Cross-Fertilization of Knowledge: The Case of MIS and its Reference Disciplines

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This study examines the characteristics of cross-fertilization of knowledge of MIS and its related disciplines. The examination is conducted from the perspective of two significantly different models of scientific development. These are the internalist model and the externalist model. Citation data is used to develop a cross-fertilization network of scientific disciplines. The patterns of knowledge-sharing among the disciplines are studied. MIS and its reference disciplines are analyzed in terms of the degree to which they remain open to the ideas of other fields. Results indicate that the patterns of cross-fertilization vary greatly among these scientific fields. This suggests that no one model of scientific development serves to describe adequately MIS and its related disciplines. The status of MIS as a scientific discipline is discussed. The authors argue that the multifaceted nature of MIS should be re-conceptualized as progress from multiple directions.

Whether a discipline is viewed as a rather tightly knit "community of scientists" (Kuhnian view) [Kuhn, 1970], or as a more diffuse "intellectual community" (as enunciated by Whitley) [Whitley, 1984], what seems certain is that scientists communicate and share ideas among themselves. This communication may occur within a single discipline, between different disciplines, or both. The evolution of a scientific discipline can be studied in terms of the pattern and nature of communication, or the cross-fertilization of knowledge that occurs among scientists. The purpose of this study is to examine the characteristics of cross-fertilization of intellectual product of MIS and its related disciplines. The cross-fertilization network developed herein should provide researchers and scholars with a clear picture of the uses and sources of intellectual product in their discipline, which in turn may affect the future development of these disciplines.

Theoretical Background

Traditionally, two major models of cross-fertilization have been dominant in philosophy of science and sociology of knowledge literature. They are the so-called "internalist" model and the "externalist" model.

Kuhn [1970], Hagstrom [1965], Cole & Cole [1973], and other internalists view the scientific consensus as relatively autonomous and independent of external factors.[1] To them, the mode of change in science derives from within rather than from without a discipline.

Scientists within a discipline are likely to be

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primarily concerned with communicating among themselves to the exclusion of the exchange of ideas from outside. Knowledge generated from within a discipline is considered to provide most that is necessary to solve the problems of that discipline. Largely on its own, a discipline identifies problems and the methods for solutions. It sets priorities on different research problems relatively independent of the impact of other disciplines. Hence, a discipline is viewed as being composed of clearly defined research areas whose communication is more or less restricted to the members of that discipline.

By contrast, Merton [1970], Bernal [1971], Nagi & Corwin [1972], Whitley [1984] and other externalists maintain that many of the factors of scientific change in content and method originate from outside the discipline. For instance, they recognize the impact upon science of the governmental, economic, military, and religious institutions in society. To them, a discipline is open to the ideas from other fields. Instead of seeing a discipline as a collection of well defined research areas (the internalist view), it is seen as a diverse network of interacting researchers; its research ideas are seldom viewed as originating solely from one specific research area.

It is obvious that these two theses are based on two significantly different models of science and scientific development. The internalist view is based on the notion of science as a set of activities practiced by a cohesive group or groups of scientists who have a clear knowledge of the prevailing, rigid boundary of their field. The fact that interaction is primarily limited to scientists within the field or faction suggests that any ideas that challenge the present, prevailing consensus are unwelcome, if they are allowed to be heard at all. Therefore, implicit in this view is the notion that the scientific consensus provides a convenient force for excluding ideas that may challenge this version of the reigning concord.

In this conception, a scientific discipline allows only one consensus to reign during the period of what Kuhn called "normal science." New paradigm, according to Kuhn, implies "a new and more rigid definition of the field. Those unwilling or unable to accommodate their work to this scientific consensus must proceed in isolation or attach themselves to some other group" [Kuhn, 1970, p. 19]. This is the reason that some philosophers of science view Kuhn's model of science as being too restrictive or monistic [Banville & Landry, 1989].

Those contending the externalist view appear unconcerned about the existence or development of a paradigm, if they even accept the notion of a paradigm. They are primarily interested in examining the nature of interaction among researchers, whatever their background disciplines might be.

To externalists, it is unnecessary for scientists to agree upon one dominant consensus which guides their scientific activities. Internalists, on the other hand, demand conformity. If the internalist view of science is seen as monistic, then the externalist view can be characterized as pluralistic.

Research Questions

The above discussion gives rise to several questions concerning the nature and extent of the interaction among groups of researchers. To what extent are the efforts and energies of scientists in a discipline driven by the work of colleagues in the same field? To what extent are they influenced by activities in other (reference) disciplines? Which fields engage in cross-fertilization of knowledge, and how does this cross-fertilization form a knowledge-sharing network structure? This same line of inquiry can be raised with respect to the discipline of MIS — the focus of the present study.

This paper addresses the following research questions:

(1) What are the reference disciplines of MIS, and what, in turn, are their reference disciplines?
(2) What are the characteristics of cross-fertilization of knowledge among this set of disciplines? In other words, what is the structure of the knowledge-sharing network in which MIS exists?
(3) Which of the two models of cross-fertilization of knowledge (internalist or externalist) provides a better description of MIS and its reference disciplines?

Citation data provide a means for investigating the nature of formal communication among scientists. Consequently, citation data are utilized to shed insight into these questions.

Citation Data for Studying Formal Communication Among Scientists

Citation analysis has emerged as an important technique for studying science in the past thirty years. This bibliometric analysis became feasible with the inception of the Institute for Scientific Information in

1963, making a mass of machine-readable citation data available. Numerous studies based on citation analysis have enabled social scientists to examine scientific activities from a sociological perspective.

For example, citation data have facilitated research on identifying journal importance [Gross & Gross, 1972; Garfield, 1972; Windsor, 1973; Hafner, 1976; Virgo, 1977; Bonzi, 1982], studying the intellectual development of a discipline [Culnan, 1986; Culnan & Swanson, 1986; Culnan, 1987; Cheon et al., 1991], characterizing reward systems in science (e.g., tenure, promotion, and the process of refereeing papers for publication), tracing dissemination of a scientific innovation, and gauging the growth of scientific output [Price, 1963].

What continues to be debated, however, is the assumption upon which these bibliometric studies are based. That is, that there exists a direct relationship between "citation frequency" and the "quality" of a scientific work [Garvey, 1979]. Many researchers have found this assumption problematic. They have argued that citation counts may not reflect true usage and thus may be poor indicators of the quality of a cited item [Martyn, 1975; Subramanyan, 1975; Sclaes, 1976; Hirst & Talen, 1977; Salton & Bergmark, 1979]. One presupposition of these studies remains unchallenged, however. This is the assumption that citation data provide a valid operationalization of the formal communication among scientists.

Citation Analysis: MIS Studies

Previous research studies have used various forms of citation analysis to investigate the structure and status of MIS as a scientific discipline. Two studies conducted by Culnan [1986, 1987] examined the intellectual development of MIS through co-citation analysis. Co-citation occurs when an author cites a pair of researchers in any single work. The method is based on analyzing the work of a select few "key" authors in a discipline as opposed to the more macro view which analyzing selected journals can provide.

Culnan [1986] analyzed the co-citation of 47 authors over the period of 1972 - 1982. The purpose of the research was to identify sub-fields of MIS as represented by clusters of citations. Nine research sub-fields of MIS were identified. The interpretation of the findings was that MIS was not well grounded in organizational theory and that MIS research was not widely utilized in organizational literature.

Culnan [1987], building on the earlier study, identified sub-fields of MIS research by focusing on research published between 1980 and 1985. Utilizing the same methodology, the analysis uncovered five sub-fields of MIS research. Taking an interalist posture, Culnan concluded that MIS was maturing as an intellectual discipline since the number of sub-fields had declined.

Culnan and Swanson [1986], analyzed 271 MIS articles published during the period of 1980 - 1984. These articles were selected from six academic journals and one conference proceedings. The motivation of the study was to examine the emergence of MIS as an independent scholarly field. The authors concluded that MIS is emerging as a distinct field of study from a "foundation base" of Computer Science, Management Science, and Organizational Science. It was also noted that these disciplines had not been drawing heavily from MIS.

Cheon, et al. [1991], replicated and extended the Culnan and Swanson study to include a ten year period (1980 - 1989), and a wider number of journals (ten). The results support the conclusions of Culnan and Swanson that although MIS is less established than its reference disciplines, it is building its own research tradition. These authors also concluded that there had been a recent upward trend in the number of MIS articles cited by other disciplines.

Method

Conceptual Framework and Operationalization

In this study we are investigating the patterns of knowledge-sharing that occur among related disciplines. A primary manifestation of knowledge-sharing is the citing of the research of others. Citations can be made from within the same field of study, or from a completely different discipline. We agree with Paisley's [1984] contention that the volume of inter-disciplinary citation indicates the impact of one discipline upon another discipline.

When a scholar of one field of study employs (and thus cites) the ideas of a scholar in a different discipline, we refer to the latter field as a "reference discipline" of the former. This inter-disciplinary communication is an example of the "cross-fertilization" of knowledge of the two fields. We use the term "imports" in addressing the source and volume of intellectual product borrowed from reference disciplines.

When the cited discipline is the same as the citing discipline, sometimes called self-citation[2], the communication is described by the term "from-within." The volume of from-within communication indicates the magnitude to which a discipline draws ideas from itself. The "openness" of a discipline is the degree to which the field is impacted by work in other disciplines. The openness of a field is inversely related to the extent to which it draws from itself— its from-within volume.

In operationalizing this conceptual framework, the citation patterns of a single journal are used to represent the citation behavior of that journal's source discipline. By categorizing each citation into its source discipline, reference disciplines of the field are identified. Furthermore, disciplinary cross-fertilization is measured by comparing relative import volume from the reference disciplines. Finally, the relative openness of various disciplines are evaluated through the comparison relative from-within volume.

While the motivation and research questions are somewhat similar, the technique employed in this study differs from previous bibliometric MIS studies. Prior citation studies have focused on *selected articles* from certain journals (e.g., Culnan and Swanson, 1986; Cheon et al., 1991) or have focused on *selected authors* (e.g, Culnan, 1986; Culnan, 1987). The present study, on the other hand, considers all citations stemming from all articles within certain journals. Since this research uses a different method to study similar constructs, replication of results can provide an assessment of convergent validity of the past and present work.

An argument can be made for the use of several journals to represent a discipline. It is the opinion of these authors, however, that the use of a single, well selected, core journal is better suited for the methodology employed here. Since this method considers all citations stemming from the journal and makes comparisons across time periods, it is believed that the consistency provided by a single journal is preferable. It should be noted that the mission and editorial policy of the journal are pivotal in evaluating construct validity.

Selection of Initial Representative Journal

The discipline of MIS is the starting point of this study. Of the journals whose editorial policy is to publish exclusively MIS articles, *MIS Quarterly* is identified consistently as being important in the field of MIS. In studies which attempt to measure journal importance based on either expert opinion or citation count, *MIS Quarterly* ranks consistently high [Vogel & Wetherbe, 1984; Hamilton & Ives, 1983; Culnan, 1986; Culnan & Swanson, 1986; Culnan, 1987; Farhoomand, 1987; Ganesh et al., 1990; Cheon et al., 1991; Alavi & Carlson, 1992]. It is well recognized as the premier "core" journal in MIS. Furthermore, *MIS Quarterly* ranks tenth in impact factor of all journals classified under "Business and Management" in the "Journal Rankings" section of the 1991 *SSCI Journal Citation Reports* [Garfield, 1992]. This is the highest ranking MIS journal listed. For these reasons *MIS Quarterly* was selected as the representative journal for the field of MIS.

Data Source and Timeframe

The data for this study were collected from the "Citing Journal Listing" of the *SSCI Journal Citation Reports* and the *SCI Journal Citation Reports*, published by the Institute for Scientific Information. This annual report provides the frequency with which individual journals are cited by other journals in a given year. The data is arranged by citing journal.[3]

The 1986 through 1991 annual volumes of the *Journal Citation Reports* were used in this study. 1986 is the first volume in which *MIS Quarterly* is indexed. 1991 is the most recent volume published at the time of this writing. In summary, then, the initial data set of this study comprises all citations made by 1986, 1987, 1988, 1989, 1990, and 1991 volumes of *MIS Quarterly*.[4]

Identifying Reference Disciplines of MIS

Reference disciplines were identified through an iterative classification procedure. The authors, working independently, first sorted the cited journal titles into (speculative) source discipline categories. The independent classifications were then compared and differences were discussed and reevaluated until they converged. In the case of unfamiliar titles, the editorial policy statement of the journal, *Ulrich's International Periodicals Directory* [Salk, 1992], or a knowledgeable colleague was consulted.

Three major reference disciplines of MIS were uncovered. They are Management Studies, Computer Science, and Management Science. These findings support the contentions of previous researchers of the intellectual structure of MIS. Recall, for example, that Culnan and Swanson [1986] argue that the "foundation base" of MIS comprises Management Science, Computer Science, and Organizational Science (this last field is captured in our notion of Management Studies).

The ties to these three reference disciplines have existed for decades. The kinship with Management

Studies has been particularly close. As early as 1958, March and Simon espoused a theory of organizational behavior in which the organization is viewed as an information processing system. Simon's [1960] distinction of programmed/nonprogrammed decisions in an organizational context, and Anthony's [1965] levels of managerial activity (operational control, management control, and strategic planning) provide the foundation of Gorry and Scott Morton's [1971] well known framework for Information Systems. More recently, Silver [1990] has applied the organizational behavioral notion of change agency to the design of Decision Support Systems.

"Management Science attends to problems, models, and solvers" [Culnan & Swanson, 1986, p. 290]. Models are the means of structuring problems, while solvers are the computational technologies employed in solving them. Most contributions to MIS are in the form of models and solvers. Three of Mason and Mitroff's [1973] Information System evidence generating strategies (Liebnitzian, Kantian, and Hegelian inquiry) emphasize Management Science/Operations Research modeling. The "model base" component of the Decision Support System is an implementation of various tools and techniques of Management Science. Furthermore, many mathematical aspects of systems theory, on which MIS relies heavily, stem from the Operations Research/ Management Science field.

"Computer Science is the study of phenomena surrounding computers" [Newell & Simon, 1976, p. 113]. MIS is a "computer-based organizational information system" [Ives et al, 1980, p. 910]. The connections between the two fields are obvious. Early, classic contributions from Computer Science come to mind in such areas as database theory [Codd, 1970], software engineering [Parnas, 1972], and information modeling [Chen, 1976].

Reference Disciplines of Management Studies, Computer Science, and Management Science

The next step was to identify the reference disciplines of these three fields so that a broader view of cross-fertilization could be generated. The journals selected to represent the disciplines of Management Studies, Computer Science, and Management Science are, respectively, the *Academy of Management Journal*, *Communications of the ACM*, and *Management Science*.

Several selection criteria were used in the evaluation and choice of these representatives. First and foremost, each of these journals is well recognized, through its mission and editorial policy, as being a top, core journal in its area. Second, these journals have received consistently high impact factor scores by journal ranking packages. Impact factor is a well recognized means of evaluating relative journal importance within a scientific discipline. In addition, these same journals have been employed by other researchers to represent the same source disciplines (although the research methods and questions were different) [Hamilton & Ives, 1983; Vogel & Wetherbe, 1984; Culnan & Swanson, 1986; Culnan, 1987; Cheon et al., 1991; Alavi & Carlson, 1992]. In the words of Culnan and Swanson [1986, p. 291] "The field of computer science is centrally represented by the journal *Communications of the ACM*...Management science is centrally represented by the journal of the same name, *Management Science*."

Citation data concerning these journals was collected using the same method, source, and time period as in the previous data collection step. New cited journal titles were added to the previous collection and the entire set of titles was reclassified into source disciplines using the approach described above. The resulting final data set comprised a total of 19,294 citations and 451 journal titles.

Findings

Reference Disciplines of MIS, Management Studies, Computer Science, and Management Science

Table 1 provides the final list of nine disciplines which were identified and used in the analysis[5]. Figures 1a through 1d illustrate the relative self-citation and import quantities for MIS, Management Studies, Com-

Computer Science Economics/Political Science Engineering * Functional Business ** Management Science + Management Studies ++ Mathematics/Statistics MIS Psychology/Sociology
* Industrial Engineering not included ** Represents Accounting, Finance, and Marketing. + Includes Production & Operations Management, Operations Research, and Industrial Engineering. ++ Includes General Management, Organizational Behavior, Organizational Theory, and Business Strategy.

Table 1: Discipline Categories

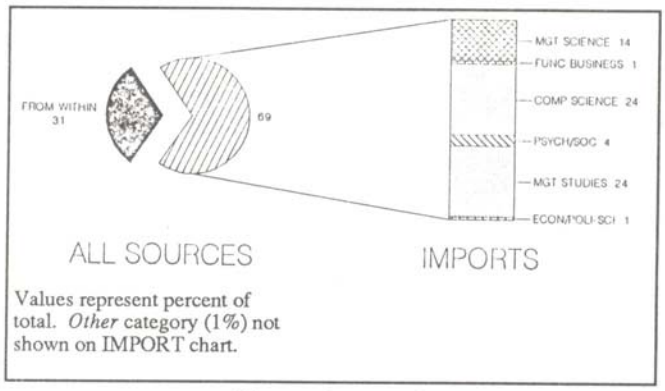

Figure 1-a: MIS

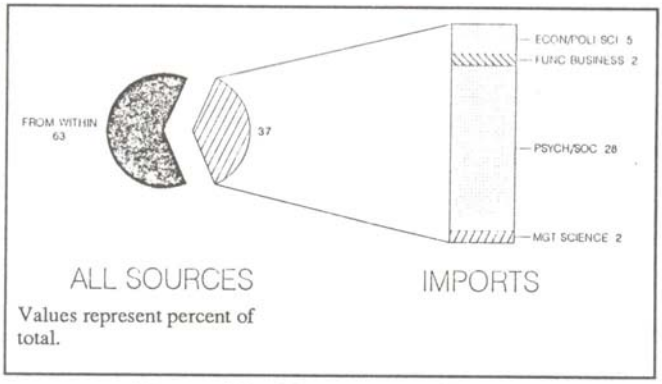

Figure 1-b: Management Studies

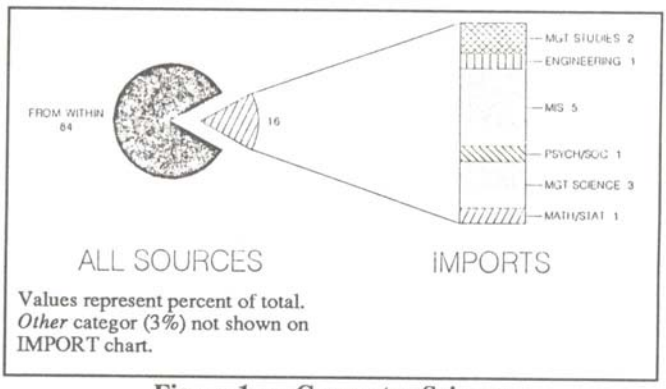

Figure 1-c: Computer Science

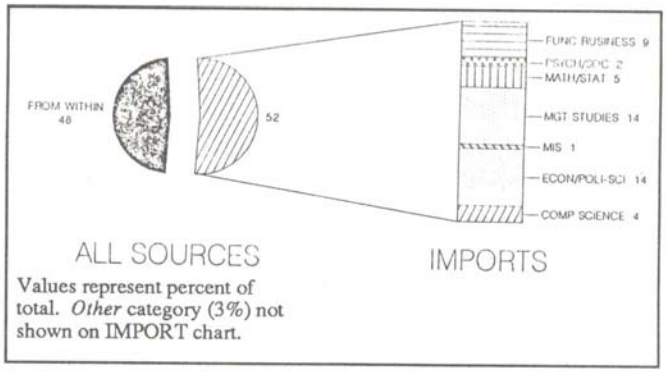

Figure 1-d: Management Science

puter Science, and Management Science. These data are collapsed across the six time periods as an initial analysis failed to reveal substantial differences across time. To simplify the discussion we apply the operational rule that a reference discipline must contribute at least five percent of the total for the field being examined.

Several conclusions can be drawn. These are outlined below. First, Management Studies and Computer Science prove to be equally valuable reference disciplines of MIS, each providing 24% of the total during the six year period. Management Science is a less significant contributor to MIS (17%). Second, the field of Management Studies draws from one major reference discipline, Psychology/Sociology, providing 28% of the total. A minimal contribution (5%) is made by Economics/Political Science. Third, the field of Computer Science does not draw significantly from a single reference discipline, though it makes minor use of MIS. Finally, Management Science employs four reference disciplines: Management Studies (14%), Economics/ Political Science (14%), Functional Business (9%), and Mathematics/Statistics (5%). The latter two appear to be of marginal importance to the field.

Openness of the Related Disciplines

In terms of openness of the fields, we see a spectrum with MIS at one extreme and Computer Science at the other. MIS relies heavily on its reference disciplines, that is, it employs greatly the intellectual contributions of other fields (69%). On the other extreme, Computer Science imports relatively little from other disciplines (16%), as it relies heavily on itself. Between these two extremes we note that intellectual imports account for 52% and 37% of the totals for Management Science and Management Studies, respectively.

Figure 2 shows that these patterns of relative openness remain consistent over the six year time period of the study. Note that MIS has been particularly stable in recent years in terms of its reliance on reference disciplines.

Cross-fertilization Network

A cross-fertilization network of disciplines can be constructed by combining the import data for the

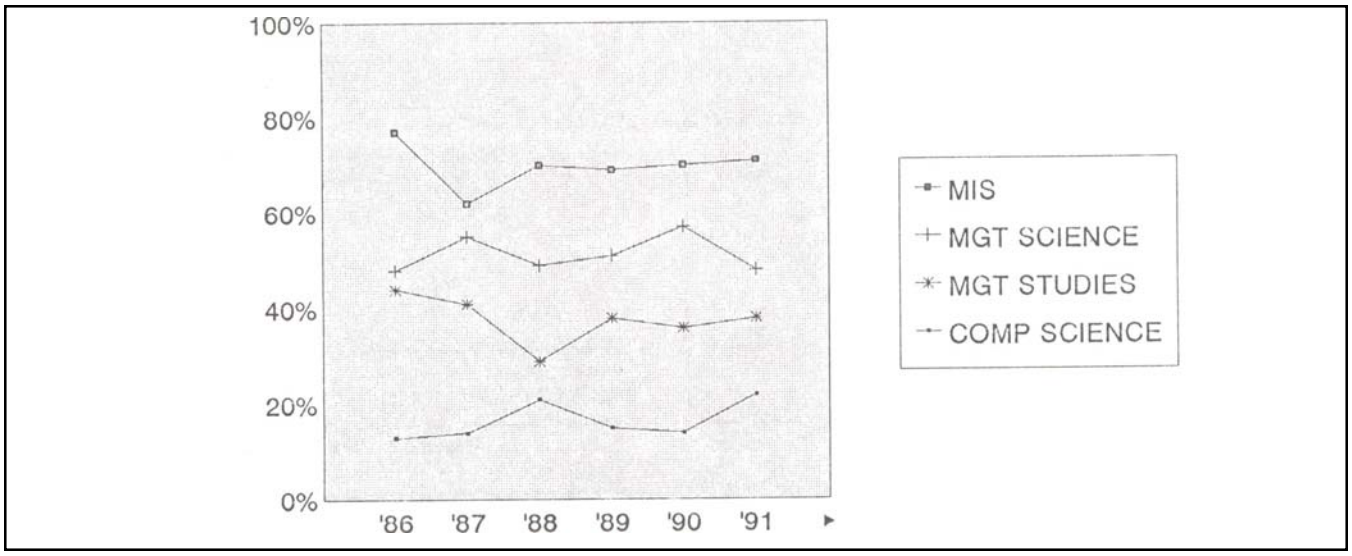

Figure 2: Openness of Disciplines, 1986-1991

various fields. The resulting network shown in Figure 3 is based on the five percent threshold rule used above. The directed arcs in this diagram represent the flow of intellectual product from one discipline to another. The numeric weights attached to the arcs can be interpreted as the importance of the contributing discipline to the consuming discipline. All weights in the diagram are comparable since they represent a common scale — percent of total used.

Figure 3 shows that the pattern of cross-fertilization among the significant reference disciplines varies greatly. One condition seems to hold for the four major disciplines considered in this study. This is the apparent lack of quid pro quo between contributing and consuming disciplines. In other words, the disciplines tend not to rely on those who borrow from them.

For example, MIS takes in heavily from all three of its reference disciplines, yet its contributions to them

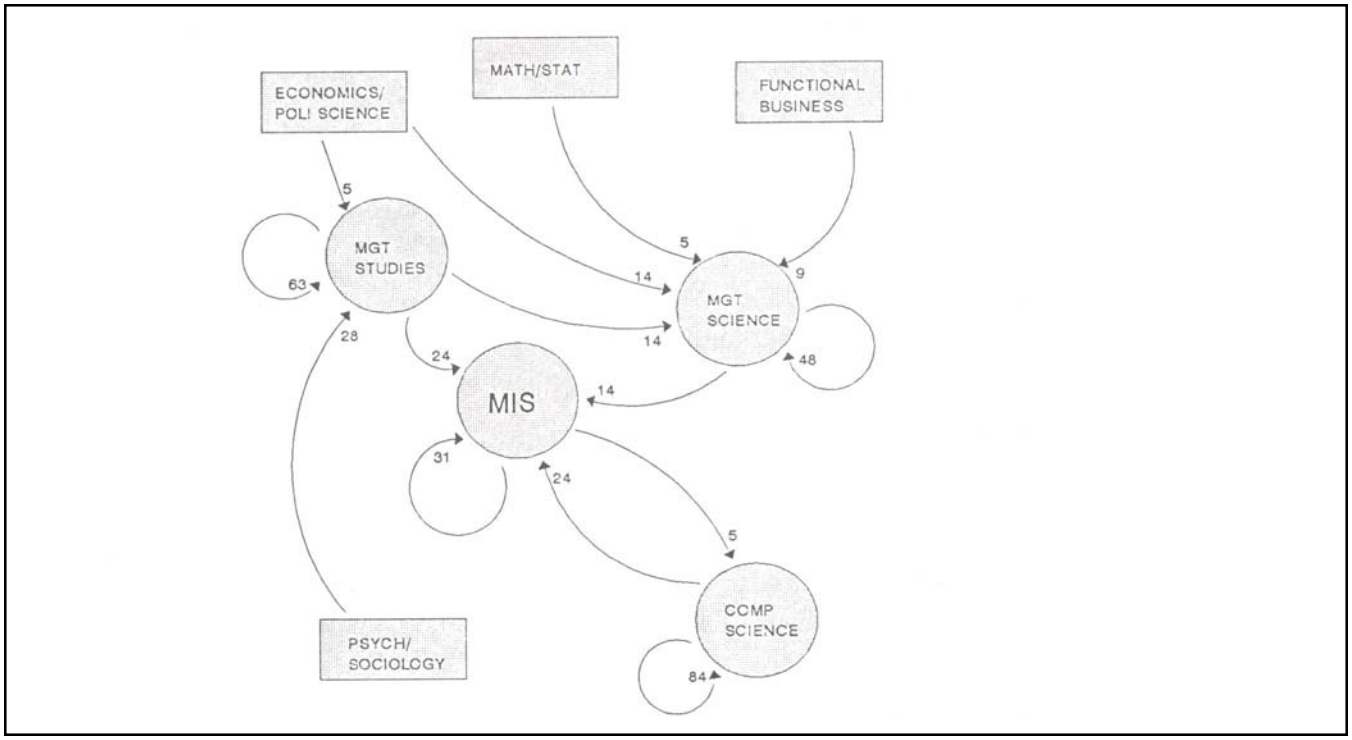

Figure 3: Cross-Fertilization Network

are almost negligible. MIS imports 24% from Management Studies while this field does not import at all from MIS. Similarly, while MIS imports 24% from Computer Science, Computer Science's imports from MIS are hardly significant (5%). MIS does not contribute to its third reference discipline, Management Science, during the period considered.

Management Science's contributions to other fields are limited except for what it provides to MIS (14%). Its pattern of use indicates that it imports from a diverse group of disciplines, however. It is the only discipline which draws from Mathematics/Statistics and Functional Business (though neither is used heavily).

While Management Studies' contributions to MIS and to Management Science are not insignificant (24%, and 14%), the field imports almost no intellectual product from either of these disciplines. Thus, the field of Management Studies, like the other disciplines considered, is not engaged in a symbiotic relationship with its reference disciplines.

A final point to note relates to the discipline of Computer Science. This field does not employ a single significant reference discipline beyond the 5% that it draws from MIS. This is not surprising since Computer Science is driven largely from within (84%).

Internalist-Externalist Spectrum

The third research question of the present study regards the suitability of the two models of cross-fertilization of knowledge (internalist or externalist) in explaining a given discipline. Considering the diverse patterns of cross-fertilization presented above, it seems apparent that no one particular model can describe effectively the full set of disciplines considered in this paper. Furthermore, it may prove risky to attempt to explain even a single discipline by employing one model to the exclusion of the other.

Perhaps it would be more appropriate to consider a continuum on which the relative position of various disciplines may be determined. These two models of cross-fertilization represent the extreme poles of such a continuum. The placement on this spectrum of any one discipline is a matter of degree. Figure 4 provides an illustration of this spectrum concept.

In comparing Computer Science with MIS, for example, we can at best say that Computer Science is more internally driven than MIS. However, to describe Computer Science solely with the internalist model would be inaccurate. Correspondingly, to describe MIS exclusively from the externalist model would be an over generalization of the research process.

Discussion and Conclusions

In reviewing the findings presented above a critical, unavoidable question arises. That is, why are the patterns of cross-fertilization of knowledge of these seemingly related disciplines so different from each other? On one hand we note that MIS and Management Science rely on several, but no single, preeminent reference discipline. On the other hand, we observe that Management Studies employs one dominant reference discipline while Computer Science is largely self-reliant. Furthermore, in considering MIS and Management Science vis-a-vis the other disciplines, we see that these fields neither rely heavily on themselves nor make heavy contributions to their related fields.

One can speculate several reasons for this phenomenon. First, the primary and traditional concerns of MIS and Management Science have been with the development, testing, and refinement of the tools and techniques of problem solving. As such, scientists in these fields may have found it difficult or have not felt compelled to specify a unifying theory by which to define their arena and focus their efforts. As relatively young disciplines (compared to Computer Science and Man-

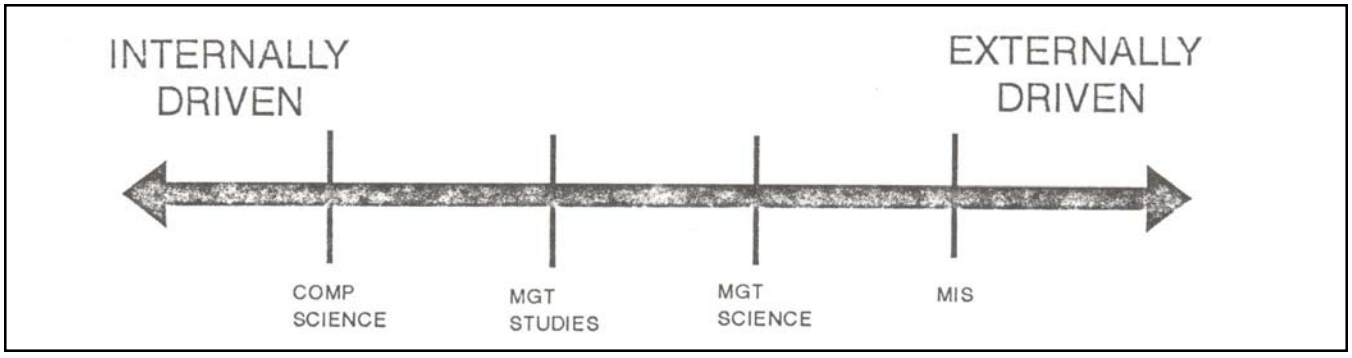

Figure 4: Disciplinary Spectrum

agement Studies) they have not, as yet, had the opportunity to establish their own research tradition.

Second, as the concerns of MIS and Management Science are closely tied with technology, and as the rate of change of technology is so rapid, the research domains of these scientific disciplines seem extremely fluid and dynamic. A possible manifestation of this situation is a deflation of the perceived value of ideas and developments in these fields. This perception could be shared by scientists in these fields as well as by scientists in related fields. This scenario explains the apparent lack of contribution of these fields to the cross-fertilization network.

To internalists the field of MIS would appear ill defined, and unstable. On the other hand, to externalists the field is merely regarded as diverse and pluralistic. In adopting a more externalist posture, MIS would not be expected to rely heavily on its own previous research, nor would MIS be expected to be considered by other disciplines as a valuable source of ideas. From this externalist perspective, MIS is not less prestigious than the other fields simply because it appears to draw from other disciplines without reciprocating.

One would expect that as MIS evolves (or as any scientific discipline evolves), its dependency on, and contribution to other disciplines would vary. Our internalist-externalist spectrum can thus be regarded as a window through which evolution of scientific disciplines can be observed. That is, a discipline should be expected to drift within this spectrum as it evolves.

The results of this study serve several distinct purposes. First, by investigating the sharing of knowledge among MIS and its related fields, the basic intellectual sources which serve as the foundations of MIS are identified. This study goes beyond earlier work by extending the investigation to the reference disciplines of the foundation fields of MIS; a broader intellectual network is uncovered. Researchers can now more clearly understand the disciplinary roots of the field and the contributions it makes to other disciplines. For example, Teng and Galletta [1990], based on a survey of MIS researchers' views, argue that Psychology is an important reference discipline of MIS. The present findings indicate that this intellectual contribution is first "filtered" through a business discipline, Management Studies (see Figure 3). Very little is taken directly from Psychology.

Second, as noted by Culnan [1987], analyzing publication and citation practices provides a basis for socializing the newest members in the field by transmitting professional norms. In addition, this study provides a means of assessing convergent validity with previous work by utilizing a different bibliometric technique.

While the results of the present study corroborate suggestions of other researchers as to the primary reference disciplines of MIS, some previous findings are not supported. Specifically, the results of our study contest earlier findings that MIS is being cited increasingly by other disciplines [Cheon, et al., 1991], and that the field is becoming more tightly knit [Culnan & Swanson, 1986]. Rather, these results are in agreement with the findings of a recent survey of MIS researchers conducted by Teng and Galletta [1990]. That is, that MIS as a research discipline remains a loosely coupled, pluralistic field. These discrepancies could be due to the fact that the present study considers all MIS articles, while earlier citation work has had a more limited focus (authors and/or articles were individually screened).

A major driving force behind previous work has been the concern with progress and maturation of the field of MIS—the assumption being that the development of a well defined, unified MIS paradigm represents progress. The present authors embrace the view of Banville & Landry [1989]; we do not agree that a monisitic conception is a necessary condition for advancement. The pluralistic perspective of MIS represents development not from one limited direction but from several directions at once. Researchers might consider reconceptualizing the idea of progress from one of linearity to one of plurality. In this light the multifaceted nature can be conceived as a blessing rather than a curse.

Perhaps the ultimate value of investigating the cross-fertilization of knowledge is best articulated by R. W. Hamming in his 1968 ACM Turing Lecture [1969, p. 4]: "Evidently the picture which people have of a subject can significantly affect its subsequent development. Therefore, although we cannot hope to settle the question definitively, we need frequently to examine and to air our views on what our subject is and should become."

Endnotes

[1] Scientific consensus implies the social agreement within a community of scientists on: (1) the way research problems are defined and prioritized; (2) the way research is to be conducted; and, (3) the way its results are interpreted and rewarded. The notion of scientific consensus as used in this paper agrees with some, but not all, aspects of the Kuhnian concept of scientific paradigm. Kuhn revised (after much controversy) his original notion of paradigm and emphasized the notion of community of scientists instead. The interested reader is referred to Kuhn [1970] with regards to this issue.

[2] Use of the term self-citation is avoided in this manuscript since its meaning is ambiguous. The term has been used in different contexts to denote citation of the author's own work, citation of an article from the same journal, and citation from within the same scientific discipline.

[3] Cited items listed in the "Citing Journal Listing" may, on rare occasions, be "non-journal" publications. While most citations of this type are represented in an ALL OTHER category, any legitimate cited item (book, dissertation, etc.) whose frequency of citation is high enough is itemized as a separate list item.

[4] Journals whose articles are cited infrequently are subsumed in an ALL OTHER category in the "Citing Journal Listing." In most instances these journals account for only one or two citations apiece. Citations captured in the ALL OTHER category were removed from the population since they cannot be classified into source disciplines. The authors have no reason to believe that the citation patterns within this aggregate category should exhibit a different behavior, however.

[5] An additional "Other" category was created from the few journals which would have resulted in one-member groups. Examples are Oil and Gas Journal, Journal of Nursing Administration, and Journal of Physical Chemistry.

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