number of dilemmas regarding its professional and intellectual future. Hilgartner (2004) described STS as at a crossroads, with an uncertain future. Even if STS can manage to make itself into a full-fledged discipline (as Hilgartner advocates), it is not clear that universities would be willing to widely support strongly institutionalized STS departments. This is especially true given Brint's (2005) work on the prevalent quest for innovation in university administration, and interviews conducted where novelty outside of traditional disciplinary ideals were heralded.[15] Further, demarcating stronger scholarly and institutional boundaries would erode or destroy the links STS makes with related and superordinate fields in universities, arguably eliminating much of its intellectual base, inspiration and legitimacy. However, without stronger institutionalization,

[15] Brint (2005) observes that elite universities will generally possess the resources and institutional identities to pursue research and innovation both in the heartland and hinterland of academia. In contrast, less wealthy universities may need to make difficult and strategic choices regarding tradeoffs between the two.

the already tenuous STS labor market will likely decline, established departments will be easier to dismantle, and it will be much more difficult for the field to reproduce itself as its first-generation scholars from the 1970's and 1980's begin to retire.

On the positive side for STS, it seems apparent that contemporary universities are increasingly welcoming (and arguably, often preferring) new fields and disciplines outside of heartland disciplines and capable of filling different niches. Being a malleable field with relatively low fact complexity and low institutionalization may be a viable niche and fruitful in the variegated political economy of higher education that Brint (2005) argues is materializing. STS may entail a representative case of new ways of organizing and valuing knowledge in higher education. After all, are the traditional professional and disciplinary enclaves, which characterize the academic heartland, necessarily the best way to organize knowledge work and spur innovation?[16] By being conducive to easy adoption, diverse linkages and interstitial and broad foci, STS may survive nicely in such an environment. However, the plight of the professionals within, and associated with STS, or any hinterland academic entity is much less certain, and will likely become much more contested.

[16] Or, to paraphrase Winston Churchill's famous quip about democracy, is it "the worst form of [organization], except for all those others that have been tried"?

CHAPTER 2

KNOWLEDGE NETWORK STRUCTURES AND GOOD IDEAS IN SCIENCE STUDIES

Introduction

Burt (2004) found that actors advantageously placed in a network are more prone to producing *good ideas*; meaning those which garner attention and esteem from others. In intellectual fields and communities, information is the key resource being judged, developed and transmitted. Published papers are relics containing facts (Carley, 1991) and symbols of information (Small, 1978), contributing to conversations on different topics with different levels of eminence (R. Collins, 1998). The footprints of these scholarly conversations and intellectual progress can be measured via citation analysis. Citation analysis has long been used as a tool to empirically map large-scale intellectual and social connections (e.g., Garfield, 1972; Hargens, 2000; Moody, 2006; Shwed and Bearman, 2010) that transcend institutional and face-to-face interactions, comprising the invisible colleges which underpin scholarly innovation and progress (Crane, 1972). This research empirically maps these networks and analyzes citation choices to reveal the strategies employed by scholars when composing scientific articles and the reward structures of the overarching field they are working within. This research uses a unique bibliographic measure of intellectual positioning, this research analyzes which intellectual and social network positions are most conducive to an article receiving citations and becoming prominent. Changes in network structure over time can be compared with the bibliographic characteristics of successful papers, to reveal scientific reward structures in a scientific field.

Networks, Innovation and Creativity

Analogous to the social network cartography of links between papers and scholars, Crane (1972) identified invisible colleges as the networks of formal and informal communication between elite, but often geographically disparate scholars which comprise the dominant ideas in a field. Price (1963) pioneered the use of citation networks to map and analyze the structure and content of invisible colleges. Merton (1968) posited that the *reward structures* of science are what shape the behaviors and ideas of scholars, and in turn, their disciplines and fields. Networks of invisible colleges operationalize the collaboration structures which underpin scholarly production, while also mapping out the intellectual and social cartography of the field. This cartography can be linked to reward structures via social networks. Scholars make decisions, consciously or not, regarding how and where their work will be situated in their field or network. Kuhn (1977) characterized this dilemma as a 'tension', which creative scholars negotiate between innovation and conformity in their fields. The creative and strategic choices scholars make in regards to this dilemma can also be operationalized through their citation patterns.[17] Authors may cite works for a variety of reasons (Latour and Woolgar, 1979; Hargens, 2000), but citations function as pivotal pieces of shared information, which are co-ordinated reference points within and between scholarly groups (Baldi, 1998). Burt's (2004) concept of "good ideas"

[17] Risks associated with nascence are also tempered by the notion of first-mover advantage, and the fact that *priority* is the most prized resource in academia (Merton, 1968, Dasgupta and David, 2002). Being first to claim ownership for a valued idea in academia, is the means by which academics accrue credit and professional benefits (Latour and Woolgar, 1979). Thus, while there are generally risks associated with nascence, rewards can also simultaneously exist. Or alternatively, liabilities of senescence (Ranger-Moore, 1997; Ganz, 2000) can exist alongside liabilities of newness.

provides a means of operationalizing credit flows and the reward structure of a knowledge network.

Citation ties between papers are almost always directed and asymmetric. Current papers cite works in the past, which cannot return the favor. In these directed networks, *given* and *received* ties are distinguished. Knoke and Burt (1983) argued that various notions and indices of power, prestige and status are derived from asymmetric relations in social networks. There are numerous networks-based definitions of this general concept. *Popularity* entails the simple number of ties a given node has directed into it (de Nooy, 2002: 151). *Status* involves the popularity of nodes which give ties to a focal node (Katz, 1953). Applied to the case of academia, citations are network connections that can involve an article giving exposure (Merton, 1986), credit (Latour and Woolgar, 1979) and/or deference (Hanneman, 2004) to another work. In turn, these systems of information exchange reveal the intellectual footprints and cartography of a field, in addition to social cliques and hierarchies which underpin field development (R. Collins, 1998; Moody, 2006). Bonacich (1987) posited that connections to high-status nodes can be more advantageous than links to other nodes. Through their citation choices, authors convey credit to authors and articles of varying status levels.

The development of networks-based methodologies and theories is complementary to bibliometric methods and data which map invisible colleges, or scholarly fields. Powell et al. (1996: 116) claimed that when the knowledge base of an industry is complex and the sources of expertise are widely dispersed – as usually is the case with invisible colleges – the locus of innovation will be found within the networks of learning, rather than in individual organizations. A recurring theme in network and creativity literatures is that certain social positions and relationships in a given network are more conducive advantageous or rewarding than others. However, studies have suggested that varying contexts can yield different equilibria for network incentive structures and payoffs (McLaughlin, 1998; Perry-Smith and Shalley, 2003). Thus, numerous – sometimes contradictory – positions and relationships in networks have been identified as desirable or advantageous for both individuals and social systems.

Sociologists have tended to emphasize the role of central positioning in creating or furthering the work and careers of advantageously placed scientists. Cole (1983) and Fuchs (1993) argued that elite researchers work at the uncertain frontier of science, and are later emulated by peripheral scholars. Merton's (1968) Matthew Effect posited that the advantages associated with centrality and eminence result in path-dependent awards accruing to privileged scholars. Further, benefits are also often derived from association with high-status alters (Bonacich, 1972; Podolny, 1993). In turn, this creates incentives for authors to link their research to popular, highly cited works. Evans (2005) argued that academics strategically cite prominent works in attempts to garner legitimacy. Science is characterized as a generally conservative entity, as well. Kuhn (1962: 64) mused, "[N]ovelty emerges only with difficulty, manifested by resistance, against a background provided by expectation." For these reasons, the incentives associated with orthodoxy should generally be positive in most scholarly contexts.

<u>Hypothesis 1</u>: More orthodox articles (i.e. articles which cite more highly-cited works) will be cited more frequently by other articles.

In addition to the degree of orthodoxy an article possess, its network positioning within the field is also important. Orthodoxy may not tell the whole story of an article's intellectual and social positioning, as it is plausible, that an article may cite highly prominent, but disparate and otherwise connected sources. Freeman (1979) posited that *closeness centrality* – a property of a node which tends to be located on short paths between other nodes in the network – is a means by which actors or nodes leverage positioning in social networks to their advantage. Nodes with high closeness act as bridges, or points of control with regards to information flow. Burt's (1995) structural holes theory suggests that actors who bridge distinct groups, brokering connections between subgroups enjoy closure (Coleman, 1990: 310-11) and information-related advantages. Closure benefits actors occupying structural holes by giving them a monopoly on contacts between the bridged clusters (Burt, 1995). In addition to closure, being situated in the middle of information flows, is another mechanism which imbues *tertius gaudens* (Simmel, 1950; Burt, 1995) benefits upon actors who occupy structural holes. If high closeness nodes were removed from the network, clusters would be more likely to be disconnected, or at least be much less conveniently reachable. Due to the benefits of bridging and reachability, high closeness nodes should enjoy rents and power from brokerage and easier access to information flows.

<u>Hypothesis 2</u>: Works with higher closeness centrality within a knowledge network's citation structure will be cited more frequently than articles with low closeness centrality.

Dynamics in Boundaries, Information Flows and Rewards

Gondal (2011) argued that during early, foundational periods in a new knowledge network, citing other highly-cited works in the network is particularly important for those attempting to publish. In general, the relatively small size and social and intellectual homogeneity of early fields should put a premium on the rewards to scholarly orthodoxy. Thus, early in a field's development, density and homophily accompany the small size of the field, with critical-mass building as its paramount task.

Hypothesis 3 – During early time periods, articles of greater orthodoxy will be cited more frequently by other articles, vis-à-vis later time periods.

As a field or scholarly community develops, increasing complexity and size also increases the stress on the network to co-ordinate information and social ties. Balancing these tradeoffs between breadth and depth are a recurrent challenge which scholars face when conducting research (Elster, 1991). Carley (1991) and Mark (1998) posited that people and groups have limited abilities to process and retain shared information. Relatedly, Mayhew and Levinger (1976) argued that increasing size of social groups decreases intimacy of ties and density of interaction, in addition to perpetuating heterogeneity (Blau, 1970; Abbott, 2001).[18] Coupled with tendencies towards preferential attachment to highly-cited nodes, these processes trigger the concentration of power in the hands of a few elites to facilitate formal and informal connections and between actors in an increasingly disparate network (Mayhew and Levinger,

[18] A question this raises, is when and how some fields or networks will maintain intellectual homogeneity and deference to elites with growth, while others will "calve off", "fractalize", and become a subfield, usually with new elites, shared information, identity and foci.

1976). This means that different groups have varying niches and carrying capacities for ideas. As R. Collins (1998: 130) observed, there is a finite amount of *attention space* available in social ecologies. Since “superstars” are based on common sites of reference (Rosen, 1981), they absorb a disproportionate amount of attention space in the network. Crane (1972) argued that in early in a field’s development, a few ideas and scholars will define and dominate the intellectual landscape. Analogously, hubs garner large amounts of connections and importance in complex, scale-free networks (Barabási and Albert, 1999), which commonly characterize academic and intellectual communities (Newman, 2004).

Increased growth and heterogeneity may also entail highly visible ideas being watered down to the lowest common denominator, as a cause and/or an effect of large-scale diffusion. For example, Hargens (2000) found that highly cited articles tend to be cited for their general principles as opposed to their substantive research, as the work diffuses further from its original research community vantage point, both intellectually and temporally. Thus, the common information, or ‘facts’ shared by a group (Carley, 1991), should generally attenuate with increases in field size. In turn, the value of central, or hub, nodes in such increasingly heterogeneous networks should also increase under such conditions. Control over information flows should become particularly advantageous when gaps between nodes (or in this case, articles) become wider. As Buskens and van de Rijt (2009) suggested, structural holes lose value if all actors attempt to occupy them. Further, the increasing breadth and sparseness of the network generates bridging opportunities between disparate nodes, and renders reachability valuable, when navigating an increasingly large and disparate field.

<u>Hypothesis 4</u> – During early time periods, articles of greater closeness centrality will be cited *less* frequently by other articles vis-à-vis later time periods.

In sum, field dynamics influence reward structures for individual scholars and *vice versa*. Through their citation patterns, academics make choices regarding how to situate their work socially and intellectually. This research examines how the choices of academics and social positioning of papers impact an article's propensity to be cited (i.e., be seen as a source of "Good Ideas"). The case study used for this research *Social Studies of Science*; the core journal of an intellectually and institutionally developing institution and knowledge network, Science and Technology Studies (STS).

To explain differences in the perceived quality of ideas and the attention they receive, both what Merton (1973) dubbed *universalistic* and *particularistic* variables and theories have been invoked. Universalist criteria involve fair rewards for contributions to scholarly knowledge and are inured from influence by extraneous factors, such as the race, sex and institutional affiliations of an author (270-272). In contrast, particularistic criteria use characteristics irrelevant to the merit of a work or argument to allocate scholarly rewards and attention (Long and Fox, 1995: 46). Social scientists have argued that often particularistic variables can influence the generation and diffusion of ideas, as well as the careers of scientists (e.g., Reskin, 1978; Burris, 2004).

<u>Hypothesis 5</u> – Papers written by authors with typically privileged personal characteristics (e.g., male, elite university) will be more cited than those without those status advantages.

Further, Long and Fox (62-64) identify absence of information, ambiguity of standards, less-developed scientific paradigms and secrecy as four main factors which contribute to particularistic standards in science. All of these factors tend to be present in a nascent academic field.

Hypothesis 6 – During early time periods, personal characteristics of authors (such as gender and institutional affiliations) will have a larger effect on the likelihood of an article getting cited vis-à-vis later time periods.

Science and Technology Studies

Science and Technology Studies (STS) represents a case study of a Social/Intellectual Movement (Frickel and Gross, 2005) progressing through various stages of development. Selznick (1949) and Tarrow (1994) argued that institutions and social movements can change substantially over time through growth and internal tension. Analogously, Kuhn (1962) posited that sciences go through various phases of consensus and upheaval via normal science and the uncovering of anomalies. Hackett et al. (2008) argued that STS has intellectually and institutionally moved from “infancy” in the 1970’s, to “adolescence” in the early 1990’s, to full-grown adulthood today. While such claims are normative and contentious (see Winner, 1996), it is obvious that STS has undergone changes and growth since inception, with numerous new Ph.D. programs instituted in the early 1990’s, increases in articles and citations, and a steadily increasing population of degree-granting and non-degree granting departments throughout the world (Hackett et al., 2008). Also, due to its relatively young age, the entire history of STS journals has been archived by the Thomson-Reuters Web of Science. Thus, STS provides the opportunity to map the social and intellectual cartography of a field and its scholars in the vital nascent stage, where resources were mobilized by intellectual entrepreneurs (DiMaggio, 1998) to facilitate survival and legitimacy, if not also diffusion of knowledge.

This study uses bibliometric methods and social network measures to operationalize the micro-level decisions scholars make locating papers in this nascent, growing scholarly community. This allows for the empirical examination of the strategies and concomitant reward structures of a scholarly field over time. The journal used for the empirical case study, *Social Studies of Science*, was the first-established and the flagship journal of the Science Studies community. Focusing on a core journal casts a wide swath within the STS community. While core or high-impact journals alone do not define fields or institutions, in this research, *SSS* is used as a *seed*, as opposed to merely a sample. This accounts for the predominant array of citations outside of the seed journal, including to books and other non-article forms of scholarship. At the macro, or field level, this enables the empirical analysis of scholarly and intellectual dynamics in a growing field or knowledge network, while also examining micro-level behaviors and changes at the scholar (or more specifically, paper) level. In sum, the *SSS* case study enables examining the trajectory of a successfully diffusing intellectual community, through numerous stages of development, from birth to professionalization (Hackett et al., 2008). This provides means to examine if and how incentive and social structures change with development. These temporal changes will be examined as well.

Data

Social Studies of Science was selected as the focal journal, for which full citation information is available, due to its history of being the first and preeminent journal in the field of Science Studies. Citation network data from the entire history of *Social Studies of Science* were collected via the Thomson Reuters Web of Science database. For each of the 1,457 articles published in *SSS* between 1971 and 2008[19], each reference in its bibliography was included in the data. In total, there were 50,942 total citations in the bibliographies of those articles. Using the Sci^2 software application, raw text files with the entire bibliographies of *SSS* articles were converted to networks with directed ties between papers, or nodes. However, the majority of nodes are books or non-*SSS* articles, which do not contain out-citation information in the ISI data.[20] Links between these references are directed, or asymmetric, as each citation from a focal *SSS* article to another work in its bibliography (which includes both *SSS* and non-*SSS* articles, and books) entails a tie from the focal article to the cited article.

While the Thomson Reuters database does not contain citation information on books, magazines or other journals outside the focal journal(s), the focal journal serves as a 'seed' to reach books and articles featured prominently in the bibliographies of the focal journal, which extend far beyond it. For example, while a highly cited book would appear in many bibliographies, and have its status as a prominent node in the *SSS* network well-established, current citation data and methods do not include information for such nodes not culled and indexed directly by Thomson Reuters, which is limited to academic journals. Thus, books and 'outside' articles are included, but in the context of how they were invoked by articles in the focal journal. Put differently, while books and other non-*SSS* works are present in all networks

[19] This includes its initial incarnate as *Science Studies*, between 1971-1974.
[20] Digitization may enable the large-scale study of book citations in the near future.

analyzed in this work, information on orthodoxy and network positioning is only available for *SSS* articles. Retaining non-*SSS* works in the bibliographic networks is important, as books and articles outside a focal journal can be among the most popular and influential works in an academic community.[21]

To measure status effects in citing behavior, the effects of citing other highly-connected articles is analyzed. Ordinarily, Bonacich's (1972) eigenvector centrality is invoked to empirically this measure status effect in social networks. However, the mixture of *SSS* nodes and non-*SSS* nodes in these networks, where the former have complete information on citations given and received, while the latter only have information on citations received, render the use of eigenvector centrality infeasible. As an alternative means of operationalizing status effects and tendencies towards preferential attachment in citing behavior, the concept of *bibliographic orthodoxy* is proffered. An article with a preponderance of highly cited articles in its bibliography exhibits a high degree of bibliographic orthodoxy, where an article cites other works which are popular, and a prominent part of the intellectual milieu of the field. To account for the unique adoption context of each citation in the bibliography of a focal *SSS* article, the number of citations to that article in the *SSS* network *previous to that citation*, is taken as the *orthodoxy score* of each citation. In other words, while being the first to cite an article in *SSS* would garner a signal, or orthodoxy score of one, while being the hundredth would yield an orthodoxy score of 100 for that particular article in the bibliography. The signal for being the first to cite a landmark, seminar article is the same as being the first to cite an article which will

[21] For example, in this case the most cited work in the *SSS* network was a book, Kuhn's (1962) *Structure of Scientific Revolutions*.

over time prove to be unpopular. The overall *orthodoxy rate* is the average of all of the orthodoxy scores in the bibliography of each focal article in *SSS*.

$$\text{Bibliographic Orthodoxy Rate}_i = \text{Total Orthodoxy Scores in Bibliography i / \# of References in Bibliography of i}$$

To account for size effects of bibliographies, *citation out degree*[22] is also included. Articles with very long bibliographies may possess a lot of links to the *SSS* network, but they also may be diluted. To add another index of strategic citation behavior, *citation depth* is invoked to examine the notion (Price, 1970; Hargens, 2000) that works which cite more recent articles are indicative of greater cumulativity and a science-oriented paradigm. Citation depth is operationalized as the average year of all works a focal article cites in its bibliography, subtracted by the year the focal article was published.[23]

Closeness centrality is a means of gauging the interstitiality and reachability of a node, and in this case, capturing the degree to which works easily reach across the entire *SSS* citation network. Freeman's formula for closeness centrality is (Freeman, 1979):

$$C_c(n_i) = \left[\sum_{j=1}^{g} d(n_i, n_j) \right]^{-1}$$

[22] This measure was taken prior to the pruning of asymmetric pendants (i.e. works cited only once by a single *SSS* focal article).
[23] For occasional references, due to multiple editions of books existing published in different years, there is an inevitable amount of noise associated with this measure.

The measure is the inverse of farness, where *i* is the citing focal article, and *j* is the cited article. Closeness centrality also possesses the advantage of distinguishing between in-degree and out-degree for asymmetric ties. In this case, the former is related to the dependent variable (citations received), while the latter involves the strategic bricolage invoked by the orthodoxy-related independent variables. For the closeness measures, asymmetric pendants (non-*SSS* articles only cited once, with an in-degree of one and an out degree of zero, and thus otherwise unconnected to the network) were pruned from the relevant networks. This ensures that an article with a large number of unconnected and idiosyncratic citations will not inflate its out-closeness centrality scores. Further, for each publication year, a unique *SSS* network[24] was generated, containing the past ten years of bibliographic links (e.g., an article published in 1982 would have its closeness centrality calculated in a 1973-1982 network).[25]

In addition to the universalistic variables of citation links and intellectual bricolage, particularistic variables are also included in the analysis. Since network positioning and ascriptive social characteristics (gender, race) are often correlated, it is important to examine for effects of particularistic variables. Social capital and resources tied to elite networks will be tested via a dummy variable associating *elite* status with Top 50 ranking in the 2010 Academic Ranking of World Universities. Geographic propinquity is tested via a *North America* dummy variable; also reflecting the division between British and American traditions in Science Studies (H. Collins, 1983: 271). Departmental effects are tested through a *core STS university* dummy

[24] Giant components of each network were extracted using Pajek. The vast majority of all articles in each network were connected.

[25] For articles published in the first decade of *SSS*, the citation history in the journal a given article has to draw upon is obviously less extensive. Thus, while the entire citation history of the journal is included in the networks of articles published in 1971-1979; the network cannot go back the entire ten years, as scholars work with a shorter time-horizon during nascent years.

variable, to examine to what degree citation outcomes may be influenced by departmental affiliation. In particular, this variable gauges the effects of being associated with a university which institutionally was a prominent early adopter of STS.[26] Finally, a *gender* dummy variable is included to account for the common thesis that scientific rewards are differentially distributed between men and women in science (Reskin, 1978; Cole and Zuckerman, 1984). For all of the particularistic, or social constructivist variables, the dummy variables were derived from the first author of the article at the time of publication.

The dependent variable is *citations per year*; a measure for determining the rate of popularity of an *SSS* article. Popularity is an index of a field's reward structure, and operationalizes which articles get identified and used as "good ideas" (Burt, 2004) in the knowledge network. Citations per year takes the mean number of citations an article receives, and divides it by the number of years since it has been published, yielding an annual citation rate.

$$\text{Citations per year}_i = \text{\# of citations received by } i / \text{\# years since publication of } i$$

Given the exponential distribution of citations (Lotka, 1927; Price, 1963; R. Collins, 1998), the citations per year measure was re-centered and logged.

While diffusion curves (Rogers, 1995) and citation life-cycles are non-linear and varied (Hargens, 2000; McCain and Salvucci, 2007; Mingers, 2008), citations per year provides a

[26] The institutions were identified through their prominence in early Science Studies and *Social Studies of Science*. They include: Bath, Birmingham, Edinburgh, Lancaster, Leicester and Manchester, in the United Kingdom. In the United States, they include Cornell, MIT, RPI and UCSD. The American departments were spurred by NSF grants in the 1980's designed to establish Science Studies, emulating the successful diffusion in the United Kingdom in the 1970's (Jasanoff, 1992).

general measure of how popular an article has been over its lifetime. Since full citation information is only available for *SSS* articles, the analysis will be confined to the 1,457 articles published in the journal between 1971-2008. By restricting the population of the field to the bibliographies within *SSS*, this allows for books and extraneous articles to be accounted for in the network to gauge degrees of bibliographic orthodoxy and closeness centrality. While all 1,457 articles were retained in the various time-slice networks of *SSS*, to restrict the analyses of social positioning of papers, to those articles where the author engaged in a reasonable amount of bricolage, works in *SSS* with fewer than six references in the bibliography of the article (i.e. out-degree below six) were excised from the regression analyses.[27] Books and non-*SSS* articles which are prominent in *SSS* bibliographies contribute to the closeness centralities and orthodoxy rates of the examined *SSS* articles.

To gauge temporal effects, articles and results are partitioned in four time periods: 1971-81; 1982-1990; 1991-1999 and 2000-2008. The first cut-point coincides with the emergence of laboratory studies in STS (Sismondo, 2007: 15), notably by Bruno Latour and Karin Knorr-Cetina, which would underpin the most cited and influential work in the field. The second cut-point coincides with the establishment of Science Studies in the United States in the late 1980's and early 1990's, via National Science Foundation grants awarded to Rensselaer Polytechnic University, Cornell University, University of California-San Diego and Massachusetts Institute of Technology. The final time period, beginning at the turn of the century, represents increased

[27] The vast majority of articles with fewer than six citations were 'non-articles', such as book reviews and editorial material. However, given that many influential works were not listed by the ISI as formal 'articles' (e.g., Review Essays), parsing by citation count was chosen over merely restricting analyses to what the Thomson Reuters dubbed as an 'article.' Amongst articles with at least six cited works in the bibliography, all were included, regardless of how many citations they received.

institutionalization and a growing sense in the core of the field that STS is a unique, autonomous discipline of its own (Hilgartner, 2003).[28]

Results

Table 2.1 shows summary statistics and general trends over four separate time periods of *Social Studies of Science*.

TABLE 2.1 – SUMMARY STATISTICS

	1971-1981 (N = 213)	1982-1990 (N=251)	1991-1999 (N=274)	2000-2008 (N=324)
Received Citations Per Year (log)	0.394	0.429	0.466	0.575
Average # of times each cited article previously cited in *SSS* prior to pub. (*signal*)	1.854	3.187	4.598	5.453
OutDegree (*Bibliography Length*)	39.609	41.195	44.73	55.437
Citation Depth	16.357	14.912	14.102	15.766
OutCloseness	0.624	0.103	0.084	0.065
Non-Elite Univ.	0.81	0.824	0.784	0.732
Outside North America	0.514	0.571	0.595	0.474
Non-Core STS Dept	0.679	0.839	0.784	0.803
Gender (M)	0.909	0.81	0.743	0.663

[28] Models were also run without these time periods, instead interacting time with key variables to gauge trends and changes over time. Results were quite similar to the models reported with four different time periods, with significant relationships in the same directions. However, as the analyses focusing on the time periods yielded higher variance explained, they are reported in the results section.

Over time, there is a steady increase in the average number of citations received by *SSS* articles. This is indicative of the accumulation of work and institutionalization of Science Studies, in addition to the successful diffusion and increased visibility of work within the journal, and beyond. Also reflective of the accumulation of some sort of shared and co-ordination knowledge within *SSS*, the average orthodoxy rates of works in the bibliographies of *SSS* articles increases steadily over time. Further, bibliography length (average out degree for a focal node) expands over time, suggesting increases in the breadth and/or depth of articles in the journal over time. Closeness centrality declines precipitously after the first time period, then more gradually over the final three periods, as smaller networks with fewer previous articles and smaller bibliographies engender higher mean levels of closeness. In contrast to the other network measures, citation depth remains relatively constant over all four time periods. Further, when the network is confined to *SSS* articles only, there is a more consistent premium put on citation recency (i.e. lack of citation depth) in the three latest time periods. Within a well-demarcated institution, it appears to be important to situate your work at the cutting edge.

The particularistic variables also reveal signs of a changing, dynamic field. The proportion of authors affiliated with elite universities steadily increased over time. In part, this is indicative of the successful diffusion and increased legitimacy of STS, and is related to the increase of authors in North America in the final time period, where a disproportionate number of elite universities are situated. Another related consequence of the diffusion of Science Studies appears to be a decline in authors affiliated with formal STS departments. While STS departments continue to diffuse and increase in number, growth in Science Studies in non-formal or tangentially related departments appears to be more rapid (Siler, unpublished: Ch. 3) These trends suggest a tradeoff between decreased homogeneity and increased size over time. Finally, the proportion of women contributing to *SSS* has steadily increased; from under ten percent in the first time period, to roughly one-third in the final time period. Table 2.2 reports the effects of the bibliometric, network and particularistic independent variables on citations per year (or in-degree).

TABLE 2.2 - MODEL REGRESSING TIMES CITED/YEAR ON ORTHODOXY, NETWORKS AND INSTITUTIONS FOR *SOCIAL STUDIES OF SCIENCE* ARTICLES (N=1068).

	Model 1	Model 2	Model 3	Model 4
ORTHODOXY				
Orthodoxy (*Average # of times each cited article previously cited in* SSS *prior to pub*)	.009*	.012**	.011**	.010*
	(.004)	(.004)	(.004)	(.004)
NETWORKS				
OutDegree		.004***	.004***	.004***
(*Bibliography length*)		(.000)	(.000)	(.000)
OutCloseness		-.037	-.034	-.035
		(.023)	(.024)	(.034)
HISTORICAL ORIENTATION				
Citation Depth				-.004***
				(.001)
PARTICULARISTIC VARIABLES				
Non-Elite Univ.			.024	.018
			(.039)	(.039)
Outside North Amer.			.069*	.068*
			(.032)	(.031)
Non-Core STS Dept			.039	.035
			(.034)	(.034)
Gender (M)			.039	.033
			(.033)	(.032)
Constant	.442***	.263***	.312***	.366***
	(.004)	(.029)	(.047)	(.048)
R-Square	.005	.090	.092	.110

+ p < .10; * p <.05; ** p <.01; *** p <.001 (two-tailed tests). Note: Standard Errors are in parentheses.

The results of Table 2.2 suggest that orthodoxy has a positive effect on the likelihood an article will receive citations. However, Model 1 shows that the variance explained by orthodoxy is minuscule (0.5%), suggesting that this positive effect is relatively weak. Bibliography length (out degree in the network) also has a significantly positive impact on citations received. In contrast, closeness centrality does not have a significant effect on citations received. Particularistic influences are limited to the geographic position of authors; European authors were significantly more likely to be cited. However, particularistic variables added roughly 0.2% variance explained, suggesting that these effects are relatively inconsequential in this model. Finally, citing older articles was significantly negatively associated with receiving citations.

Distinguishing between different time periods in the history of *SSS* reveals stronger effects of the variables, which vary over time. These results are reported in Table 2.3. Across all four models, a consistent pattern over time emerges in regards to the effect of orthodoxy, as operationalized by *orthodoxy rate*, on citations received per year. Orthodoxy is particularly conducive to receiving citations in the first time period. During the second period, effects of orthodoxy on prominence remain significantly positive, but are relatively weaker, before attenuating over the final two time periods. In contrast to the decrease of the efficacy of orthodoxy, the effects of closeness centrality in citation choices on prominence positively increase over each time period. Note that the downward trend of rewards associated with orthodoxy, and upward trend with rewards associated with centrality are in contrast to, as shown in Table 2.1, the general trends of increasing orthodoxy and decreasing closeness of articles. This suggests that professional rents and rewards may be linked to holding scarce positions in social fields. Network out-degree, or bibliography length, becomes strongly associated with scholarly rewards after the first period, much like closeness centrality. Articles which pass peer review, and are permitted to retain lengthy bibliographies and more extensive ties to other works, garner greater rewards in the larger and sparser networks of later time periods.[29]

[29] To ensure that results were not being unduly skewed by shorter articles, an additional set of models was generated, limiting analysis to articles with twenty or more citations in the bibliography. Results were quite similar to the results in Table 2.3.

TABLE 2.3 - MODELS REGRESSING TIMES CITED/YEAR ON ORTHODOXY, NETWORKS AND INSTITUTIONS FOR *SOCIAL STUDIES OF SCIENCE* ARTICLES.

	MODEL 1				MODEL 2				MODEL 3				MODEL 4			
Time Period	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08
ORTHODOXY																
Orthodoxy (*Average # of times each cited article previously cited in* SSS *prior to pub*)	.115***	.017	.006	-.007	.112***	.034**	.008	-.004	.108***	.036**	.005	-.002	.103***	.035**	.005	-.002
	(.027)	(.013)	(.007)	(.006)	(.028)	(.013)	(.007)	(.006)	(.029)	(.013)	(.007)	(.006)	(.030)	(.013)	(.007)	(.007)
NETWORKS																
OutDegree					.001	.004***	.005***	.003***	.001	.004***	.005***	.003***	.001	.004***	.005***	.004***
(*Bibliography length*)					(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
OutCloseness					-.014	4.558***	6.471***	10.147***	-.007	4.651***	6.270**	10.331***	-.009	4.606***	5.999**	9.298***
					(.024)	(1.271)	(1.950)	(1.749)	(.024)	(1.266)	(2.086)	(1.814)	(.024)	(1.288)	(2.172)	(1.786)
HISTORICAL ORIENTATION																
Citation Depth													-.001	.000	-.001	-.009***
													(.001)	(.001)	(.002)	(.002)
PARTICULARISTIC VARIABLES																
Non-Elite Univ.									.146+	-.162*	.038	-.008	.146+	-.162*	.037	-.015
									(.083)	(.078)	(.077)	(.069)	(.083)	(.078)	(.077)	(.067)
Outside North Amer.									-.211**	.012	-.029	-.024	-.210**	.012	-.029	-.031
									(.069)	(.058)	(.061)	(.006)	(.069)	(.058)	(.061)	(.058)
Non-Core STS Dept									-.135*	-.168*	-.070	.094	-.131+	-.162*	-.069	.081
									(.067)	(.072)	(.063)	(.068)	(.068)	(.067)	(.063)	(.067)
Gender (M)									-.132	.164*	-.033	.068	-.132	.162*	-.035	.066
									(.103)	(.066)	(.054)	(.056)	(.104)	(.067)	(.055)	(.054)
Constant	.181**	.375***	.438***	.613***	.177*	-.309*	-.345*	-.238*	.284*	-.086	-.260	-.350*	.303*	-.076	-.225	-.160
	(.057)	(.050)	(.042)	(.044)	(.079)	(.141)	(.156)	(.121)	(.118)	(.155)	(.177)	(.143)	(.121)	(.162)	(.193)	(.147)
R-Square	.080	.007	.003	.004	.080	.143	.225	.166	.131	.201	.218	.176	.133	.201	.218	.219
N	213	251	274	324	213	251	274	324	213	251	274	324	213	251	274	324

+ p < .10; * p <.05; ** p <.01; *** p <.001 (two-tailed tests). Note: Standard Errors are in parentheses.

The effects of citation depth on prominence are completely confined to the last decade. This raises a larger question with the data and analysis; namely whether it is reasonable to interpret temporal differences as a result of qualitative and historical differences between time periods. Hargens (2000) suggests that articles tend to be cited for different reasons throughout their life-cycle, which leaves a reasonable counter-hypothesis that differences between time periods may be influenced by the fact that older articles will likely have passed through more of their diffusion-curve and life-cycle than more recent works. To test these effects, as reported in Table 2.4, an additional model was run using *citations in the first six years since publication*[30] as the dependent variable (see Table 2.3).

Even when restricting the dependent variable to citations received in the first six years since publication, familiar patterns and coefficients emerge throughout the first three time periods. Thus, it seems that time period differences in Tables 2.3 and 2.4 are in fact influenced by qualitative temporal influences, as opposed to life-cycle or diffusion-curve effects of articles. The influence of social constructivist variables on citations received is confined to the first two time periods. The clearest trend across both tables is that effects with being associated with a department outside of the initial core of STS departments were negative over the first two time periods. In early and foundational periods of STS, being situated at the periphery of the field appears to have been a significant disadvantage. The other consistent trend is that male authors possess a brief significant advantage in the second time period. This advantage quickly disappears, perhaps owing in part to the increasing representation of women in the field over

[30] As articles are published in volumes throughout each calendar year, but Thomson-Reuters only tabulates citation counts yearly, this means that this variable will actually mean citations from anywhere from five to six years since publication. Further, since this is a relatively small amount of time for ideas to diffuse on a large scale, this reduces citation inequality sharply, and obviates the need to log this dependent variable.

time, and more extensive diffusion of Science Studies outside of its initial core universities and scholars.[31] The influence of these particularistic and institutional variables over early time periods suggests that such factors are most influential when a network is nascent and homogeneous, and a field has yet to be strongly or formally institutionalized. Coupled with the network and orthodoxy outcomes, the results suggest that intellectual and social homophily are most influential in smaller, more intimate networks.

Table 2.5 reports an additional robustness check where the network is pared down only to articles published in *Social Studies of Science*. While this network is much smaller than those analyzed in Tables 2.3 and 2.4, it possesses the advantage of including complete information on all nodes. Results follow similar trends to the larger network reported in Table 2.3. Orthodoxy is most conducive to receiving citations in early time periods, while centrality increases in importance later. While orthodoxy effects decline considerably after the first time period, they remain marginally significantly positive over the remaining three periods, suggesting that within the more tightly bounded institutional network of *Social Studies of Science*, there is a more consistent premium put on orthodoxy.

[31] While there was no gender effect in the first time period, it should be noted that as per Table 2.1, only roughly nine percent of publications came from females (many of whom were repeat authors) during that time slice. Thus, there were very few published female STS scholars to make a comparison with.

TABLE 2.4 – MODEL REGRESSING TIMES CITED/YEAR ON ORTHODOXY, NETWORK POSITIONING AND PARTICULARISTIC VARIABLES IN THE FIRST SIX YEARS SINCE BEING PUBLISHED IN *SOCIAL STUDIES OF SCIENCE*.

	>5 Citations in Bibliography			>19 Citations in Bibliography		
Time Period	**'71-'81**	**'82-'90**	**'91-'99**	**'71-'81**	**'82-'90**	**'91-'99**
ORTHODOXY						
Orthodoxy (*Average # of times each cited article previously cited in* SSS *prior to pub*)	1.291* (.501)	.410** (.154)	.102 (.079)	2.845*** (.544)	.654** (.236)	.269* (.127)
NETWORKS						
OutDegree (*Bibliography length*)	.008 (.015)	.036*** (.010)	.048*** (.009)	.005 (.013)	.026* (.013)	.031* (.012)
OutCloseness	-.036 (.411)	65.132*** (15.219)	93.688*** (24.512)	.039 (.343)	70.899*** (19.543)	84.433** (30.719)
HISTORICAL ORIENTATION						
Citation Depth	-.022 (.025)	-.023 (.021)	-.005 (.027)	-.002 (.020)	-.012 (.024)	-.010 (.033)
INSTITUTIONS/ CONSTRUCTIVIST VARIABLES						
Non-Elite Univ.	3.215* (1.397)	-.096 (.922)	-.180 (.870)	2.830* (1.336)	.315 (1.263)	-.097 (1.111)
Outside North Amer.	-2.936* (1.162)	.191 (.691)	.063 (.693)	-1.412 (1.087)	-.189 (.929)	-.105 (.874)
Non-Core STS Dept	-1.868 (1.134)	-1.934* (.854)	-.196 (.715)	-2.316* (.988)	-2.836* (1.118)	-.150 (.959)
Gender (M)	-1.720 (1.740)	1.086 (.786)	-.383 (.616)	-.755 (1.535)	1.678+ (1.002)	-.239 (.794)
Constant	3.715+ (2.039)	-2.856 (1.913)	-5.503* (2.178)	.570 (1.948)	-2.964 (2.641)	4.066 (2.849)
R-Square	.097	.173	.197	.261	.182	.137
N	200	238	260	141	171	194

+ p < .10; * p <.05; ** p <.01; *** p <.001 (two-tailed tests). Note: Standard Errors are in parentheses.

TABLE 2.5 - MODELS REGRESSING TIMES CITED/YEAR ON ORTHODOXY, NETWORKS AND INSTITUTIONS FOR *SOCIAL STUDIES OF SCIENCE* ARTICLES (*SSS* ONLY).

	MODEL 1				MODEL 2				MODEL 3				MODEL 4			
Time Period	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08	'71-'81	'82-'90	'91-'99	'00-'08
ORTHODOXY																
Average # of times each cited article previously cited in *SSS* prior to pub. (*signal*)	.046***	.005	.008*	.005	.048***	.012+	.008*	.006+	.047***	.013+	.008+	.006+	.046***	.010	.007+	.006+
	(.013)	(.006)	(.004)	(.003)	(.014)	(.007)	(.004)	(.003)	(.014)	(.007)	(.004)	(.003)	(.014)	(.007)	(.004)	(.003)
NETWORKS																
OutDegree					.000	.001***	.001**	.001*	.000	.001**	.001**	.001+	.000	.002**	.001**	.001*
(*Bibliography length*)					(.000)	(.000)	(.000)	(.000)	(.00)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
OutCloseness					-.004	.680***	3.427***	4.082***	-.007	.642+	2.975**	4.037***	-.008	.591+	2.697**	3.889***
					(.015)	(.343)	(.945)	(.711)	(.016)	(.356)	(.973)	(.748)	(.016)	(.356)	(.978)	(.752)
HISTORICAL ORIENTATION																
Citation Depth													.000	-.002+	-.003+	-.002+
													(.001)	(.001)	(.001)	(.001)
PARTICULARISTIC VARIABLES																
Non-Elite Univ.									.039	-.060	-.021	-.014	.039	-.065	-.023	-.016
									(.039)	(.042)	(.044)	(.039)	(.039)	(.042)	(.044)	(.039)
Outside North Amer.									-.012	.007	-.008	-.026	-.012	.010	-.009	-.027
									(.069)	(.031)	(.035)	(.033)	(.033)	(.031)	(.035)	(.033)
Non-Core STS Dept									-.098**	-.040	-.018	-.014	-.097**	-.036	-.015	-.017
									(.032)	(.039)	(.036)	(.039)	(.032)	(.039)	(.036)	(.038)
Gender (M)									-.049	.055	.000	-.005	-.049	.047	-.003	.006
									(.049)	(.036)	(.031)	(.032)	(.049)	(.036)	(.031)	(.032)
Constant	.003	.103***	.117***	.129***	-.014*	-.233+	-.988***	-1.033*	.041	-.150	-.808**	-.980***	.045	-.107	-.225	-.911***
	(.027)	(.025)	(.023)	(.024)	(.041)	(.136)	(.156)	(.193)	(.056)	(.142)	(.294)	(.207)	(.058)	(.144)	(.193)	(.211)
R-Square	.060	.002	.015	.007	.065	.058	.107	.119	.121	.080	.091	.121	.122	.092	.104	.129
N	213	251	274	324	207	251	274	324	200	238	260	310	200	238	260	310

+ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$ (two-tailed tests). Note: Standard Errors are in parentheses.

Global Network Structure

The changes in the citation choices in *SSS* publications made by authors (Table 2.1) and the reward structure of the field (Tables 2.2, 2.3, 2.4 and 2.5) are also related to general changes in the larger network structure of *SSS*. Specifically, changes in network centralization and modularity in the *SSS* network over time are relevant.

In her study of developing labor markets, Gondal (2011) identified degree distribution and connectivity as key measures of global knowledge network structures. Figures 2.1 and 2.2 reveal an exponential degree distribution of citations, where a relatively small number of nodes garner a disproportionate amount of attention.

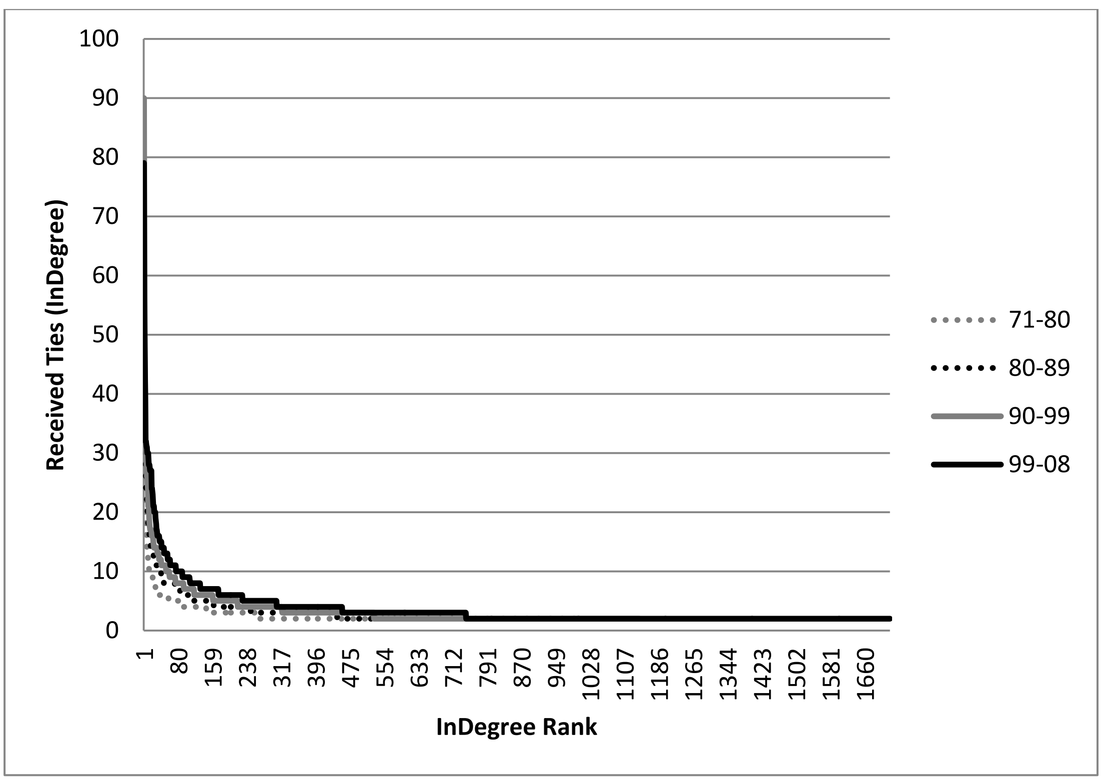

FIG. 2.1 - DEGREE DISTRIBUTIONS OF *SOCIAL STUDIES OF SCIENCE* ARTICLES BY TIME PERIOD.

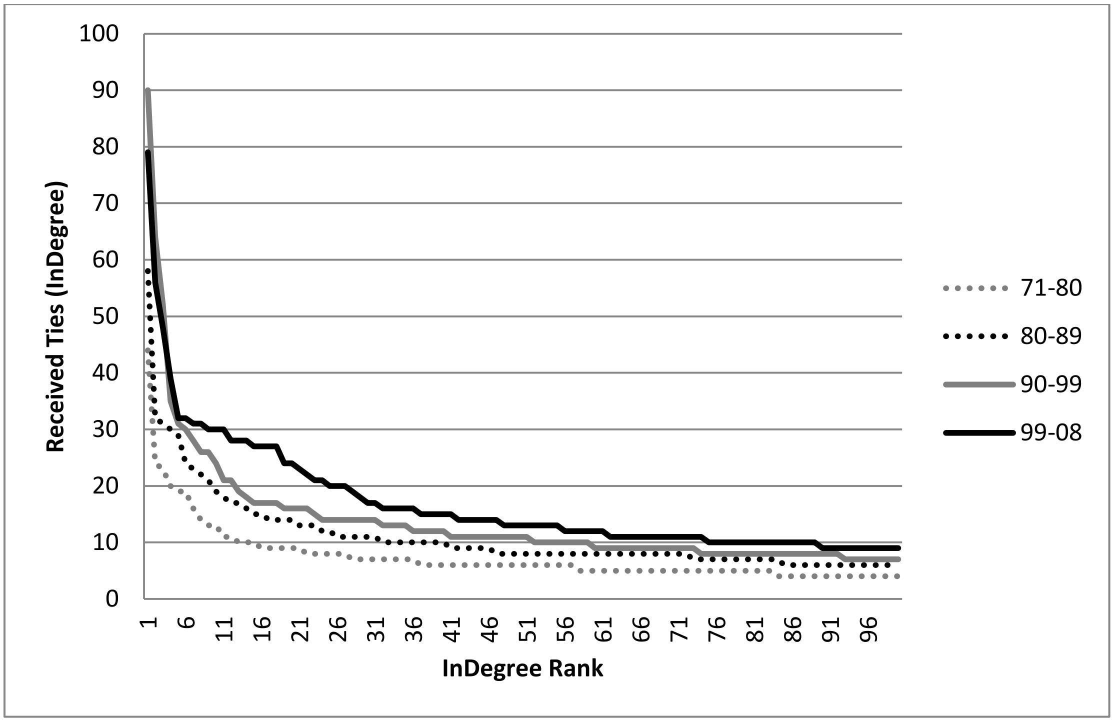

FIG. 2.2 - DEGREE DISTRIBUTIONS OF *SSS* ARTICLES (TOP 100 ARTICLES ONLY).

This suggests a strong core-periphery network structure, which is characteristic of most large academic networks (Price, 1963). Table 2.6 shows that in later time periods, the proportion of received ties held by the most cited articles in the network increases. Later networks exhibit a slightly more pronounced core-periphery structure. Despite this, due to their smaller size, earlier networks are more brittle and prone to disconnection.

TABLE 2.6 – CONCENTRATION OF CITATIONS OF 1%/5% MOST CITED *SOCIAL STUDIES OF SCIENCE* ARTICLES.

	1971-1979	1980-1989	1990-1998	1999-2008
1%	0.072891	0.090893	0.104167	0.105992
5%	0.171639	0.180829	0.224248	0.225531

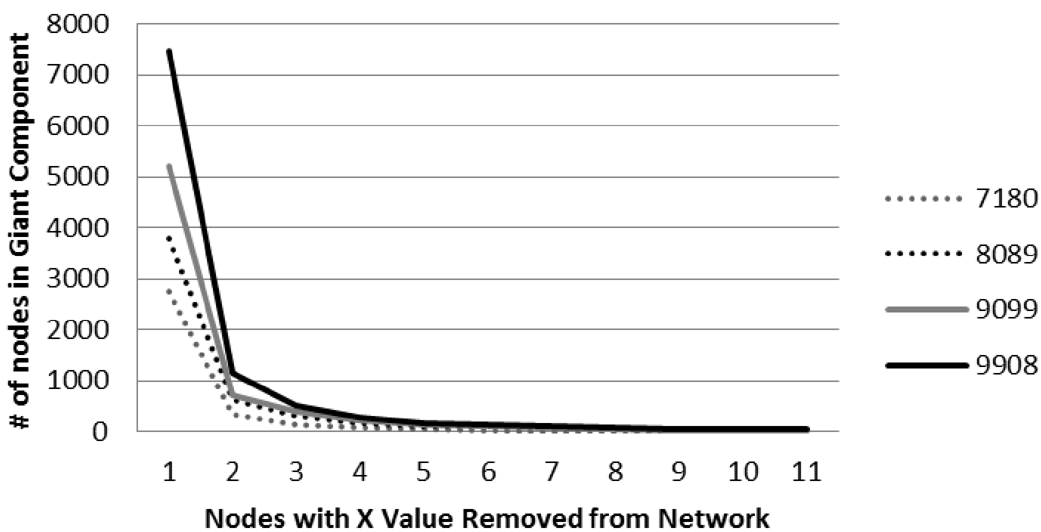

FIGURE 2.3 – DEGREE DISTRIBUTIONS OF *SSS* NETWORKS.

TABLE 2.7 – GIANT COMPONENT SIZE AFTER REMOVAL OF NODES WITH X CITATIONS.

indegree	’71-‘79	’80-‘89	’90-‘98	’99-‘08
0	2751	3796	5206	7468
1	342	631	723	1138
2	139	296	381	500
3	74	176	214	290
4	36	118	145	177
5	28	93	100	135
6	0	65	63	111
7	0	49	35	68
8	0	30	14	50
9	0	28	11	45
10	0	21	10	38

Figure 2.3 and Table 2.7 show that early networks are more easily disconnected, and have their giant components shrunk via the selective deletion of a few high-popularity nodes. Since earlier networks are smaller and more prone to disconnection of high-status nodes, this is a potential explanation for why orthodox positioning (i.e. citing other popular papers) is particularly conducive to receiving citations in the future.

Modularity is another structural feature relevant to knowledge networks. Whitley (1984) theorized that the structures of academic disciplines are distinguished by subfield composition within the larger field. Concretely, Moody (2006) contrasted the highly clustered and relatively homogenous network of economics with the disparate, loosely connected clusters of sociology. A network comprised of connected clusters can connect disciplines (Moody, 2004) and maximize innovation potential, both at the individual and global levels (Uzzi, 1997; Uzzi and Spiro, 2005) Given Blau's (1970) edict that size increases heterogeneity, sub-fields and cliques can develop within knowledge networks. Identifying subfields and communities is an analogous challenge in social network analysis. Newman and Girvan (2004) devised an algorithm to measure modularity; the degree to which a network is comprised of distinct clustered groups of links and nodes in larger connected networks. The Girvan-Newman equation is:

$$Q = \frac{1}{2m}\sum_{i,j} A_{ij} - \frac{k_{ij}}{2m}\delta(c_i, c_j)$$

where Q is total modularity, m is the number of edges, A_{ij} is the weight of the similarity matrix, k_i and k_j are the in-degrees of the corresponding nodes, while c_i and c_j are cluster indices for the two relevant nodes. δ is a function that equals one when two nodes are in the same cluster, and zero when they are not. The Girvan-Newman algorithm works by first calculating the betweenness centrality for all nodes, then removing those nodes and repeating the calculations until no nodes remain.

Figures 2.4 and 2.5 show trends in overall network modularity over time in the *SSS* network.

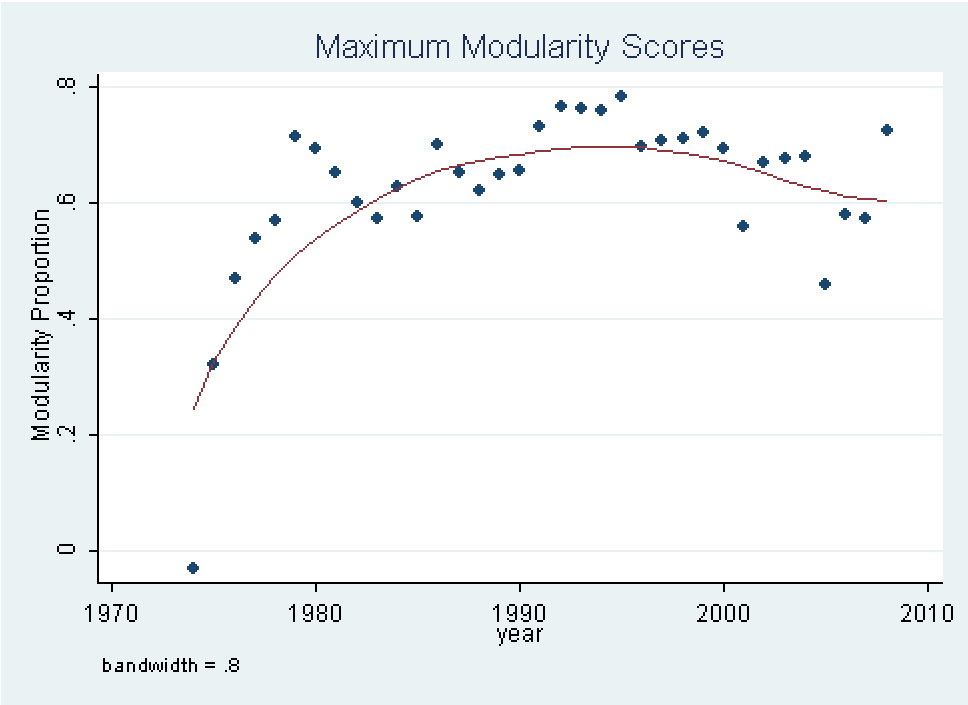

FIGURE 2.4 – MAXIMUM GIRVAN-NEWMAN MODULARITY SCORES OVER TIME

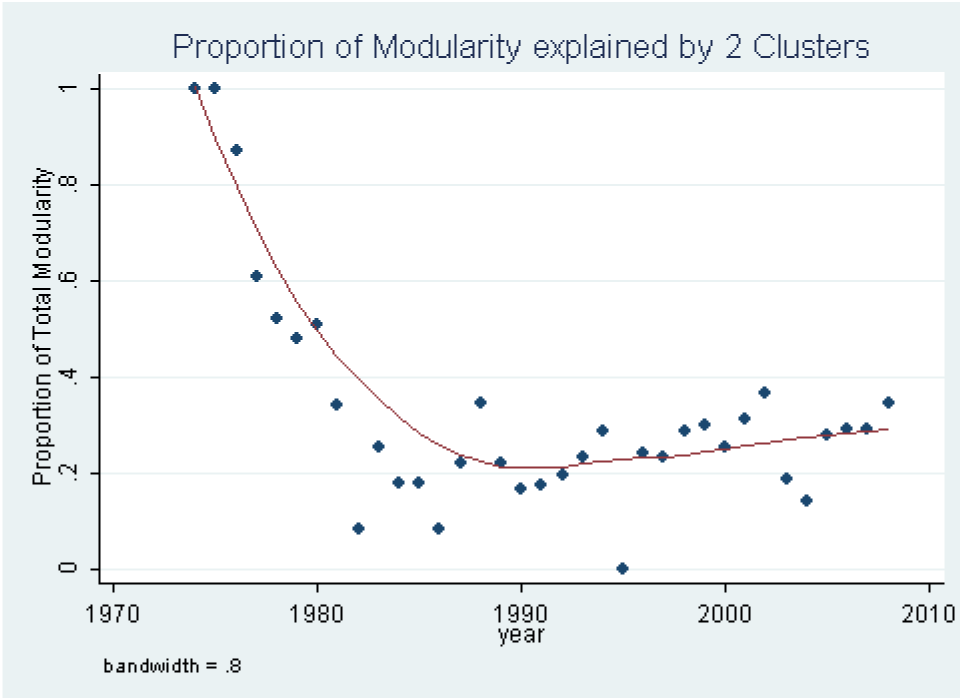

FIGURE 2.5 – PROPORTION OF MODULARITY EXPLAINED BY 2 CLUSTERS WITH GIRVAN-NEWMAN ALGORITHM

Changes in network modularity appear most obviously over the first decade of the network. Figure 2.4 reports a steady increase in maximum modularity levels over the first two decades of *SSS*, which flattens out over the 1990's, and even declines slightly over the 2000's. Early, the *SSS* network was relatively homogeneous with few differentiated clusters.[32] Over time, sub-groups and specialty areas became more prominent within the network. Figure 2.5 shows that the number of differentiated clusters increased over time as well. The Girvan-Newman algorithm reports goodness-of-fit measures for various clustering levels. Figure 2.5 reports the proportion of modularity explained by the lowest level of clustering (two clusters). Once again, the first ten to fifteen years of *SSS* show substantial changes, followed by a leveling off over later

[32] Of note is that calculations for networks before 1974 were not computed by UCInet due to the primitiveness and small-size of the network. Thus, modularity levels were very low for the first four years of the network.

time periods. Figure 2.6 shows that the level of clustering with the largest proportional contribution to goodness-of-fit oscillates over time, peaking at middle time-periods, then declining again later.

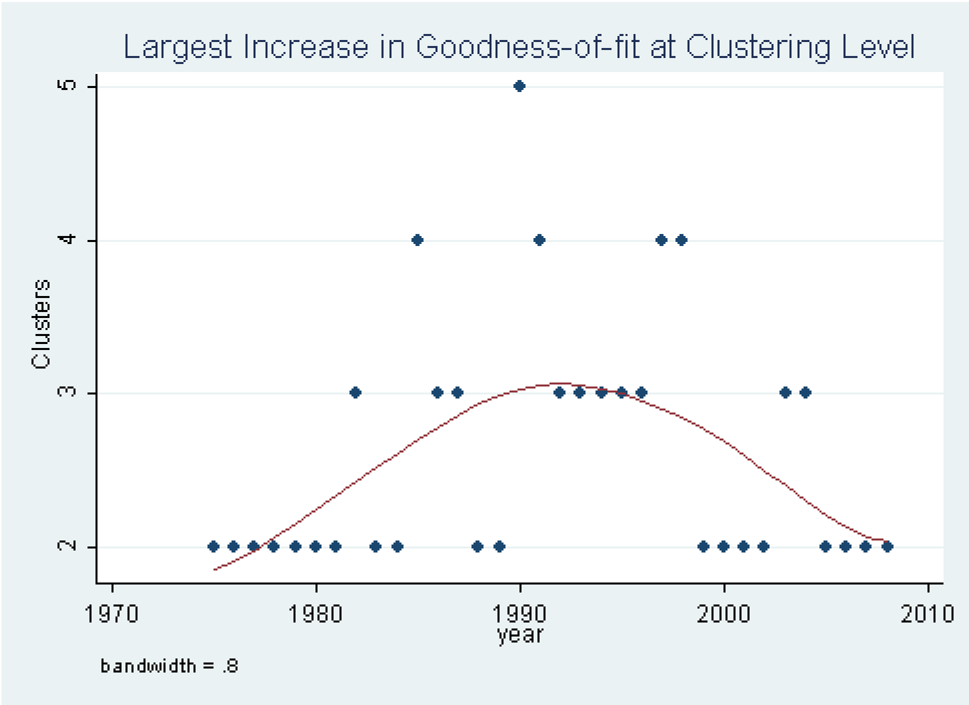

FIGURE 2.6 – LARGEST GOODNESS-OF-FIT OF GIRVAN-NEWMAN ALGORITHM OVER TIME

This later decline suggests that in the 2000's, the *SSS* network became more homogeneous and connected, despite continually growing in size over time. In turn, knowledge networks may oscillate between periods of increased clustering and synthesis. Regardless, as per Figures 2.4 and 2.5, even during this later time period, the simplest 2-Cluster level contributes a smaller proportion of goodness-of-fit over time, relative to the smaller and nascent networks from the 1970's.

Discussion and Conclusion

Results suggest a dialectical interplay between individual-level scholarly reward structures and the intellectual cartography, or opportunity structures, of the overarching field. Hypothesis 1 was supported, while Hypothesis 2 was not. Without distinguishing between time periods, orthodoxy was significantly positively related to receiving citations, although the variance explained was minuscule in this scenario. Closeness centrality had no significant effect on citations received in the model pooling articles from all time periods.

Distinguishing between different time periods changed and amplified results. Orthodoxy and particularistic influences were positively linked to receiving prominence in the early history of *SSS*. Articles that cited more frequently cited works were more likely to be cited. In later time periods, these effects were supplanted by the reachability and bridging of closeness centrality. The influence of social constructivist and institutional variables vanished over these later two time periods, when STS had diffused, grown and developed further as an intellectual canon and an institution. The results support Hypotheses 3 and 4, suggesting that knowledge networks move from rewarding orthodoxy in nascent periods, to rewarding reachability once the field is established.

Finally, there was weak support for Hypothesis 5, with geography being the only significant particularistic variable in the model without time specifications. Support for Hypothesis 6 was much stronger. During early time periods in *SSS*, geographic, institutional status and gender variables exerted significant influence over the likelihood an article will receive citations. In later time periods, effects of these particularistic variables became non-significant.

The growth, diffusion and increased intellectual breadth of *SSS*, coupled with the diversifying demography and scope of Science Studies, suggests an expanding, increasingly heterogeneous field. During earlier, more nascent time periods, the field was more dependent on zealous actors and strong intellectual and social ties maintaining the field's clarity, militancy and critical mass. Consequently, social and intellectual propinquity is a conspicuous asset in this context, having been shown to have a positive link to prominence (i.e. receiving citations). Hackett et al. (2008: 2-12) identify ambiguity of standards and absence of information in the incipient paradigms and time periods of STS. Long and Fox (1995: 62-64) hypothesized that such factors contribute to increased particularistic influences in science. The importance of particularistic variables in early time periods in STS seems to support this notion. Given the influence of affiliation with European and core institution in early time periods, closeness to personal and intellectual networks appears to have been very important during foundational times, suggesting that in this case, 'secrecy' arose at least in part out of the relative obscurity of STS and a lack of established diffusion networks.[33]

In contrast, in later time periods, a larger, more developed field, with increased intellectual, institutional and social sparseness, generates brokerage opportunities. The locus of power in the field shifts from clustering relatively intimate ideas and actors, to bridging disparate entities. Once a critical mass has been established, the rewarded priorities of *SSS* shift to outward

[33] Access and connections to interpersonal and institutional networks is an additional cause which has been argued to adversely affect women in professions (Burt, 1998).

expansion and linkages.[34] Depth is being traded for breadth over time, and in turn, the reward structures and incentives change. Niches for information ‘hubs’ in complex scale-free or small-world networks further ensconces benefits for a few highly visible and reachable articles (or nodes) which co-ordinate and bridge between increasingly disparate expanses of the field. While a large, heterogeneous network may be able to retain connections between disparate scholarly works, these hubs may also be watered down to the “lowest common denominator”, reflective of the breadth/depth tradeoff, and also retaining some incentive for authors to utilize more specialist niches and bricolage, in lieu of, or in addition to, more generalist strategies.

The intellectual demographics and reward structures of the scholarly community centered around *Social Studies of Science* have changed considerably over the course of its history. Rewards initially accrued to highly orthodox work, which declined over time. In contrast, as the STS field developed, rewards to closeness centrality increased over time. These results are analgous to Mulkay et al.’s (1975) model, where scientists initially struggle to find and achieve consensus, but are later able to concentrate on growth and social and intellectual integration amongst successful innovations. Consensus, or knowledge of what the intellectual zeitgeist would be in STS, may have been scarce in the first time period, but rewards for achieving intellectual orthodoxy were highest during this time. Finding consensus through strategic intellectual bricolage, social skill (Fligstein, 1997; Rojas, 2007) and/or luck, may be difficult to do in a developing field. This leads to a paradox where signals, or knowledge of the intellectual canon of STS, are weakest during nascent times, but rewards are strongest. Over time, while orthodoxy levels increase due to the accumulation of articles and intellectual and professional canon, rewards associated with orthodoxy decline.

[34] In other fields, tradeoffs and equilibria may be different than in *SSS* and Science Studies.

Results associated with closeness centrality contrast with intellectual orthodoxy. In the intimate, clustered field in early time periods, closeness was relatively very high overall, but rewards associated with closeness were non-existent. During the second time period, the increasing diversity and size of the field opened new niches, suppressing rewards associated with orthodoxy, while also beginning to reward closeness centrality. As a field grows beyond its formative cluster, and becomes increasingly heterogeneous, bridging opportunities emerge and incentive structures change. Over the third and fourth time periods, as the *SSS* field developed and continued to expand, mean levels of closeness continued to decreased, and the effect of closeness on prominence increased. Once again, this suggests that scarcity is a key mechanism in perpetuating prominence in intellectual fields. The increases in rewards associated with closeness over time, as the field becomes increasingly heterogeneous and sparse, suggests a premium on reachability and bridging developed. This suggests a reward system which may be at least somewhat opaque to some scholars. Additionally, getting cited and getting published may be overlapping, but different processes and incentives. Receiving citations is hardly the only incentive structure in academia, which may also influence the research and rhetorical choices scholars make. While authors make decisions on how to construct and frame persuasive research (McCloskey, 1994), their intellectual preferences, values, institutional constraints and competing reward structures from outside of the scholarly core, may not entirely align with the current reward structure of the field.

Just as knowledge networks change over time, so do their reward structures. Reward structures are related to, if not influenced by the properties of the networks they are contained in. In the case of *Social Studies of Science*, a smaller, less structurally cohesive network in its nascent, early time period resulted in more orthodox articles being more heavily cited. As the network grew and developed over time, there were precipitous increases in size and modularity. After this first foundational period, centrality and reachability in the larger, more modular network became conducive to receiving citations, while the influence of orthodoxy declined. In a larger network, with more options and connections, the need to cite a few specific focal articles decreases. Further, as global centralization increases, a network develops a stronger core-periphery structure, the benefits of centrality also increase. In sum, the processes by which scientific contributions are hailed as "good ideas," are influenced by network structures and dynamics.

CHAPTER 3

INNOVATION DIFFUSION AND SOCIAL STRATIFICATION IN SCIENCE:

THE CASE OF *LABORATORY LIFE* AND SCIENCE STUDIES

Introduction

The generation of new ideas and creative destruction of old ones underpins innovation and productivity. Kuhn (1962) theorized that scientific communities oscillate between consensus and dissensus. Scientific change is propagated via opposing processes of *exploiting* entrenched and established paradigms, and *exploring* alternative theories and possibilities after the revealing of anomalies and weaknesses with conventional thinking and research. This raises questions of what the diffusion mechanisms underpinning such intellectual change are, and how they operate in contentious and competitive scientific communities. How do seminal ideas diffuse through scholarly disciplines? How are Scientific/Intellectual Movements catalyzed, then entrenched? How is the diffusion of an idea – and more broadly, an article's or idea's life-cycle – related to professional rent creation and social stratification in science? To study these dynamics empirically, this article examines the diffusion of Bruno Latour and Steve Woolgar's 1979 book, *Laboratory Life: The Social Construction of Scientific Facts*, as a case study of a bellwether book diffusing through the interdisciplinary field(s) of Science Studies.

Diffusion research has shown that the quality and/or application of ideas vary over the course of an innovation's life-cycle. Rogers (2003) and Bass (1969) posited that innovations and goods go through a life-cycle shaped like a normally distributed bell curve, populated with varying proportions of early, middle and late adopters. Adopters on various points of the diffusion curve tend to have different personal characteristics and preferences regarding how and why they adopt a given innovation. Using the case study of *Laboratory Life* as an exemplar of a burgeoning social construction of science paradigm, this article analyzes *who* adopts (in this case, represented by a scholar citing the article in their work) a particular bellwether academic publication, and *how* they apply it. The individual characteristics of scholars used to explain differing propensities for adoption at various points in the life-cycle of an article or paradigm, are author eminence, orthodoxy (how conventional an author's citation choices in an article are) and status.

The remainder of the article is organized as follows. First, various social science theories are invoked to illustrate the relevance of *Laboratory Life* as a case study in diffusion, and the main explanatory variables for the academic/scientific case study used in this research. The eminence of a scholar prior to publication, the bibliographic orthodoxy present in a given paper and institutional affiliations are all presented as potential explanations for varying propensities to cite the book. Second, a citation analysis methodology is developed to examine the effects of the independent variables (eminence, orthodoxy, institution status) on whether an article cites *Laboratory Life*. Third, logistic regression results are presented and interpreted, revealing varying effects of the independent variables on citation propensities over time. Fourth, variations and changes in how *Laboratory Life* has been used by scholars in text, are examined via qualitative coding of citations. Finally, the implications of these results are discussed, particularly for innovation dynamics and idea diffusion in academia. Diffusion processes influence social stratification and the division of labor in the overarching scientific field.

Laboratory Life

Laboratory Life is a foundational, bulwark publication in the Science Studies paradigm and community, which was influential throughout social and information sciences. The book was based on a two-year observation of the Salk Laboratory at the University of California – San Diego. Specifically, the laboratory examined the chemical sequence of thyrotropin. Latour and Woolgar would argue that the eventual identification of the Pyro-Glu-His-Pro-NH_2 chain was deeply influenced by social factors and processes, as opposed to being wholly based on the material or natural properties of the substance. The emphasis on social constructivism distinguished the book, and in turn, Science Studies itself.

Cole (1992: ch. 1) identifies a continuum in the study of science between naturalistic and social constructivist theories. The former assumes that scientific results and processes are inherently derived from physical or cognitive phenomena. In contrast, constructivism takes a relativistic stance, arguing that scientific facts are underpinned by social interests and processes. While these are ideal types, *Laboratory Life* is an exemplar of the social constructivist paradigm. Underscoring their belief that constructivism had long been underemphasized in traditional accounts of science, Latour and Woolgar (1979: 280) argued for a ten year moratorium on naturalistic explanations of science.

In addition for being a classic reference for social constructivist perspectives on science, *Laboratory Life* was the first of what became a tradition of laboratory studies of science (Chubin and Restivo, 1983: 104; Sismondo, 2007: 15). The book not only brought prominence to the laboratory as an empirical resource for constructivist scholars, but also proffered a new *anthropological strangeness* perspective for practitioners. Latour and Woolgar (1979: 29) argue that cognitive or technical familiarity with the work of a laboratory should not be prerequisite for understanding the work of scientists, emphasizing the dangers of "going native."[35] The laboratory vantage point allows the observer to see disjunctures between how facts emerge in the laboratory and how they are eventually presented (176). Further, the actions of scientists are also seen in a strategic light, in that they are believed to be undertaking actions for the primary purpose of accruing credibility, as opposed to the 'pure' pursuit of knowledge (ch. 8). Scientific credibility can be reinvested into new projects and relationships, even if credit is not always reciprocated by credibility-granting higher status scientists and entities right away. In sum, the laboratory study conducted in *Laboratory Life* revealed key theoretical and methodological precepts that would come to be associated with the constructivist paradigm in Science Studies.

Since *Laboratory Life* was the first major laboratory study published in Science Studies, first-mover advantages and *priority* benefits (Merton, 1957; Dasgupta and David, 2002) appear to have accrued to the book, particularly within the Science Studies community. Further, *Laboratory Life* served as a harbinger of new methods and theories in Science Studies, namely

[35] This also greatly reduces the learning curve and increases accessibility for those interesting in applying the laboratory analysis techniques proffered by Latour and Woolgar, which should also help facilitate diffusion, especially amongst less zealous or later adopters of the theoretical and empirical innovations in *Laboratory Life* and Science Studies more generally. Fuller (2000) argues that while this complementary relationship with science has been professionally beneficial for Science Studies in the short-term, this relationship also has stunted its intellectual growth, by discouraging scholarship which is more critical, or subversive towards science (also see: Winner, 1999).

laboratory studies and social constructivism. The success of these innovations would later underpin Actor Network Theory, popularized by Latour in his 1987 book *Science in Action* (Knorr-Cetina, 1995: 147). The personal characteristics and intellectual biographies of Latour and Woolgar were also influential in the creation and diffusion of ideas encapsulated in *Laboratory Life*. Latour's background in anthropology and philosophy at the University of Tours, combined with Woolgar's doctorate in sociology from Cambridge University[36], situated them in a niche outside of mainstream sociology of science, largely tied to quantitative and functionalist theories in elite American sociology departments. The emergence of constructivism as the dominant paradigm in Science Studies also corresponded with a decline in contributions from citation analysts and information scientists (Siler, Ch. 1) Both Latour and Woolgar finished their doctorates and began publishing in the mid-1970's, leaving them at a gestated but early part of their careers and life-cycles, which tends to be associated with high ambition and productivity in scholars (Simonton, 1987; Hermanowicz, 2003).

While *Laboratory Life* introduced new theoretical and empirical innovations, they were not necessarily radical changes to the existing orthodoxy in Science Studies. Instead, these innovations were largely complementary to the preeminent constructivist paradigm, which in turn influenced the diffusion trajectory of the book. Menzel (1960) posited that when innovations do not break existing norms or social orders, they tend to be adopted first in the center of the field, then diffuse outward to the periphery. Doing (2007: 279) argues that laboratory studies extended the relativistic framework that the Edinburgh Strong Programme had established in Science Studies in the 1970's. Hargens (2004: 65) further illustrates this link, showing that

[36] Geographically and intellectually, a combination of a French and a British scholar is eclectic, if not also advantageous bridging.

progenitors of the Strong Programme (Bloor, Barnes, Collins) would later coalesce around Latour in co-citation maps. Cole (1995) lamented that mainstream sociology quickly fell out of favor in Science Studies during its formative years in the 1970's, as practitioners moved to social constructivist accounts of science (also see Siler, Ch. 1). These ideas remain foundational in Science Studies, as shown by Hilgartner's (2003: 203, italics added) definition of "[Science Studies] is an academic field concerned with the study of *knowledge* as a *social phenomenon*." In summary, *Laboratory Life* offered a complementary innovation to the existing intellectual order in Science Studies. Further, by establishing the laboratory as a potential site for empirical research, Latour and Woolgar established new intellectual and professional turf in Science Studies, as well as setting the groundwork for symbiotic or complementary relationships with practitioners of science.

Hypotheses

Author Eminence and Status

Personal, or authorial status, is an important factor influencing the preferences and strategies of a scholar, as well as the reception of their work. Professional, if not also intellectual, advantages have been shown to accompany high status positions. Leahey (2004) found that subjects viewed written work from low-status sources more critically and stringently than those from high-status authors. Merton's (1968) Matthew Effect posits that possessing status propagates future advantages, which enables the scholar to further accrue additional status and rewards, in a self-fulfilling prophecy (also see Tol, 2009). Relatedly, citation networks in academia have long been identified as possessing a power-law distribution. Such networks are skewed towards a few scholars and ideas who receive a disproportionate amount of attention in a given field (Lotka, 1927; Price, 1963; Barabási and Albert, 1999). Merton (1968) and Latour and Woolgar (1979) identify the exchange of credit and deference between scholars as the main reward structure in academia. Citation networks reveal chains of attention, visibility and credit between scholars. Applying Podolny's (2001) networks analogy to science, popularity functions as both a 'pipe' and a 'prism', where rewards flow from visibility and individual status, in addition to status also functioning as a lens through which scholars are perceived and evaluated.

Cole's (1983) research on stratification and paradigmatic cohesion in science reveals a recurrent division of labor that exists in numerous academic disciplines. Elite scientists work at the research core as gatekeepers, evaluating and filtering new ideas and work, which later diffuse through the rest of the field via lower status scholars. Fuchs (1992) argues that scientists located at major research centers are more likely to engage in path-breaking, revolutionary research, while lower status scholars tend to engage in applied work derived from those high-status innovations. Similarly, DiMaggio and Powell (1983), Stinchcombe (1994) and Rogers (2003) all offer models of social organization where high-status actors are later emulated by their more peripheral counterparts. Social positioning – often a corollary to status – is also influential, as increased network centrality and number of ties increases access to new information (Freeman, 1979) and professional advantages (Burris, 2004). Finally, this division of labor in academia extends to an institutional level as well. Abbott (2002) and Brint (2005) identify an existence of a hierarchy where elite research universities create and adopt new innovations first, which then later diffuse to non-elite institutions. In Science Studies, Fuller (1997) identifies a continuum between “High Church” (theoretical/abstract) and “Low Church” (applied/*praxis* motivated) scholars. Further, as mentioned earlier, the complementary and non-radical nature of the innovations proffered by *Laboratory Life*, should also be conducive to a diffusion pattern which originates from the elite core.

Rogers (2003: 276) suggests that early adopters tend to be more cosmopolitan and risk-taking, so it makes sense that they would not be entirely orthodox in their approach. This is somewhat of a paradox, given that elite adopters are prone to be invested in, and/or benefit from the prevailing orthodoxy. Rogers (288-289) cites early adopters as possessing higher social status, tending to be more abstract, coping better with uncertainty and risk, having higher aspirations, relative to middle and late adopters. Also, taste and agenda-setting are additional advantages that often accompany central and leadership positions. Frickel and Gross (2005) argued that Scientific/Intelletual Movements and their practitioners, are more likely to coalesce and succeed in central research networks and institutions, as opposed to more peripheral settings. Further, entrenched status grants security, and the ability to take risks (Phillips and Zuckerman, 2001: 280). In turn, this should entail a greater propensity for high-status actors to cite new books and ideas; in this case, *Laboratory Life*.

<u>Hypothesis 1a</u>: Increased eminence of an individual scholar will be positively related to their propensity to cite *Laboratory Life* in an article.

<u>Hypothesis 1b</u>: The positive effect of eminence on propensity of an author to cite *Laboratory Life* will decrease over time.

Hypothesis 2a: Elite university affiliation status will have a positive effect on the propensity to cite *Laboratory Life*.

Hypothesis 2b: The positive effect of elite university affiliation on the propensity of an author to cite *Laboratory Life* in an article will decrease over time.

Orthodoxy

Authors contribute creative content via published work, revealing personal preferences and strategies regarding existing innovations. Adoption of prior ideas is particularly important with scientific work, as scholars "stand on the shoulders of giants", and draw upon previous literatures and research to generate their own work. Lévi-Strauss (1966) dubbed this re-combination of existing entities to create a new innovation *bricolage*. Bricolage is the process by which scholars contribute to science, while also carving out professional and cultural identities out for themselves within their field(s). As per Rogers' (2003) diffusion model, which suggests that the nature of adopters varies over the life-cycle of an innovation, it follows that the quality and nature of scholarly output generated by the bricolage of these different types of adopters, will also vary across the life-cycle.

More specifically applied to academia, Hargens (2000) suggests a chasm existing between the nature of citations early and later in the life-cycle of an article. Hargens found that articles cited within five years of its initial publication tended to be referenced for their substantive research. Beyond five years, the few articles that persisted in being well-cited tended to be used as Orienting Reference Lists (ORLs), used as broad exemplars of an established innovation or paradigm. Hargens (2000: 860) argues that where and when paradigms and scientific consensus are strong, there is less need for ORLs to co-ordinate complex scholarly communication (which, in this study, would contribute to high orthodoxy scores, since they are cited so frequently). Paradoxically, this implicit consensus may allow scholars to engage the inherent uncertainty, which Cole (1983) identified at the research frontiers of numerous sciences. As works get reduced to a general exemplar of an idea, this entails 'watering-down' the complexity of the research. While fact complexity may increase solidarity, it also suppresses diffusion and adoptability (Carley, 1991; Mark 1998). Simplification of facts and symbols enables mass diffusion to less committed or zealous adopters.

Rogers (2005: 289) identifies early adopters as being more connected, cosmopolite and having more contact with change agents and opinion leaders than later adopters. Given the argument that *Laboratory Life* will exhibit a core-to-periphery diffusion pattern, it is expected that earlier citers will also use the book to write more orthodox articles than later citers. Such later citers should be less intellectually and socially connected to the scholarly core of Science Studies. In other words, orthodoxy levels of articles that cite the book will decrease over time. Further, given the central importance of *Laboratory Life* to the field of Science Studies, it is expected that orthodoxy will be positively associated with citing the book. In the context of mainstream Science Studies, citing *Laboratory Life* is an orthodox decision on its own and may serve as a signal for a conventional intellectual orientation in a publication.

Hypothesis 3a: The orthodoxy level of a given article in Science Studies will have a positive initial effect on the propensity to cite *Laboratory Life*.

Hypothesis 3b: The positive effect of orthodoxy on the propensity of an author to cite *Laboratory Life* in an article will decrease over time.

Citation Context and Abstraction

The content and application of citations should also be affected by the diffusion process. Abbott (1988) posited that professional and intellectual closure rents are derived from claiming abstract intellectual turfs. These benefits are contingent upon receiving credit, or deference from others, so it follows that status should be correlated with a penchant for abstract or theoretical reasoning. More substantively, Stinchcombe (1994) and Cole, (1983) proffer models of science where leading high-status scholars concentrate on defining and establishing problems for the paradigm, while lower-status scholars do applied work on more focused problems within those established paradigms. Assuming high-status scholars will tend to early adopters of new ideas, and introduce innovations and influence tastes and preferences throughout the discipline, it is expected that early citations will be more broad and theoretical than empirical and focused in nature. Later citations will be relatively more empirical and applied.

Hypothesis 4a: The content of earlier citations to *Laboratory Life* will be more theoretically-oriented than later references.

Further, it is expected that earlier citers of *Laboratory Life* will be more embedded within and zealously committed to the ideas proffered in the book, and in Science Studies more broadly. Thus, it is hypothesized that citations from such early authors will be more detailed. Citing a specific page is taken as a signal that the content of the book is being engaged, as opposed to only as an exemplar of a paradigm and cultural reference point. Citations which do not cite a specific page of *Laboratory Life* will be heavily associated with Orienting Reference Lists (Hargens, 2000: 86); serving as convenient exemplars of general ideas. These more superficial citations are made possible by the widespread diffusion of the book, and the establishment of intellectual meanings and signals associated with it.

Hypothesis 4b: Early references *Laboratory Life* will be more likely to engage specific details from the book vis-à-vis later articles.

Methods

Citation analysis has long been used as a means of tracking the structure of intellectual fields, by revealing the communication and social links between individual scholars (Garfield, 1963; Price, 1963; Moody, 2006). Citations serve as links between ideas (Small, 1978), which in turn create intricate networks of intellectual and social ties between scholars. Information and credit flow between individuals in these networks, which in turn underpin the reward structures of the science and profession. Citation data allow for the tracking of the diffusion of innovations through an academic community, while revealing the nature of these informational and credit flows. Citation data from 1979-2008 was downloaded from the Thompson Reuters Web of

Science, covering every published article in *Social Studies of Science* over that time period. *Social Studies of Science* was chosen as it is the first-established journal of Science Studies, and is the only such journal to be in existence when *Laboratory Life* was published. The bibliography of each article was compiled in text format, which enabled the creation of variables regarding whether an article cited *Laboratory Life*, in addition to author popularity and paper orthodoxy. Each published article also contains information on the current institutional and departmental affiliations of the first author. Using Sci^2 bibliometric software, raw text data from the Web of Science was organized into spreadsheet format, which enabled the coding and analysis of university status and institutional affiliation. To measure the scholarly experience of each scholar, the entire oeuvre of articles for every scholar who has ever published a first-author *SSS* article was downloaded from the Web of Science, allowing for the identification of their debut year.[37]

The diffusion of *Laboratory Life* is studied in the journal *Social Studies of Science*. *SSS* is the first-established and flagship journal of the field of Science and Technology Studies. By focusing on adoption in a bounded institution or community – in this case, a core scholarly journal – this allows for the comprehensive study of citers and non-citers alike. *Laboratory Life* is one of the few extensively cited works in *Social Studies of Science,* which also allows for large and varied populations of non-adopters and adopters to analyze and compare.

[37] Using the Web of Science database may be a liability in the rare case that an author's debut work is a book. However, even in such a case, it is expected that a scholar will eventually make an appearance in some scholarly journal.

TABLE 3.1 – MOST CITED WORKS IN *SOCIAL STUDIES OF SCIENCE*, 1971-2008.

	Citations in *SSS*	Total Citations (Google Scholar)
Latour, Bruno. *Science in Action: How to Follow Scientists and Engineers through Society*. Cambridge: Harvard University Press, 1987.	180	10637
Latour, Bruno and Steve Woolgar. *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills: Sage, 1979.	163	5130
Kuhn, Thomas S. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press, 1962.	123	44452
Collins, H.M. *Changing Order: Replication and Induction in Scientific Practice*. Chicago: University of Chicago Press, 1985.	120	1651
Bloor, David. *Knowledge and Social Imagery*. London: Routledge, 1976.	76	2877
Shapin, Steven. *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life*. Princeton: Princeton University Press, 1985.	76	2139

Eminence is an index of individual status, operationalized as the logarithm of the number of times an author had been previously cited *at the time of publication* in *Social Studies of Science*.[38] At the time of publication, being the first on the bandwagon of an eventually successful innovation (in this case, being the first to cite a scholarly work) is equivalent to being the first to adopt an unsuccessful innovation. Since popularity in academia tends to disproportionally accrue to relatively few articles and scholars – as is the case with the *SSS* data

[38] In cases of articles with two or more authors, the popularity and institutional status for the first author was used.

– this variable is derived from the logarithm of its raw value for the analytic models. This measure of popularity gauges the degree to which prominent scholars and opinion-leaders are citing an article, which helps propagate broader diffusion amongst non-elite actors. In the case of dual or multiple authorship of an article, the popularity and university affiliation of the first author of the article, were used as the default measures of popularity and status. Social capital and resources tied to *elite status* networks are tested via a dummy variable, defining *elite* status as being affiliated with an institution in the Top 50 of the 2010 Academic Ranking of World Universities.

O*rthodoxy* gauges the popularity of works an author cites in an individual article is.[39] The orthodoxy score of an article is calculated by the total number of citations that the works cited in a bibliography in an article had been cited in *SSS* at the time of publication. An article which cites other highly cited works will have a high *orthodoxy score*, while an article which cites works that were rarely cited in *Social Studies of Science* at the time of publication will have a relatively low orthodoxy score. The overall *orthodoxy rate* is the average of all of the orthodoxy scores in the bibliography of each focal article in *SSS* (see Siler, Ch. 2), and is calculated as follows:

$$\text{Bibliographic Orthodoxy Rate}_i =$$

$$\text{Total Orthodoxy Scores in Bibliography } i \,/\, \text{\# of References in Bibliography of } i$$

[39] To calculate orthodoxy scores, articles with fewer than six works cited in the bibliography were excluded, in order to exclude most editorial material, book reviews, and other very short articles.

To gauge changes in eminence, institutional status and orthodoxy over time, interaction variables were derived by interacting *article age* (i.e. years since 1979, the publication year of *Laboratory Life*) with the measures for popularity, institutional status and orthodoxy.

Small (1978) and McCain and Salvucci (2006) showed the importance of understanding the specific qualitative content of citations, in addition to their more quantitative and abstract properties. Thus, qualitative codes were assigned citations in each of the 157 articles that cite *Laboratory Life* in *Social Studies of Science*. As some articles cited the book multiple times, up to four different codes per article were transcribed, explaining the context in which *Laboratory Life* was invoked. Further, to gauge the degree of engagement with the book, whether the *SSS* article cited a specific page or passage from *Laboratory Life* was also coded. Inductively, six main qualitative categories of citations to *Laboratory Life* were identified. While these codes are not mutually exclusive, and may overlap to varying degrees[40], each code was assigned according to the general tenor of the citation and surrounding text in the article. Most articles that cited *Laboratory Life* only cited the book once (see Figure 3.1); even those that cited the book more than once did not necessarily invoke more than one code. The main codes identified for the various uses of *Laboratory Life* were: constructivist philosophy, inscription devices, laboratory research sites, social construction of science, strategic scientific action and the manipulation of scientific processes for persuasion. For further detail on the various sub-codes that were subsumed into the larger categories, see Appendix 4.

[40] In one sense, it could be argued that all citations to *Laboratory Life* are concentric subsets of within the broad theory that "science is socially constructed."

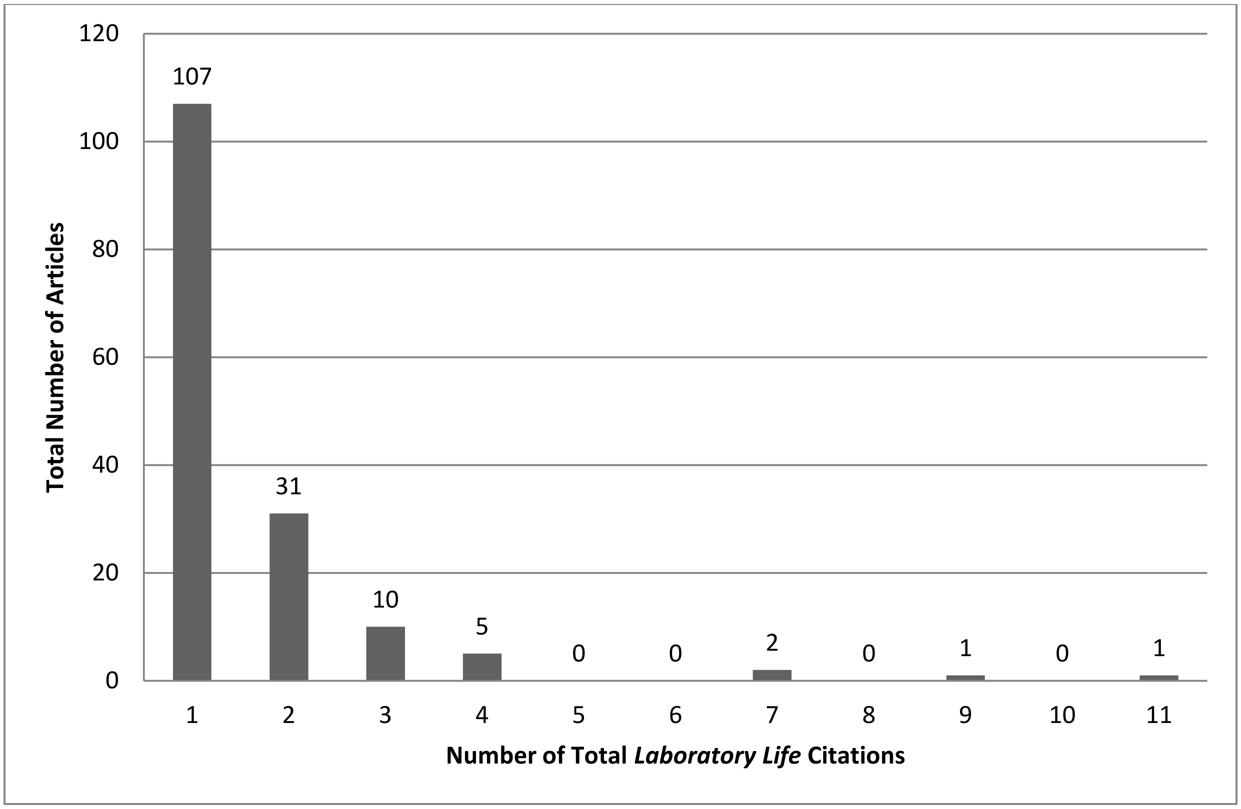

FIGURE 3.1 – DISTRIBUTION OF *LABORATORY LIFE* CITATION FREQUENCIES

RESULTS

Table 3.2 presents logistic regression models, showing effects of author eminence, institutional status and bibliographic orthodoxy on the propensity of a *SSS* article to cite *Laboratory Life*.

TABLE 3.2 - LOGISTIC REGRESSION OF EMINENCE, STATUS AND ORTHODOXY ON *LABORATORY LIFE* CITATION (N=864)

	M1	M2	M3	M4	M5
Eminence	.084	.501***			.351**
	(.052)	(.099)			(.125)
Elite University Affiliation	.064	-.399			-1.001+
	(.211)	(.470)			(.554)
Orthodoxy			.227***	.734***	.727***
			(.025)	(.072)	(.081)
Interaction: Eminence*Article Age		-.027***			-.029***
		(.006)			(.008)
Interaction:		.032			.067*
Elite University Affiliation*Article Age		(.024)			(.029)
Interaction: Orthodoxy*Article Age				-.021***	-.019***
				(.003)	(.003)
Constant	-1.641***	-1.684***	-2.687***	-3.416***	-3.495***
	(.126)	(.129)	(.168)	(.215)	(.236)
Pseudo R-Square	.003	.032	.125	.216	.243

+ p < .10; * p <.05; ** p <.01; *** p <.001 (two-tailed tests). Note: Standard Errors are in parentheses.

The results of Models 1-4 suggest that the bibliographic orthodoxy is much more influential than author eminence and status, regarding whether an article will cite *Laboratory Life*. In Model 1, Eminence and elite affiliation alone have no effect on whether *Laboratory Life* is cited. Model 2 includes a variable interacting eminence and elite affiliation with article age, yielding a significant positive result for eminence, while also yielding a negative result for the interaction of eminence and article age. Thus, the positive effects of eminence decline over time. Still, the variance explained by Model 2 is only 3.2%, suggesting that eminence and status have relatively small influences over paper citations, at least pertaining to *Laboratory Life*. Models 3 and 4 focus on orthodoxy, which has a much stronger influence on citation choices than eminence. Model 3 shows that orthodoxy has a positive effect on the propensity of an article to cite *Laboratory Life*. Model 4 adds an interaction variable between orthodoxy and time. This strengthens the orthodoxy main effect, while revealing a negative effect with the orthodoxy/time interaction variable. Similar to the eminence trend, the positive impact of orthodoxy attenuates over time. Additionally, the 21.6% variance explained by orthodoxy variables in Model 4 is much larger than eminence effects shown in in Model 2.

Model 5 is the most extensive of the analyses, combining eminence, orthodoxy and time effects. The model supports Hypothesis 1a regarding the positive effect of eminence, but contradicts Hypothesis 2a, by showing a negative main effect for elite affiliation that approaches significance. Hypothesis 1b is supported by the significantly negative coefficient for the eminence-article age interaction. Hypothesis 2b is contradicted, as the affiliation-article age interaction shows that authors citing *Laboratory Life* in later years were more likely to come from elite institutions. In support of Hypothesis 3a, orthodoxy has a positive overall association with citing *Laboratory Life*. The significantly negative value for the orthodoxy-article age interaction supports Hypothesis 3b, which predicted that orthodoxy effects would decline over time.

Table 3.3 reports the various main codes associated with citations to *Laboratory Life*, with Figure 3.2 illustrating the proportional distributions of these themes over varying time periods.

TABLE 3.3 - CODED THEMES IN *LABORATORY LIFE*-CITING ARTICLES IN *SSS*

	1980-1986	1987-1993	1994-2000	2001-2008
Epistemological/Constructivist Philosophy and Theory	14	7	4	4
Inscription via text and/or devices	6	4	8	3
Laboratory Site	12	12	21	14
Other	0	3	3	3
Science is Socially Constructed	12	14	8	4
Scientific Expertise and Involvement is Strategic	6	4	6	4
Scientists Manipulate Presentation of Laboratory Processes; Persuasion and Rhetoric	14	4	12	8
Total	64	48	62	40

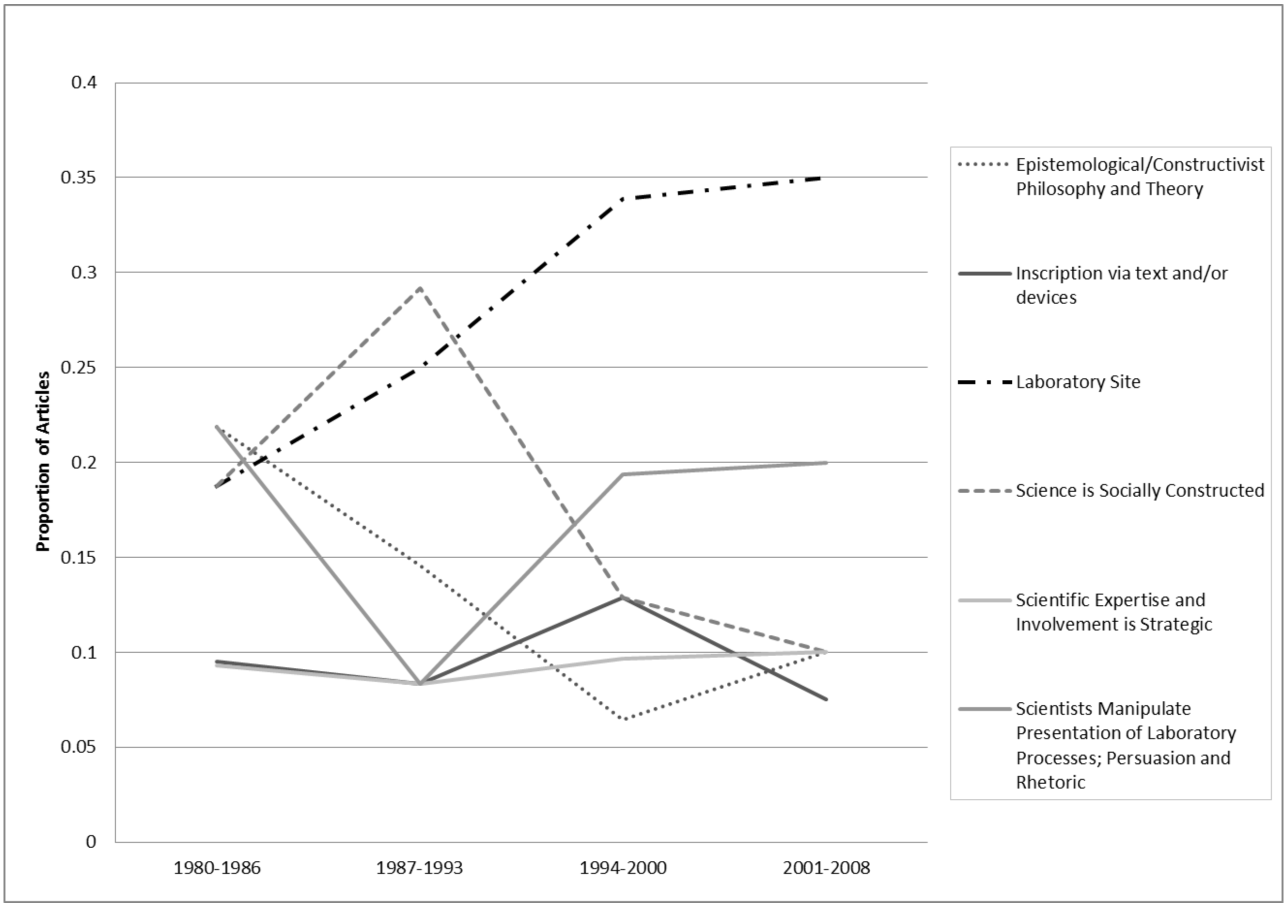

FIGURE 3.2 – CITATION CODES OF *LABORATORY LIFE*-CITING ARTICLES IN SOCIAL STUDIES OF SCIENCE.

With citation contexts, the most conspicuous trends over time are the increase of citations referring to the laboratory empirical approach in *Laboratory Life*, and the decrease in references to the general notion that "science is socially constructed" and to epistemological theory. This lends support to Hypothesis 4a, as theoretical topics were more popular amongst early citers, while later citers were more likely to cite *Laboratory Life* in an empirical context. The apparent engagement of scholars with *Laboratory Life* is also related to the specific intellectual purpose they cited the article for. Figure 3.3 shows proportional variation between different codes in the likelihood of an article to cite a specific page or passage of the book.[41]

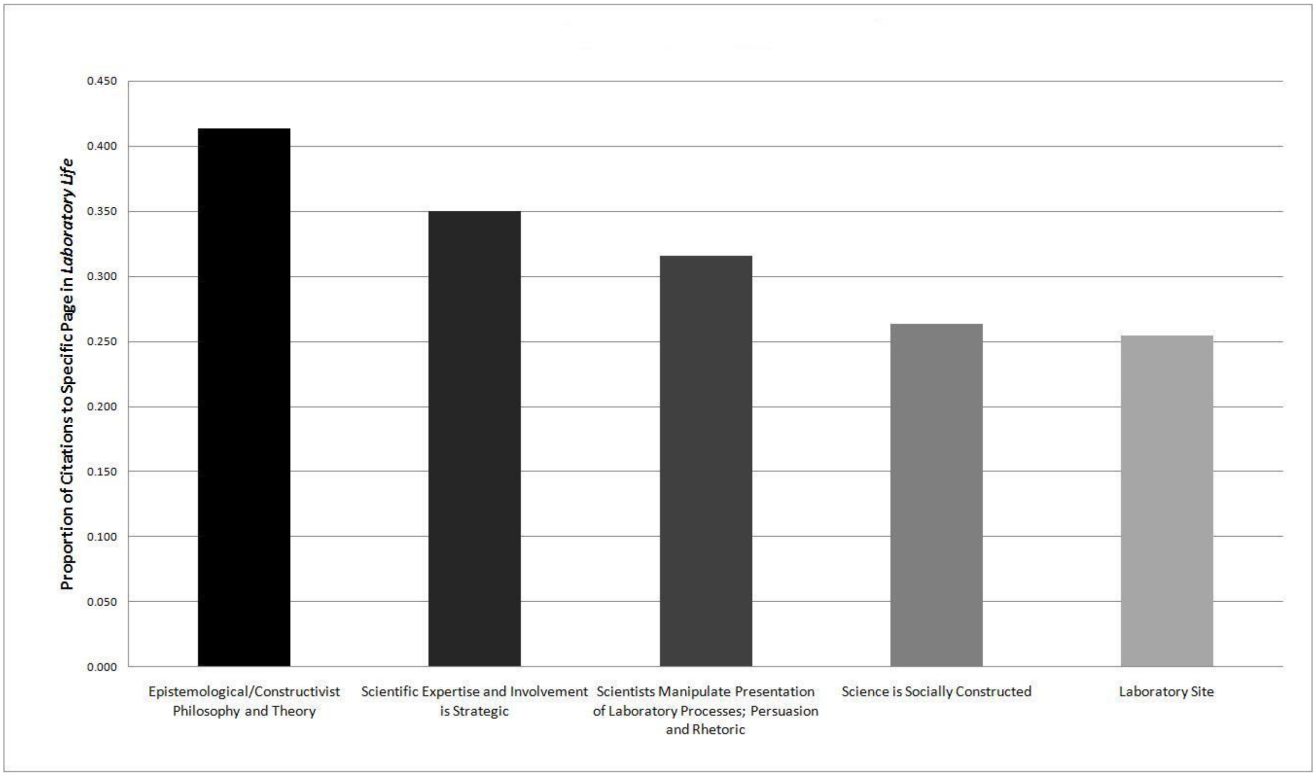

FIGURE 3.3 – CITATION CODES AND CITATION DEPTH

TABLE 3.4 - CITATION CODES AND CITATION DEPTH

	Weak Cite	Specific Page
Epistemological/Constructivist Philosophy and Theory	17	12
Inscription via text and/or devices	13	8
Laboratory Site	44	15
Other	7	2
Science is Socially Constructed	28	10
Scientific Expertise and Involvement is Strategic	13	7
Scientists Manipulate Presentation of Laboratory Processes; Persuasion and Rhetoric	26	12

[41] Discrepancies between codes are possibly slightly understated, as a code with lower odds of being in a paper which cites a specific passage of *Laboratory Life*, can exist in the same paper additional citations with coded contexts which have a higher likelihood of citing a specific page. As the majority of articles only had one citation code, this is not an issue for most articles.

The two most prominent codes, “Laboratory site” and “Science is socially constructed” were the least conducive to an author citing a specific page of the book. In contrast, the use reference to “Epistemological Theory” is most conducive to citing a specific page. While epistemology and “social construction of science” references are generally theoretical in nature, the former involves much more contention and nuance, while the latter is a central and relatively uncontested tenet in Science Studies. Thus, references to epistemological issues rendered authors more likely to need to marshal specific evidence and detail to back up their arguments.

References to inscription devices were also relatively likely to be included in a paper with a specific page reference. Latour and Woolgar (1979: 51) define inscription devices as objects which transform pieces of matter into written documents, or transform matter into a diagram or figure which is useful outside of the laboratory. Due to the specificity of the term, this often requires a reference to one of the few pages of *Laboratory Life* to explicitly mention inscription. Given that citations to inscription could often be seen as a more specific instantiation of the less-specific but related citation code “scientists manipulate presentation of laboratory results”, some authors may choose specificity over simplicity in their writings for theoretical and/or rhetorical reasons.

Table 3.5 suggests that differences in the propensity of an article to cite a specific page of *Laboratory Life* are more influenced by the citation context (as reported in Figure 3) than the life-cycle of the book.

TABLE 3.5 - CITATION DEPTH AND TIME

	Shallow Citation	Specific Page Cited	Proportion of Specific Citations
1980-1986	31	10	0.244
1987-1993	31	6	0.162
1994-2000	33	13	0.283
2001-2008	26	7	0.212

Thus, Hypothesis 4b is rejected, as there appear to be no consistent time trends regarding citation specificity in Table 3.5. However, there is additional evidence that engagement through citations with *Laboratory Life* has become less specific over time within *Social Studies of Science*, but has increased elsewhere. Table 3.6 reports citation rates in *SSS*, while Figures 3.4 and 3.5 report rates including the entire population of academic journals.

TABLE 3.6 - *LABORATORY LIFE* CITATION AND TIME PERIODS IN *SSS*

	No *Lab Life* Citation	Cites *Lab Life*	Proportion of Papers Citing
1980-1986	142	41	0.224
1987-1993	165	37	0.183
1994-2000	186	46	0.198
2001-2008	261	33	0.112
Total	754	157	0.172

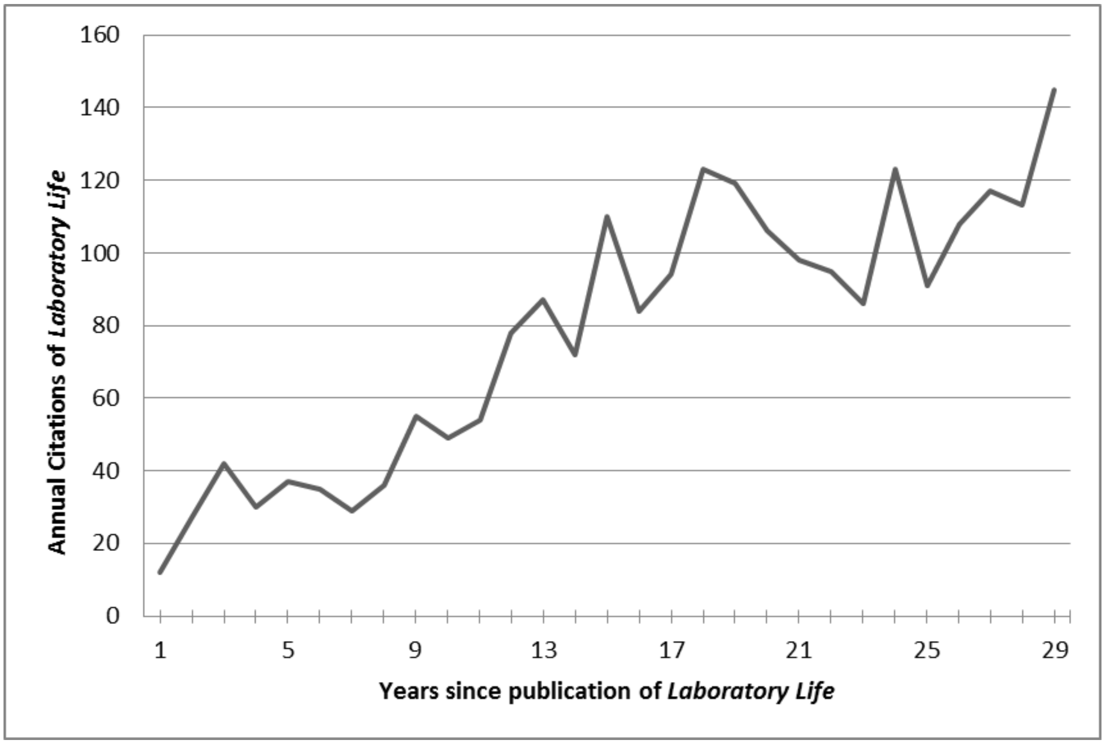

FIGURE 3.4 – ANNUAL *LABORATORY LIFE* ADOPTIONS – ALL JOURNALS, 1980-2008.

The scope and degree of *Laboratory Life* citation has continually increased outside of the disciplinary core institutionalized in *SSS*. As Table 3.7 further underscores, this increase can largely be attributed to growth outside of the core of Science Studies and core intellectual turfs in the History and Philosophy of Science.

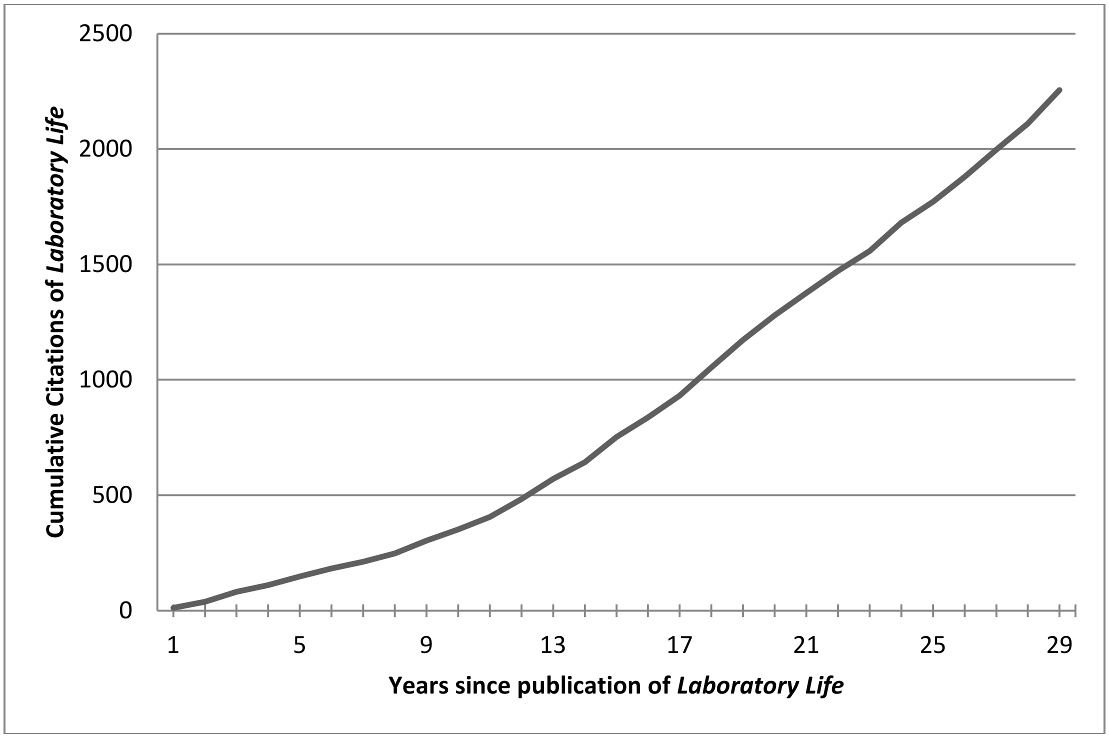

FIGURE 3.5 – CUMULATIVE *LABORATORY LIFE* ADOPTIONS – ALL JOURNALS, 1980-2008.

TABLE 3.7 - ISI JOURNAL CATEGORIES OF ARTICLES CITING *LABORATORY LIFE*

	History/Philosophy of Science	*SSS/STHV*
1980-1986 (N=212)	54 (25.5%)	48 (22.6%)
1987-1993 (N=430)	100 (23.3%)	62 (14.4%)
1994-2000 (N=734)	131 (17.8%)	63 (8.6%)
2001-2008 (N=883)	108 (12.2%)	35 (4.0%)

Over time, the prevalence of articles published in journals categorized as "History and Philosophy of Science" by Thomson Reuters has decreased. Owing partly to the expansion of journals, citations to *Laboratory Life* have continually increased in journals outside of the initial Science Studies niche the book emerged from. Declines in prominence in the main journals of Science Studies – *Social Studies of Science* and *Science, Technology and Human Values*[42] are

[42] *STHV* was not founded until 1985, which makes the concentration of citing articles in main Science Studies journals during the initial time period even more notable. Further, both *SSS* and *STHV* are included in the History and Philosophy of Science Thomson Reuters journal category.

particularly notable. Thus, diffusion dynamics moving innovations from professional and intellectual cores to peripheries appear operant, even outside of the intellectual and social boundaries of Science Studies.[43]

DISCUSSION

The citation diffusion of *Laboratory Life* suggests the book possesses properties of both conventional and unconventional innovations. Both eminence and orthodoxy variables exhibited core-periphery diffusion dynamics with *Laboratory Life*. As per Menzel's theory (1960), such a diffusion pattern is indicative of an innovation which complements existing beliefs and orders. *Laboratory Life* was complementary to the existing paradigm of Science Studies, plus it expanded new empirical turf for the field by opening up the laboratory as a site of research. Further, the "anthropological strangeness" orientation towards the laboratory that *Laboratory Life* advocated facilitates a relatively gentle learning curve for potential new adopters.[44] Low adoption thresholds are particularly important for attracting middle and later adopters. Thus, the logistic regression results point at Social/Intellectual Movement (Gross and Frickel, 2004) dynamics where more zealously committed scholars are early adopters, who gradually give way to more casual adopters later in the diffusion cycle.

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[43] Even during the final time period, when the proportional influence of the History and Philosophy of Science category and the two core Science Studies journals are lowest, they still represent the modal values for each time period. While *Laboratory Life* is being used frequently, citations are not coalescing in great concentration in any particular area or journal, suggesting a peripheral role in these new fields, the most prominent being Management, Education and Information Science.

[44] Some have argued that making arrangements to study laboratories, and the laboratory studies paradigm in general, have rendered Science Studies subservient and obsequious to the scientists and science they study (Fuller, 2000; Winner, 1998).

In contrast to a typical conventional innovation, the effects of elite status on the propensity to cite *Laboratory Life* reveal opposing dynamics to eminence and orthodoxy. Indicative of a non-conventional innovation (Menzel, 1960), early citers tended to come from non-elite institutions. Over time, the representation of citers from elite universities increased. Given that Science Studies was founded with the explicit notion that scholars should break free from disciplinary intellectual and professional fetters (Fox, 1995: ix) and was initially rooted in mid-status British technical universities (Collins, 1983), it is not surprising that in this sense, *Laboratory Life* was initially an unconventional contribution. The increased prevalence of citers with elite university status over time hints at the acceptance and diffusion of the ideas of Science Studies and *Laboratory Life* into the institutional cores of academia. The movement of prominent Science Studies scholars to elite institutions (e.g., Karin Knorr-Cetina, Chicago via Bielefield; Trevor Pinch, Cornell via York (UK)) also reflects this phenomenon.

Cole (1983) and Hargens (2000) suggest that the relatively high degrees of intellectual, social and cultural propinquity amongst core scholars is a mechanism which enables scholars to take risks, with lesser concerns about how to manage the uncertainty and dissensus associated with exploratory thinking and research. The ability to deal with these challenges in their work is both a source and privilege of their distinctive status. Further, that propinquity and investment in the existing paradigm, scientific order or status quo provides another incentive to keep orthodoxy rates high. Nevertheless, the *exploratory* (March, 1991) orientation of early adopters, who tend to focus on breaking new ground, suppresses orthodoxy rate, vis-à-vis later adopters, who focus more on the *exploitation* of existing innovations.

The lack of precipitous changes in yearly citation rates from over the entire lifecycle of the book may be explained in part by the fact that the *Social Studies of Science* citation network was still relatively small and undeveloped in 1980 (Siler, Ch. 2). Beyond a small core of zealous researchers working in *SSS*, there were relatively few peripheral outlets for the innovation to initially diffuse to. Of course, the success of *Laboratory Life* helped open new outlets, and preceded an expansion of the intellectual and social scope of *SSS* and Science Studies in general. However, as Figures 3.4 and 3.5 show, even outside *SSS*, this expansion was consistent, but never dramatic in nature. Possibly, a finite carrying capacity for *Laboratory Life*-influenced contributions existed in *SSS*, especially given the heterogeneity of the field and its culture of intellectual pluralism. However, since Science Studies simultaneously harbors links to sciences, social sciences and humanities in academia, it possesses an unusually large periphery outside of its small scholarly core.

The steady annual increase of citation rates shown in Figure 3.4, and mildly exponential cumulative increase in Figure 3.5 suggest that citations of the book have been continually expanding over time. Additionally, while general citation trends in the core journal of *Social Studies of Science* have declined over time, *Laboratory Life* continues to have a substantial presence in *SSS* even three decades after its initial release (see Table 3.6). On the whole, these trends lend evidence to the argument that the book is expanding mostly in the periphery of the field, while gradually declining in the core. However, the resilient presence of *Laboratory Life* in *SSS* over thirty years suggests that the core is not necessary entirely divesting itself of the older innovation, nor has there necessarily been a large or sudden paradigm shift in Science Studies.

Despite the fact that the shape of the cumulative adoptions curve was not a conventional S-curve, the results revealed familiar differences between actors who cited the book at various points in the diffusion process. The divergence from the normal distribution of adoptions is not surprising, particularly with idea and paradigm diffusion in science, given Mingers' (2008) research showing a variety of citation and diffusion patterns for different articles. Even if academic adoptions do not always conform to the normal distribution bell curve model of diffusion, as was the case with *Laboratory Life*, early and later citers exhibited showed disparate citation behaviors. These different roles and strategies have implications for how knowledge diffuses, and how science is organized. Kuhn's (1962) famous model of paradigm change and scientific consensus posits that science entrenches in long periods of "normal science", where most scholars work within an orthodox paradigm. Over time, anomalies and shortcomings become revealed within normal science, which in turn catalyzes dissention, and eventually, a paradigm shift to eliminate or ameliorate the exposed problems with the previous paradigm.

The differing strategies and roles played by scholars at varying points of the diffusion life-cycle are also relevant to social stratification in science, and in this particular case, the Science Studies paradigm. Stinchombe (1994) argued that a professionally healthy scholarly discipline involves peripheral actors accepting and applying theories and insights derived from elites. However, some research has suggested that innovations are often derived from peripheral (Dogan and Pahre, 1990) and "optimally marginal" (McLaughlin, 2001) actors, whose lack of resources and investment in the status quo renders them ideal candidates to innovate, despite their relative lack of status and resources. In particular, Menzel (1960) found that as long as norms were not being violated, innovations were more likely to come from a central location. In contrast, innovations that involve norm-breaking are more likely to emerge from the periphery.

In the process of protecting scholarly and paradigmatic norms, gatekeepers can often be protective and risk-averse as well, sometimes with the potential to stifle innovation, if not also disconfirming information and ideas. For example, Gans and Shepherd (1994) chronicle the rejections of work from leading economists. Many bulwark ideas – some of which would eventually be responsible for the awarding of Nobel Prizes – faced strong initial resistance, and received rejections from leading journals. Rejections may occur due to the inherent uncertainty of the research frontier, but in other cases, out of conservative fear of introducing significantly new ideas to the core. Lamont (2010: 8) argues that gatekeepers tend to be more central and senior, which contributes to a potential conservative bias in peer review; more creative projects are believed to have to clear a higher bar in order to gain acceptance. Further, if gatekeepers tend to be senior and higher status, this gives upwardly mobile scholars to conform to the prevailing status and intellectual orders defining the field. This could be another factor which creates inertia for highly influential ideas and articles in their later years, and may explain often the citation choices of middle and late-adopting citers. While rewards associated with orthodoxy declined over time, they remained positive, underscoring incentives to conform across all time periods.

Trends in citation contexts suggest a general movement from theoretical issues early in the life-cycle of *Laboratory Life*, to empirical issues later. First, broad problems and ideas in the field are defined, often contentiously. Then, based on these theories and issues, empirical applications are then worked out. Risks and rewards accompany abstract and theoretical work.

Abbott (1988: ch. 2) argues that professional rents are derived from abstractions, but only when deference from others is achieved. An additional risk that often accompanies theoretical work in the social sciences is that there are fewer outlets to publish abstract work, vis-à-vis empirical applications (King and Lepak, 2011: 207). Hence, pre-existing status that eminent scholars possess is a potential resource to temper risks associated with abstract work.

CONCLUSION

The results and analyses reveal the diffusion dynamics and characteristics of *Laboratory Life* within the core *Social Studies of Science* institution, and in the general overarching field. As the book aged and diffused in the community, different adopters cited the book with different strategies and purposes. Early citers of the book (and by extension, the paradigms represented) tended to be more eminent scholars with higher status. This suggests both informational advantages regarding the ability to quickly develop, identify and/or capitalize on cutting-edge ideas and research. Further, status security, halo effects of status, and less constrained networks may enable greater risk-taking amongst leaders in a field. The ability to take these risks with nascent innovations, and deal with some degree of uncertainty in one's thinking and research, may also be a key asset which high popularity actors derive further status, rents and advantages from. Citation context analysis suggests that the ideas derived from *Laboratory Life* tended to be more theoretical early in the book's life-cycle, then became increasingly empirically oriented in later years. The prevalence of abstraction in the early years of an innovation's existence and potential diffusion, also may underpin the characteristics and behaviors of early citers.

Over time, the eminence and orthodoxy of scholars citing *Laboratory Life* decreased, revealing a core-periphery diffusion of the book and its ideas. In contrast, the prominence of *Laboratory Life* citers associated with elite universities increased over time, suggesting that Science Studies has achieved some degree of acceptance from elite institutions in academia, despite its intellectually iconoclastic and institutionally semi-peripheral roots. While the popularity, status and experience variables provide insight on *who* cited *Laboratory Life*, the orthodoxy variable and citation context analyses gave evidence showing *how* scholars used the innovation. Over time, scholars citing *Laboratory Life* were less orthodox in their citation choices elsewhere in their articles. The steady decline of orthodoxy rates over time, coupled with the declining eminence effects over time, suggests that while citations of *Laboratory Life* are not slowing down outside of *SSS*, they are increasing prominent in the periphery of the field of science studies. The broad reach of Science Studies beyond its small core and scholarly community to sciences, humanities and social sciences alike, suggests a broad expanse for casual adopters of its ideas. This unusually expansive periphery across numerous scholarly fields may be a quirk of Science Studies, which can give a seminal book like *Laboratory Life* the potential for a long life-cycle through these vast and varied peripheries.

CONCLUSION

The three chapters of this thesis offered varying theories and cases through which to examine the question of how leading ideas in science are chosen and diffuse through knowledge fields. In STS, scholars often had to exert considerable social skill (Fligstein, 1997) in order to access resources for their new and often unconventional and legitimacy-challenged field. Further, the success and growth in STS changed the size and structure of its knowledge networks, in turn altering the incentives presented to scholars working within the field. Bibliographic choices made by authors impact the propensity of an article to receive citations. The final chapter revealed how even seminal texts can have fluid meaning, and be appropriated in different manners by various stakeholders. Characteristics of adopters of an innovation change over the course of diffusion, and in turn, so does the perception and content of that innovation. Analogously, the ideas and scholars associated with *Laboratory Life* – and often by extension, STS – varied considerably over its diffusion life-cycle.

Chapter 1: Establishing STS in the Academic Hinterland

Frickel and Gross (2004) proffered the concept of Social/Intellectual Movements (SIMs) to explain the organization of new academic entities to challenge incumbent intellectual and professional orders. STS provides a vivid example of a successful SIM that can be analyzed from its incipience in the 1970's until today. Fligstein and McAdam (2011) emphasize the importance of strategy for social movements face in competitive fields. These strategic challenges are applicable to STS. Respondents devised a diversity of strategies in order to further their work and STS more broadly from intellectual and professional standpoints.

Establishing institutions to support a fledgling academic discipline was a primary challenge mentioned by all interview subjects. As a young and often unfamiliar discipline, STS was frequently met with skepticism from administrators, and at times, derision from neighboring disciplines with entrenched interests. In turn, STS institutional entrepreneurs had to be creative, and exert social skill (Fligstein, 1997) in order to negotiate important things like office space, funding and formal recognition in their home universities. Savvy resource mobilization of like-minded allies in friendly academic areas was vital for establishing and maintaining a long-term department. At the same time, avoiding antagonism from potentially threatened interests in established disciplines was also important for survival, particularly in vulnerable nascent time periods.

In general, respondents emphasized the importance of basing institutional entrepreneurship strategies on the unique institutional context of the university, including potential private and public funding sources, allied scholars and other important stakeholders. Modifying Tarrow's (1993) political opportunity structure, identifying and capitalizing on the institutional opportunity structure was of particular importance to founding STS scholars. This dependence on local circumstances is another contributing factor to the high degree of variability in the organization and intellectual orientation of various STS departments and theories. Depending on the particular context, STS departments have been founded on intellectual and professional principles that span the entire continuum between cooperation and antagonism with neighboring disciplines.

The most obvious – and contentious – way that STS departments differ is in organization is regarding their hiring decisions and philosophies. Some departments adopt what is dubbed a partially-open labor market, where departments are willing – sometimes eager – to hire new faculty who were not trained in STS. Such hires were inevitable when STS was young, was comprised of very few scholars, and did not have well-developed doctoral programs. Over time, STS developed distinct intellectual traditions and norms, as well as its own institutions and autonomous departments. This contributes to a divergence in logics in the discipline. As STS was founded as an interdisciplinary 'escape' from the intellectual and professional constraints that many founding scholars perceived in their home disciplines. Stinchbombe's (1965) concept of *imprinting* suggests that institutions will retain vestiges of their founding principles, even after time has passed, and the organization has changed considerably since its founding. This can explain in part why some prominent STS departments continue to hire scholars from other disciplines, even when there is a growing cabal of STS doctorates being produced in core departments.

Alternatively, partially-open labor markets may also be a source of intellectual and professional vitality for STS. As mentioned repeatedly throughout this thesis, there can be considerable innovative and professional benefits associated with eclecticism, bridging and variety. Traditional academic labor markets are closed in nature. The ability to control credentialing allows professions to reproduce themselves (Bourdieu, 1988) and garner professional power (Abbott, 1988) and demarcates scientific boundaries (Gieryn, 1983). STS may provide a case study that shows an exception to this notion. In this case, professional power may be derived from professional openness, as opposed to closure. However, some STS observers (e.g., Fuller, 2003) express concern that while intellectual eclecticism and openness has helped the discipline flourish in the short-term, it is also putting its potential for widespread diffusion and long-term survival in peril, by inadequately defining and protecting professional turfs. In turn, normative debates over whether STS departments and the discipline as a whole, should resemble traditional disciplines in its intellectual and professional orientations can become quite contentious (Winner, 1996).

Despite the challenges, or liabilities of newness (Stinchcombe, 1965) associated with new ventures, respondents also emphasized numerous advantages of social and intellectual links with a new academic venture like STS. While respondents generally conceded that pursuing STS was somewhat of an intellectual and professional risk, particularly in its early days, they also felt that the risk was still a good investment. Liabilities of newness can be potentially tempered by first-mover advantages and the rewards that tend to accrue to scholars who establish priority in regards to a particular idea or research finding. Respondents often had unusual backgrounds in lieu of, or in addition to training in a more traditional discipline. In other cases, respondents were trained in a hard science, but after becoming disillusioned, or intrigued by the social implications of their work, they migrated to STS. Respondents argued that working within the confines of a traditional discipline prevented them from utilizing the full extent of their skills, and in turn, constrained the quality of their work. As per Burt (1995, 2004), an actor combining different, but uncommonly coupled skills, can be a source of innovation, as well as being advantageously positioned for professional benefits.

Ch. 2 – Intellectual Positioning and Good Ideas

Bibliographic networks provided a means of empirically mapping the "intellectual cartography" of STS. Citations between articles represent flows of credit, as well as serving as signals of the social and intellectual identities of authors. These flows of credit between authors and papers underpin the reward structure of a scientific field. The bibliographic citation network of *Social Studies of Science* grew considerably over time, as STS attracted more scholars to the field and developed a distinct intellectual corpus. Additionally, as STS grew, it developed a dense inner citation core of articles, while also retaining a number of articles that cited more peripheral and unfamiliar sources. These changes in the general network over time are related to the central question of which intellectual and social positions are most conducive to innovation, and in this case, receiving attention and credit from peers.

In early networks of *SSS*, small bibliographic networks of articles were sparsely connected, in a field which was only beginning to establish a history and corpus. As a result, average orthodoxy rates for early articles tended to be relatively low. After all, it is impossible to achieve a high orthodoxy score by citing frequently cited articles, when there has been little time for potentially important articles to accrue citations. In contrast, average closeness centrality scores for articles in these early networks were relatively high. In a small network, few nodes will require a large number of steps in order to be reached. In more recent time periods, as the

SSS network grew in size and scope, average centrality scores for articles declined precipitously, as reaching nodes in increasingly remote corners of an expanding field requires numerous steps through the network. Increased size and heterogeneity in the discipline also begets diversity and specialization, which also appears to underpin later benefits from central, bridging positions. As closeness centrality scores decreased, orthodoxy levels increased for articles, as *SSS* (and STS more broadly) developed its own unique history and intellectual corpus. In particular, reflecting the general tendency of citations in any scientific field to assume a power-law distribution, highly cited 'hubs' (or seminal works) emerged, which inflated orthodoxy scores.

In contrast to these trends in the bibliographic network characteristics of articles, regression models suggest that the reward structures of *SSS* moved in contrary directions. During these early time periods, articles with higher bibliographic orthodoxy rates were significantly more likely to receive citations from others. Meanwhile, closeness centrality initially had no measurable effects, but developed a significantly positive relationship with received citations in later time periods. During these later time periods, orthodoxy effects declined and eventually became null. In short, while articles became less central and more orthodox, articles that were more central and less orthodox received increasing rewards over time. Since reward structures for orthodoxy and closeness centrality moved in opposite directions to general trends in the bibliographic network properties of articles, this suggests that reward structures are opaque, or at least not entirely heeded by academics. Alternatively, there may be rewards associated with scarcity for articles with an unconventional composition, if they can make it past peer review, which tends to have a conservative bias.[45]

[45] A couple of interviewees charged that *Social Studies of Science* tended to be insular and self-consciously protective of status quo ideas in STS. Regardless if this is true, such complaints are hardly confined to STS.

The results in Chapter 2 also speak to the longstanding controversy in the sociology of science regarding whether articles receive credit meritocratically for the quality of their scholarly contributions, or due to personal characteristics and relationships irrelevant to science. In early time periods, there appear to be some small and limited effects of particularistic variables, such as gender and affiliations with central STS departments. However, results also show that these effects dissipated over time, and were entirely irrelevant for the last half of the history of *SSS*. STS was largely confined to a small core of European departments in the 1970's, and in turn, it is not surprising that articles written by authors in these departments were more likely to be cited. In a small field without a large critical mass of contributors, coordinating like-minded people can be a challenge. Thus, scholars who enjoyed these connections were more likely to be exposed to key ideas in the field. As STS diffused over time, widespread exposure becomes less of a problem and information asymmetries between the connected and relatively peripheral become less significant.

Chapter 3: Understanding a Scientific Success Story: The Case of Laboratory Life

Laboratory Life is a seminal work in STS and has had considerable influence in other academic fields as well. While the ideas proffered in *Laboratory Life* are often mentioned as an exemplar of the STS paradigm in general, multiple interpretations of the book were derived. Similar to Lamont's (1987) characterization of how Jacques Derrida rose to prominence in philosophy via abstract contributions that allowed for multiple interpretations, the malleability of *Laboratory Life* (whether it was intended or not) played a role in propagating it to prominence. Early scholars who cited the book tended to be central in STS, and emphasized the general theory of “social construction of science” contained in the book. As the book aged and diffused, less central STS scholars followed the lead of central scholars in using the book. Further, *Laboratory Life* diffused beyond the confines of STS. In later years, scholars from business, anthropology, library science and other interdisciplinary social sciences joined core STS scholars in citing the book. Since STS is a relatively young and small discipline in the ecology of higher education, middle and later citers from elsewhere in the social sciences represented the majority of citers of the book in later years, even though citations from the core did not decline much. In contrast to the more theoretically oriented interpretations favored by early adopters and more central STS scholars, later citers were likely to focus on potential empirical applications of *Laboratory Life*. Particularly by later citers the book is frequently invoked as a justification for and exemplar of using the laboratory as an empirical site to examine science. Further, later citers are more likely to cite the book as a general exemplar of an idea. In contrast, early citers exhibited greater degrees of engagement with the text, being much more prone to citing a specific page of the book in their own work.

The diffusion trajectory of *Laboratory Life* simultaneously exhibits characteristics of what Menzel (1960) identified as ‘legitimate’ and non-legitimate innovations. For the most part, the book exhibits a fairly typical diffusion life-cycle of a conventional innovation which does not challenge existing norms. On the whole, scholars with higher degrees of eminence (i.e. scholars who have received more citations from others throughout their careers) and exhibit more orthodox citation choices in their own bibliographies, were more likely to cite the book. Given that *Laboratory Life* is a central book in STS, it makes sense that scholars more deeply embedded in the field were more likely to cite such a contribution. Eminence and orthodoxy effects were strongest in early time periods, then gradually declined as the book aged and STS continued to grow as a field. These trends resemble a core-periphery model of diffusion indicative of a conventional innovation. However, results also show that in general, scholars affiliated with elite universities were less likely to cite *Laboratory Life*. Over time, the propensity of scholars affiliated with such institutions increased. Thus, looking at institutional status, *Laboratory Life* exhibited a diffusion trajectory which moves from the periphery to the core, indicative of a non-legitimate innovation. The iconoclastic roots of STS and initial departmental foundings at non-elite British polytechnic universities are relevant factors to explain why *Laboratory Life* (and by extension, STS) was generally not cited by scholars affiliated with elite universities until later time periods.

Conclusion

The success of scholars, academic contributions and institutions within STS, as well as the STS field as a whole has been influenced by a number of sociological factors. Chances for the diffusion and long-term success of STS have been bolstered by strategic action to entrench the discipline institutionally in universities. Individual scholars face varying incentives from a growing and changing field. In the early, nascent days of STS, articles exhibiting relatively high bibliographic orthodoxy levels received more citations. Later, orthodoxy was supplanted by closeness centrality as the main factor contributing to the propensity of an article to be cited. In addition to these general properties of highly cited articles, the specific case of *Laboratory Life* reveals a variety of social factors which underpin the unique diffusion trajectory of a seminal book. Ideas derived from the book can vary considerably based on the time of citation and the social location of the citing scholar. In sum, the personal aptitudes and biographies of scholars interact with various social contexts, to alter the content, success and interpretation of new scholarly innovations.

Appendix 1

Complete List of Institutional Affiliations of Authors in *Social Studies of Science*
(Percentages Listed)

	71-85	86-96	97-07
General Academic	20.5	21.5	24.5
Anthro	0.8	1.5	2.4
Astro	0.5	0	0.5
Bio	0.8	0.5	0.5
Business/Mgmt	1.1	1.4	1
Chem	1.6	0.3	0
Comm	0.3	1.5	1.6
Compsci	0	0.9	0.3
Crim	0	0.3	0.5
Econ	0.5	2.8	0.1
Educ	0.8	0.3	1
Engg/Applied Math	0.8	1.2	0
English	0.5	0	0
Environmental	0.7	0.3	0.5
Govt/Poli Sci	3.2	0.9	3
Public Insts	4.4	3.4	4
History - Qualified	9	9	5.2
History - Pure	4.4	4.7	3.2
Info Sci	3.2	1.4	1.3
Law	0.2	0	0.5
Linguistics	0	0.9	0
Math	0	0	0.4
Med/Health	0.6	0.3	0.8
No affiliation	2.7	2.6	2.6
NGO	0.9	0	0.5
Philosophy - Qualified	1.1	1	2.4
Philosophy - Pure	3.9	3.9	3.4
Physics	1.1	2.1	1.1
Private Industry	1.4	0.2	0.4
Psych	3.9	3.3	1.9
STS/Sci Studies	7.8	15.8	15.4
Sociology	20.9	18.1	19.5
Social Work	0.5	0	0
Urban Studies	0.3	0	0
Other	1.7	0.9	1.5
N (Articles)	**233**	**312**	**365**

Appendix 2

Complete List of Keyword Distributions in *Social Studies of Science*
(Proportions Listed)

	75-85	86-96	97-07
Agriculture	0.003	0.005	0.005
Art. Intell.	0.000	0.006	0.001
Bio/Genetics	0.010	0.013	0.026
Chem	0.007	0.001	0.001
Cite	0.020	0.012	0.004
Psych/Cognition	0.000	0.007	0.002
Computer	0.000	0.006	0.007
Econ	0.006	0.010	0.005
Engineer	0.001	0.006	0.005
Environ.	0.000	0.007	0.003
Ethics/Epistem/Philos.	0.006	0.001	0.006
Evolution	0.002	0.004	0.004
Geol	0.002	0.003	0.002
Health/Medicine	0.000	0.017	0.027
History	0.012	0.002	0.007
Inventions	0.000	0.008	0.001
Law/Legal	0.004	0.001	0.004
Mathematics	0.001	0.003	0.004
Nuclear	0.003	0.004	0.007
Natural Disasters	0.000	0.000	0.004
Physics	0.025	0.010	0.007
Policy/Politics	0.007	0.014	0.007
Profession/Expert	0.008	0.016	0.015
Technology	0.008	0.037	0.029
N (Keywords)	**909**	**1438**	**2430**

Appendix 3 – Correlation Matrix

	Received Citations Per year (log)	Average *signal*	OutDeg	Closeness	Citation Depth	Non-Elite Univ.	Outside North Amer.	Non-Core STS Univ.	Gender (M)
Received Citations Per year (log)	1.000								
Average *signal*	.062	1.000							
OutDeg	.271	-.131	1.000						
Closeness	-.068	-.146	-.029	1.000					
Citation Depth	-.070	-.126	.253	-.007	1.000				
Non-Elite Univ.	-.036	-.044	-.019	.007	-.025	1.000			
Outside North Amer.	-.069	.019	.002	.049	-.006	.489	1.000		
Non-Core STS Univ.	-.027	.032	.003	-.091	.024	.199	-.004	1.000	
Gender (M)	.065	.057	.084	-.072	-.018	-.101	-.013	.065	1.000

Appendix 4: Citation Codes

Epistemological/Constructivist Philosophy and Theory

Epistemic challenges
Exemplar of constructivism
Exemplar of reflexivity in science
Exemplar of interpretive methodology
Exemplar of non-positivist theory
Exemplar of relativistic epistemological literature
Scientific Facts only exist and entrench after successful contagion

Inscription via text and/or devices (No sub-codes)

Laboratory Site

Anthropological strangeness method
Exemplar of laboratory/ethnographic work
Knowledge is produced locally at site
Laboratory observation shows social construction of facts
Laboratory observation opens "black boxes"
Scientific hierarchy in laboratory work based on replaceability
Unique norms and idiosyncracies of individual laboratory

Science is Socially Constructed

Cognitive and social facts are not distinct
Consensus amongst scientists less than usually assumed
Exemplar of key work in science studies paradigm
Political and social ties underpin scientific credibility
Science can be understood via social/sociological factors
Science is a locally situated, embodied activity; not entirely natural
Scientific facts are developed via social negotiation
Separation between technical and social

Scientific Expertise and Involvement is Strategic

Credibility is the coin of realm in science; cycles of credibility
Demarcation of science from non-science
Division of labor in laboratory
Organization of science linked to funding institutions
Scientific expertise and involvement as strategic, social choices on the part of scientists
Scientific institutions built through social bonds

Scientists Manipulate Presentation of Laboratory Processes; Persuasion and Rhetoric

Importance of discourse/rhetoric to persuasion
Published science does not fully capture the processes by which scientific facts are created
Role of scientists in framing, communicating results
Scientists manipulate results and/or presentation to be persuasive
Texts differ from actual laboratory processes

Other

Nine articles (three in each of the last three time periods) were not categorizable

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