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The Entangling of Technology and Work in Organizations

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Abstract

We begin by juxtaposing the pervasive presence of technology in organizational work with its absence from the organization studies literature. Our analysis of four leading journals in the field confirms that over 95 percent of the articles published in top management research outlets do not take into account the role of technology in organizational life. We then examine the research that has been done on technology, and categorize this literature into two research streams according to their view of technology: individuality and duality. For each stream, we discuss three reviews spanning the last 20 years of scholarship and join with them in concluding that despite a widespread perception that much is known about the consequences of technology, empirical research has produced not only mixed, but often conflicting results. Going forward, we suggest that further work is needed to theorize the entanglement of technology and work in organizations, and that additional perspectives are needed to add to the palette of conceptual lenses in use. Drawing on work in the sociology of technology, we discuss one such promising alternative — sociomateriality — which questions the assumption that technology, work, and organizations should be conceptualized separately. We illustrate this approach with a discussion of two specific examples of sociomateriality — web search and financial decision-making. We conclude by suggesting that a reconsideration of our conventional views of technology will help us more effectively study and understand the multiple, emergent, and dynamic sociomaterial configurations that constitute contemporary organizational practices.

INTRODUCTION

We begin with what we believe is a telling observation about the management literature on technology in organizations. And that is that, for the most part, technology is missing in action. Consider that from the point of view of organizational phenomena, technology seems to be everywhere in the world of practice. Annual corporate budgets for technology range in the billions of dollars for large firms, and spending on technology is for many firms their largest investment. The business press abounds with stories of huge technological opportunities (e.g., the dot com boom) and difficulties (e.g., stock market losses due to computer-based trading strategies). Technology has arguably become an integral aspect of most business operations — whether the small Internet start-up, mid-sized law firm, or large automobile manufacturer. Technology is a principal mediator of work on the production floor, in retail interactions, in front and back offices, on the road, at client sites, and in the global market place.

Yet a quick perusal of the management literature would suggest that from the point of view of organizational research, technology is largely absent from the world of organizing. We inspected the leading journals in the field of management to assess whether and how published scholarship addressed the role and influence of technology in organizations. We selected four journals — *The Academy of Management Journal* (AMJ), *The Academy of Management Review* (AMR), *Administrative Science Quarterly* (ASQ), and *Organization Science* (OS) — and examined every research article published in these journals for the past decade (from January 1997 to December 2006). For each article, we scrutinized title, keywords, abstract, and body to identify those research studies that dealt (in some way or other, and at various levels of analysis) with the issue or implications of technology. Based on the 2,027 articles we analyzed, we found that 100 (4.9%) directly addressed the role and influence of technology in organizations. Table 1 provides the detailed breakdown by journal.

Table 1: Publication of Technology Articles in Management Journals (1997-2006)

	Academy of Management Journal	Academy of Management Review	Administrative Science Quarterly	Organization Science	Total Across Journals
Number of published research articles	668	670	206	483	2027
Number of articles addressing technology	27	11	10	52	100
Percentage of articles addressing technology	4%	1.6%	4.9%	10.8%	4.9%

Thus, over the past decade of management research, over 95% of the articles published in leading management journals do not consider or take into account the role and influence of technology in organizational life. This is a surprising and paradoxical finding, particularly given the following: (i) the pervasive empirical presence of technology in mediating organizational activities within and across firms, industries, and economies; (ii) the fact that much early organizational research recognized the important role of technology in organizational affairs (e.g., Aldrich 1972; Blau et al. 1976; Blauner 1964; Hage and Aiken 1969; Harvey 1968; Hickson et al. 1969; Leavitt and Whistler 1958; Perrow 1967; Thompson and Bates 1958; Trist and Bamforth 1951; Woodward 1958); and (iii) the various calls over the years to redress the lack of attention paid to artifacts in organizational studies (e.g., Gagliardi 1990; Goodman, Sproull and Associates 1990; Huber 1990; Dewett and Jones 2001; Rafaeli and Pratt 2006; Rousseau 1979; Weick 1990).

Part of the reason for the paradox may be that the growing complexity and specialization of organizational life requires detailed investigation of multiple issues— economic, political, strategic, psychological, and sociological—alongside technological ones. Attending to all these elements within a single study or even single program of study is not feasible. So choices have to be made. An additional explanation for the paradox may point to the growing complexity, speciality, and rapid change in technological systems that make it difficult for management scholars to track and analyze in detail. And yet another piece of the paradox may be attributed to the general belief that technology is simply part of the institutional infrastructure, akin to the "utilities" of electricity, telephony or public transportation, and thus to be taken for

granted and not requiring particular attention. Whatever the reasons, it leaves us with the apparent contradiction that while technology is everywhere to be found in organizational practice, it is largely absent from the recent research discourse within the management literature.

We believe such an oversight is problematic. Not only are technologies critical in contemporary organizing, but they will arguably continue to be so, as firms attempt to grow globally, as they move onto the web, as they deploy enterprise-wide infrastructure systems, and as they invest in new communications media to allow their members to work anywhere and anytime. Such technological entailments are far from simple, straightforward, certain, replicable, or predictable. And they are associated with a range of organizational outcomes, many of which are emergent and unanticipated. What do such technological mediations imply for organizations, their norms and forms of structuring, their capabilities to act and interact, their performance of current and future strategies, their possibilities for innovation and learning? Who decides what technologies get deployed in organizations, how are these designed, who gets to use and change them, and with what consequences? Given increasing technological dependence within organizations, these questions are highly salient and their answers profoundly affect the manner, quality, and outcomes of organizational realities.

Our aim in this paper is two-fold: to provide a broad overview of the research that has been done on technology in organizations, and to offer a programmatic proposal for future research that may be done in this area. In our review, we identify and discuss two streams of research on studying technology that are evident in the organizations literature, and for each, we consider key characteristics, contributions and challenges. Space constraints preclude an exhaustive review of all published articles on technology in organizations, so we focus our attention on key articles and reviews that have been particularly influential in the field. In our proposal for future research, we consider a third research stream on technology, one that is not much evident in the management literature but which has become quite prominent in the sociology of technology. We believe that some of the premises, concepts, and approaches in this stream may be especially useful in future research on technology in organizations. We draw on this perspective to illustrate some ways that future organizational studies may engage with questions of technology and work. We conclude by arguing that developing such additional and alternative approaches is particularly important given the

emerging and interdependent nature of technologies in use today, and the dynamic and unprecedented ways in which they are shaping and will continue to shape organizational realities.

THE LITERATURE ON TECHNOLOGY IN ORGANIZATIONS

Assumptions are central to all research. As Ackoff (1979) reminds us, they make the complex phenomena tackled by social science researchable. These assumptions shape what researchers do, why they focus on which aspects of the phenomena, what they see as more or less salient, how they design their study, and what they find (Morgan 1983). This is no more evident than in the studies of technology in organizations where over the years researchers have adopted and implemented a number of diverse approaches, reflecting quite different assumptions about the nature of technology and its role in organizations, the logical structure of theoretical accounts, the key empirical mechanisms at work, and the preferred methodological orientation. To understand this diverse literature, it is helpful to have a sense of the various approaches and the implications of their different choices.

We found it useful to identify two dominant research streams within the literature on technology in organizations, each with distinctive approaches to conceptualizing and analyzing technology, leading to differences in the research results obtained, the contributions made to knowledge, and the recommendations proposed for future research. The primary characteristics of these two research streams are depicted in Table 2. Broadly speaking, the first research stream reflects an ontological commitment to a world of individual entities that have some inherent and relatively stable characteristics. This is a focus on discrete, self-standing people and things that are seen to be largely independent, but linked through uni-directional causal relationships, and having largely determinate effects on each other. The second research stream is generally committed to an ontology of duality, assuming people and things are related through a reciprocal and emergent process of interaction, leading over time to interdependent systems. We consider each of these two research streams in turn.

Table 2: Two Streams of Research on Technology and Organizations

	Research Stream I	Research Stream II
Ontological Priority	Individuality	Duality
Key Mechanisms	Impacts	Interaction
Main Concepts	Technological Imperative Technology Effects	Structurational perspectives Social Constructivism
Logical Structure	Variance	Process
View of Social and Technical Worlds	Humans/organizations and technology are assumed to be discrete, independent entities with inherent characteristics	Humans/organizations and technology are assumed to be interdependent systems that shape each other through interaction
Examples	Blau et al. (1976) Huber (1990)	Barley (1986) Prasad (1993)

Research Stream I: ***Individuality***

In this stream of work, technology is treated as a specific and relatively distinct entity that interacts with various aspects of the organization, becoming particularly salient during moments of technology design, diffusion, implementation, deployment adoption, adaptation, or breakdown. Many of the studies in this stream posit technology as an independent variable (operationalized variously as number, type, or cost of machinery, devices, techniques, etc.) having a range of effects — at different levels of analysis (individual, group, enterprise, and inter-organizational) — on multiple organizational outcomes (the dependent variables). Other studies in this stream depart from treating technology as an independent variable, viewing technology instead as a moderating variable that influences in various ways the relationship between organizational variables (e.g., structure, culture, inter-organizational relations) and certain outcomes (e.g., efficiency, innovation, learning). Whether considering technology as an independent or moderating variable, studies in this stream tend to adopt a variance approach in their research designs (Mohr 1982).

Examples of this stream of work include the following: research into the meanings or attitudes towards computing at the individual level (e.g., Davis 1989; Griffith 1997; Rafaeli 1986; Rice and Aydin 1991); studies of changes in communication and decision making at individual or group levels related to technology

use (e.g., Huber 1990; Hinds and Kiesler 1995; Trevino et al. 2000); investigations of productivity improvements at both individual and enterprise levels linked to the adoption or investment in new technologies (e.g., Brynjolfsson and Hitt 1998; Kraut et al. 1989); research into shifts in firm structure associated with technology (e.g., Blau et al. 1976; Burkhardt and Brass 1990; Fry 1982; Pfeffer and Leblebichi 1977); and examinations of transformations in market or industry conditions attributed to the widespread diffusion of new technological capacities (e.g., Malone et al. 1982; Tushman and Anderson 1986).

Given the broad scope of this literature, across multiple levels of analysis and multiple topics (from individual attitudes to market structures), it is not possible to do a comprehensive review of this work here. We decided instead to discuss three influential reviews of this literature (Attewell and Rule 1984; Huber 1990; Dewett and Jones 2001), which allow us to highlight the key rationales, problematics, views, logics, and recommendations of this stream of research. Table 3 provides a summary of these reviews of the literature.

Rationale for Studying Technology in Organizational Research

All three of the reviews motivate the need to study technology in organization studies by appealing to the rapid and widespread deployment of technology (especially, information technology) throughout organizations and society. Attewell and Rule (1984) argue that the rapid diffusion of technology raises critical issues about such social impacts as skills and quality of work, shifts in balance of power among workers and managers, and changes in employment levels. Huber (1990) in turn, contends that organizations are increasingly adopting technologies that are substantially more varied and more sophisticated than earlier technologies, and that these can be expected to have profound effects on organizational design, intelligence, and decision-making. Dewett and Jones (2001) pick up on Huber's argument and extend it by pointing to the ubiquity and range of contemporary information technology that mediates organizational affairs at multiple levels (from individual aids to inter-organizational linkages). They also highlight the extensive investment in information technology evident among firms, noting that by 1991, US companies "spent more on information technology than any other form of investment: total spending on computers, and related services doubled from approximately $80 billion in 1984 to over $160 billion in 1998" (2001, p. 313).

Table 3: Reviews of the Literature on Technology and Organizations – *Research Stream I*

	Attewell & Rule (1984)	Huber (1990)	Dewett & Jones (2001)
Rationale for Studying Technology	Widespread use of information technology (IT) in society raises critical issues about their social consequences. Need to understand both socio-economic impacts (e.g., employment, efficiency, decision making) and social experiences (e.g., how fulfilling is computer-mediated work?).	Organizations are increasingly adopting "advanced information technology (IT)," whose effects are more sophisticated and more varied than those of earlier technologies. We need to investigate the impacts of such new technologies on the nature of organizational design, intelligence, and decision-making.	Information technology (IT) is ubiquitous and multiple (ranging from enterprise-wide systems and global databases, to personal digital assistants and the fax machine). Spending on technology amounts to the largest investment made by firms (in billions of dollars) and this is growing. We need to understand what impacts these technologies have on "strategic outcomes."
Problems with Existing Literature	Need to challenge the widespread view that IT impacts are "foregone conclusions" (e.g., deskilling or upgrading). Need to develop theories that account for the fragmentary, disparate, and seemingly conflicting results associated with computing.	The use of "advanced IT" in organizations is associated with multiple empirical findings that cannot be explained by existing organization theory that was developed in an earlier time, when technological capabilities were simpler and constant. Need a theory of the effects of IT on organizations, which synthesizes, integrates, and explicates the multiple empirical results.	The implications of IT for organizational outcomes are significant and evolving, and many of the basic building blocks of organization studies will need to be reexamined and rewritten. Need to enhance Huber's (1990) model to develop an updated and "theoretically plausible" account of IT's role in strategic organizational outcomes.
View of Technology	Focus on IT (also referred to as "computing"), which is seen as an impetus to organizational and societal innovation, enhancing efficiency and cost-effectiveness.	Focus on "advanced IT," which are devices that include (i) transmit, manipulate, analyze, or exploit information, (ii) in which a digital computer processes information integral to the user's communication or decision task, and (iii) that have made their appearance since 1970. In order to survive in competitive environments, organizations must adopt and properly use such rationality-enhancing IT.	Focus on IT which is seen to have certain "useful properties," specifically: (i) *information efficiencies* (i.e., the cost and time savings that result when IT enables increased task performance and expansion of roles), and (ii) *information synergies* (i.e., the performance gains that result when IT enables individuals or units to pool resources and collaborate across roles or unit boundaries).
Logic of Argument	View IT as an independent variable affecting: (i) number and quality of jobs (i.e., job satisfaction, changes in skills over time, alienation, unemployment, worker productivity); (ii) management decision-making (i.e., extent of centralization of information and power), and (iii) organizational interactions with their environments (i.e., how technology mediates dealings with the public, clients, and customers).	Develop propositions that posit the use of computer-assisted communication and the use of computer-assisted decision-aiding technologies as independent variables, and posit the following as dependent variables: (i) characteristics of organization intelligence and decision-making (e.g., more rapid and accurate identification of problems and opportunities), and (ii) aspects of organization design (e.g., size and heterogeneity of decision units, number of levels).	Build on Huber's (1990) account of IT as an independent variable that enhances organization intelligence and decision-making, thus firm performance. But propose IT as a moderating variable that links employees, codifies the knowledge base, increases boundary spanning, improves information processing, and enhances coordination. In doing so, IT moderates the relationship between organization characteristics (e.g., structure, size, culture, inter-organizational relations) and strategic outcomes (i.e., efficiency and innovation).
Research Agenda	No simple set of theoretical relationships can account for all the data revealed through empirical inquiry. While the social impacts of computing are infinitely variable, the sources of these variations are accessible to study. Thus need large samples and extensive replication so as to characterize the effects of computing in their full variety at multiple levels of analysis: skills, jobs, workers, organizations, unemployment, etc. Recommend a two-pronged focus for future research: (i) determine what particular cause-effect relations prevail in specific contexts, and (ii) locate such cases within the larger ranges of cases in which similar cause-effect relations can be expected to prevail.	Organization theory has always been concerned with processes of communication, coordination, and control, and the nature and effectiveness of these processes are changing with advanced IT. Organization scholars should thus accept that IT fits within the domain of organization theory, and that it will have a significant effect on organization design, intelligence, and decision-making. Recommend researchers study advanced IT as: (i) an intervention or jolt in the life of an organization that may have unanticipated consequences; (ii) a variable that enhances the quality and timeliness of organizational intelligence and decision-making; and (iii) a variable that enables organizations to be designed differently than was possible before.	The full implications of IT for organizational characteristics are still evolving and will continue to do so. Need to recognize that there are feedback loops as people learn how to "optimally apply" the IT to its context over time. Recommend researchers focus on several issues going forward: (i) how does IT moderate the way strategy affects performance and how does IT facilitate competitive advantage; (ii) what is the relationship between IT and firm performance (may need to develop a contingency framework to sort out the mixed and ambiguous results); (iii) what is the role of time in applying IT (how to deal with learning and change over time); and (iv) what are the different types of IT employed at different levels of the organization, and what different roles does IT fulfill at different levels.

Problems with Existing Literature

Interestingly, the three reviews—spanning almost 20 years of scholarship—identify similar difficulties with the existing management literature in making their case for increased attention to technology in organization studies. All three point to the disparate, fragmentary, and apparently conflicting results reported by empirical research on the effects of technology. Attewell and Rule (1984) criticize what they see as a widespread perception that much is known about the consequences of computing and that these effects are "foregone conclusions" (1984, p. 1184). They argue that such *a priori* assessments are inappropriate given the mixed empirical record, and the range and variety of variables that are relevant. Huber (1990) also points to the mixed empirical results to argue that existing organization theory cannot account for these findings because it was developed in an earlier time when technologies were simpler and much less varied. Dewett and Jones (2001) likewise suggest that new organization theories are needed to more fully explain the implications of information technology (IT) for organizations. They write "We believe that the pace of IT change that has swept through the economy has left the academic community behind and that the definition, meaning, and current significance of many of the basic building blocks and theories of organizational studies need to be reexamined" (2001, p. 335). They call for the development of a more "theoretically plausible" account of IT and its role in a wide array of strategic organizational issues (p. 315).

View of Technology

The views of technology advocated by the three reviews are related in that they all assume technology is a distinct entity, but they also differ somewhat, reflecting perhaps the changing contours of and knowledge about technological artifacts over the years. In 1984, Attewell and Rule concentrate their attention on information technology, which they generically refer to as "computing" without indicating the particular features, dimensions, or properties designated by their term. Six years on, Huber (1990) emphasizes "advanced information technology," which he defines as devices having both "basic characteristics" (e.g., data storage capacity, transmission capacity, and processing capacity), and "advanced properties" (e.g., features that facilitate easier, less expensive, more precise, and more controlled communication and information access and retrieval). He argues that these latter properties are particularly typical of devices that entail the

following features: (i) they transmit, manipulate, analyze or exploit information; (ii) they include a digital computer which processes information integral to users' communication and decision-making tasks; and (iii) they were developed after 1970.

Eleven years later, Dewett and Jones (2001) focus on what they label "information systems and information technologies" (which they proceed to refer to as "IT"). With this term they encompass a wide variety of software and hardware platforms, from enterprise-wide accounting applications and inter-organizational distribution systems to communication media such as intranets, voice mail, fax, email, and videoconferencing, as well as personal digital assistants and mobile phones. They follow Huber in claiming that these technologies have some important properties that are particularly useful in organizational affairs. They single out two such properties: (i) information efficiencies, which represent the cost and time savings that result when IT facilitates task performance and allows role expansion; and (ii) information synergies, which represent the gains in performance that follow from the pooling of resources and collaboration across roles or boundaries enabled by IT.

Logic of Argument

All three of the reviews privilege a variance approach in understanding the existing literature and in their characterization of the relationship between technology and organizations. Where they differ is in whether they posit technology as an independent or moderating variable. Thus, Attewell and Rule (1984) assume IT is an independent variable, which affects a number of outcomes at multiple levels of analysis, for example, the quality of work (assessed through studying changes in job satisfaction, alienation, and skills), the level of unemployment (measured as declines in jobs available across sectors) worker productivity), management decision-making (as observed in the extent of centralization/decentralization of information and power), and organizational interactions with their environments (examined in terms of how technology affects an organization's dealings with its publics and customers). Huber (1990) similarly posits IT as an independent variable that enhances organization intelligence and decision-making, thus firm performance. Distinguishing between the use of "computer-assisted communication technologies" and "computer-assisted decision-aiding technologies," he develops fourteen propositions concerning these independent variables and

a range of dependent variables related to the following: (i) characteristics of organization intelligence and decision-making (e.g., the speed and accuracy of problem identification, the quality of decisions made), and (ii) aspects of organization design (e.g., the size and heterogeneity of decision units, the number of organizational levels, the extent of centralization/decentralization, etc.).

While building on Huber's (1990) model, Dewett and Jones (2001) depart from it by positing IT as a moderating variable. In particular, they contend that IT offers five important benefits — linking and enabling employees, codifying the knowledge base, increasing boundary spanning, improving information processing, and enhancing collaboration and coordination — which moderates the relationship between organization characteristics (specifically, structure, size, culture, learning, and inter-organizational relations) and the strategic organizational outcomes of efficiency and innovation.

Research Agenda

In making recommendations for future research, each of the three reviews offers specific suggestions concerning what should be studied and how. Attewell and Rule (1984) note that while the social impacts of computing are infinitely variable, the sources of these variations are accessible to study. They thus advise the use of large samples and extensive replication so as to characterize the effects of computing in their full variety at multiple levels of analysis (i.e., skills, jobs, workers, organizations, and employment levels). They recommend that future research should proceed along two tracks, the first to determine what particular cause-effect relations prevail in specific contexts, and the second to locate such specific findings within the larger array of cases in which similar cause-effect relations might be expected. Huber's (1990) recommendations are aimed at the management literature more generally, urging organization scholars to pay more attention to IT. He argues that organization theory has always been concerned with processes of communication, coordination, and control, and that these are changing dramatically with the advent of advanced IT. He urges organization scholars to incorporate IT more centrally within the domain of organization theory as it is having and will continue to have significant effects on organization design, intelligence, and decision-making. He recommends researchers study advanced IT as: (i) an intervention or jolt in the life of an organization that may have unanticipated consequences; (ii) a variable that enhances the quality and timeliness of organizational intelligence

and decision-making; and (iii) a variable that enables organizations to be designed differently than was possible before the advent of advanced IT.

Dewett and Jones (2001) note that the full implications of IT for organizations are still evolving and will continue to do so. Researchers need to keep this in mind, while also recognizing the feedback loops that arise as people learn how to "optimally apply" the IT to its context over time. For future research, they recommend that researchers focus on the following sets of issues: (i) how does IT moderate the way strategy affects performance and how does IT facilitate competitive advantage (e.g., through reducing transaction costs, increasing quality or innovation, differentiation, leveraging knowledge, etc.)? (ii) what is the relationship between IT and organizational performance (for which they suggest that more fine-grained analyses and a contingency framework may be needed to sort out the range of mixed and ambiguous results)? (iii) what is the role of time in applying IT in organizations (as this will help address how to deal with learning and change over time)? and (iv) what are the different types of IT employed at different levels of the organization, how do these effects play out, and what different roles does IT fulfill at these different levels?

Research Stream II: *Duality*

In this second stream of literature, technology is understood as part of the complex process through which organizational activities are accomplished. Departing from the individualist ontology of the first research stream, the focus here is on the dynamic interactions between people (or organizations) and technology over time. These interconnections are understood to be embedded and emergent, and thus as not fully determinate. Studies in this stream of work do not posit either independent or dependent variables, but rather adopt a processual logic where interactions and outcomes are seen to co-evolve over time.

Examples of studies here include research regarding the interplay between aspects of technology and various elements of organizational life, such as what meanings emerge to make sense of a new information system (e.g., Prasad 1993), how do technological implementations entail the mutual adaptation of technology and organization (Leonard-Barton 1988), how does the use of electronic media get shaped by existing cultural norms and practices (e.g., Markus 1984; Yates et al. 1999), how do technologies serve as boundary objects to afford knowledge sharing across disparate communities (e.g., Bechky 2003; Carlile 2002), how does the design

and use of technology shift the nature of work (e.g., Boudreau and Robey 2005; Orlikowski 2000; Zuboff, 1988), how does the use of technology restructure organizational relations (e.g., Barley 1986, 1990; DeSanctis and Poole 1984), how do existing power positions shape the design of technologies over time (e.g., Thomas 1994), when and how does the design, implementation, and adoption of a new industry-wide information system shift relations among multiple players in a financial market (e.g., Barrett and Walsham 1999).

As with the first research stream, the wide range of issues and phenomena covered by this stream precludes an exhaustive review of the literature. We thus discuss three detailed reviews of this literature (Barley 1988; Orlikowski 1992; Roberts and Grabowski 1996), which allow us to highlight the key rationales, problematics, views, logics, and recommendations of work in this area. Table 4 provides a summary of these reviews of the literature.

Rationale for Studying Technology in Organizational Research

The rationale for why organizational scholars should study technology echoes many of the issues raised by the first research stream: an articulation of the widespread advance and use of complex technologies is following by a discussion of the lack of solid organizational knowledge to explain the empirical patterns. Barley (1988) suggests that given the many advances in technology (e.g., robotics, microelectronics, artificial intelligence, and genetic engineering), Western society is on the verge of a transformation on a similar scale to the industrial revolution. However, there is little or no consensus on the character and direction of these transformations. More focused research in organizational studies is needed if scholars are to tackle this important phenomenon. Orlikowski (1992) similarly notes that while technology has been a central variable in organizational theory since the late fifties, there is little agreement about the nature and definition of technology, and no compelling evidence of its distinctive role in and implications for organizational affairs. As a result, she suggests that the field needs to fundamentally re-examine current conceptualizations of technology so as to develop alternative constructions of its nature and role in organizations. Roberts and Grabowski (1996) also point to the rapid advances of technology in organizations, and the inability of management research to keep pace. They highlight a number of problems associated with existing views of technology in organizations, particularly with measurement and assessment, and argue for rethinking the utility of the technology construct within organization research.

Table 4: Reviews of the Literature on Technology and Organizations – *Research Stream II*

	Barley (1988)	Orlikowski (1992)	Roberts & Grabowski (1996)
Rationale for Studying Technology	Given advances in technology (robotics, microelectronics, genetic engineering), Western society is on the verge of a transformation akin to the industrial revolution. But there is no consensus in the direction of these changes. Need an alternative approach to studying changes in this area.	Technology is a central variable in organizational theory, but despite years of research there is little agreement on the definition of technology, and no compelling evidence of its role in organizational affairs. Need to fundamentally re-examine the current conceptualization of technology and develop an alternative construction of its nature and role in organizations.	Technology advances rapidly, yet there are multiple problems with existing views of technology in organizations, particularly with its measurement and assessment in a changing world. Need to rethink the utility of the technology construct in organization research, and develop frameworks that afford considering technology as both a process and a product.
Problems with Existing Literature	Scholars have been misled by the dual status of technology as both physical and social object. A focus on the former leads to *technological determinism,* while a focus on the latter results in *social determinism*. The desire to explain all events with a single logic has discounted social complexity, distorted the nature of technology, and led to inappropriate claims that technology's effects are foregone conclusions. Consequently, current theories of technology and work are too brutish or too brittle to capture the multiple ramifications of technical change.	The organization literature is characterized by three prevailing perspectives on relations between technology and organizations: (i) *technological imperative* (where technology is seen to have direct impacts on organizations); (ii) *strategic choice* (where technology is seen to be shaped by human choices, meanings, and actions); and (iii) *trigger of change* (where technology is seen to intervene in relations between people and structure). None of these perspectives, however, can adequately account for the ongoing and mutual interaction of human agents and technology in organizations.	Organizations and technology are undergoing profound changes, resulting in the growing inadequacy of existing conceptions of technology. The literature includes two separate views of technology: (i) a *descriptive* view (focusing on definitions and role of technology in organizations), and (ii) a *relational* view (focusing on relations between technology and structure). These views need to be integrated to account for both what technology is and how it develops, and how its relations with organizations are changing in the post-industrial age.
View of Technology	Restrict the term technology to objects and actions that "admit the possibility of ostensive definition."	Focus on information technology, and restrict the scope to material artifacts (i.e., configurations of hardware and software).	See technology as comprising the set of mechanical (i.e., hardware), human (i.e., skills and human energy), and knowledge (i.e., meanings and concepts) systems.
Logic of Argument	Technology has a dual nature – as a physical and social object. Propose an *interpretive materialism* that views technology as a social object. This perspective recognizes that technologies are construed and reconstrued as they are designed, built, sold, and used, but also acknowledges that this process of social construction is limited by technology's physical properties and by the larger socio-economic context.	Technology is a duality – it is both the medium and outcome of recurrent human action. Propose a *structurational model of technology* that includes four key relations: (i) technology is constituted by human action (interpreted, designed, and used); (ii) technology constitutes human action; (iii) institutional conditions shape people's interactions with technology; (iv) institutional consequences arise from people's ongoing interactions with technology.	Technology has a dual nature – as a product and a process. Propose adoption of both positional and relational views of technology drawing on structuration theory. A *positional* view, focusing on technological and structural constructs (e.g., complexity, task definition, workflow integration, etc.), should be followed by a *relational* view that examines the relations between technology and structure in organizations (understood to be continuous, changing, and interactive).
Research Agenda	Unidirectional patterns of change are inappropriate when one examines a technology's ramifications across a range of occupations or organizations (e.g., the same technology's capacity can occasion contrasting social orders in different contexts). Need to entertain complex and equivocal trends in the relations between technology and organizations. To understand how technology restructures work, researchers need to focus on actions and interpretations, as well as relevant technical attributes, characteristics of occupations and organizations, and parameters of the larger socio-economic environment.	Future analyses should focus on the relationship between different organizational forms and the interaction of technology and human agency. Focus analytically on how human action in different organization contexts may produce certain kinds of technologies, and how use of these technologies in turn may reinforce or transform existing structural and work configurations over time. Need more empirical research to examine the conception, development, and use of technologies with different degrees of interpretive flexibility, to assess their interaction with social practices in organizations, and examine the resulting consequences, intended and unanticipated.	Uniform or generalized descriptions of technology and organizational adaptability or utility are no longer appropriate. Instead, need a contingency framework, and more refined typologies of technology. Also need more studies of decision settings that are characterized by increasing knowledge, complexity and turbulence. Need temporal and longitudinal studies of organizations and technology, in particular to account for the dual nature of technology as process and product, and the changing relations between technology and organizations in a fluid and changing world.

Problems with Existing Literature

The three reviews highlight somewhat different concerns with the existing literature, concerns they suggest lead to the literature's difficulties in explaining existing technological phenomena. Barley (1988) for example, argues that scholars have been misled by assuming that technology is either a physical object or a social product. He observes that a focus on the physical aspects of technology has led researchers to an inappropriate materialism that often results in *technological determinism,* the view that technology's effects on social life are determining and inevitable. A focus on technology as a social production has led to an overreliance on culture as a primary driver, leading sometimes to a *social determinism.* Barley further criticizes the existing literature for seeking "to subsume all events under a single ethos," which has led to "visions that shortchange social complexity, distort the nature of technology, and lead ultimately to a claim that a technology's effects are foregone conclusions" (1988, p.34). As result, he contends, current theories of technology and work are too brutish or too brittle to capture the multiple and subtle ramifications of technical change.

Orlikowski (1992), in turn, suggests that the organization literature on technology can be characterized in terms of three prominent perspectives on relations between technology and organizations: (i) *technological imperative* (where technology is seen to have direct impacts on organizations); (ii) *strategic choice* (where technology is seen to be shaped by human choices, meanings, and actions); and (iii) *trigger of change* (where technology is seen to intervene in relations between people and structure). She argues, however, that none of these perspectives can adequately account for the ongoing and mutual interaction of human agents and technology in organizations. Roberts and Grabowski (1996) note that both organizations and technology are undergoing profound changes and that these changes are leading to the growing inadequacy of existing conceptions of technology in the literature. They suggest that the organizations literature includes two distinct views of technology: (i) a *descriptive* view (which focuses on definitions and role of technology within organizations), and (ii) a *relational* view (which focuses on relations between technology and structure). They argue that these two views on their own are incomplete, and thus need to be integrated so to account for both the nature and development of technology, and for its relations with organizations, particularly as these evolve over time with the changes brought on by the post-industrial age.

View of Technology

The views of technology are somewhat different across the three reviews. Barley (1988) restricts the term "technology" to objects and actions that "admit the possibility of ostensive definition," while Orlikowski (1992) focuses specifically on information technology, and restricts the scope of this to configurations of hardware and software. Roberts and Grabowski (1996) discuss seven different definitions and views of technology evident in the literature, noting interesting and conflicting differences. They end with a broad view of technology, drawing on Collins et al.'s (1986) proposal, which includes three aspects in the notion of technology: mechanical systems (i.e., hardware); human systems (i.e., skills and human energy); and knowledge systems (i.e., abstract meanings and concepts).

Logic of Argument

All three of the reviews privilege a process approach in characterizing the existing literature, and propose a framework that incorporates such a view in their analysis. All three point to the "dual nature" of technology, although each frames the duality somewhat different. Barley (1988) points to technology's nature as both a social and physical object. He proposes an *interpretive materialism,* which recognizes that technologies are construed and reconstrued as they are designed, built, sold, and used, but also acknowledges that this process of social construction is constrained both by technology's physical properties and by the larger socio-economic context in which the technology is situated. Orlikowski (1992) focuses on what—borrowing from Giddens (1984)—she calls the "duality of technology," referring to technology's role as both the medium and outcome of recurrent human action. She proposes a *structurational model of technology* that includes human actors, technological artifacts, and institutions and four key relations: (i) technology is constituted by human action (interpreted, designed, and used); (ii) technology constitutes human action; (iii) institutional conditions shape people's ongoing interactions with technology; (iv) institutional consequences arise from people's ongoing interactions with technology. Roberts and Grabowski (1996) focus on technology's status as a product and a process, and propose the adoption of both positional and relational views of technology to capture this duality (drawing on structuration theory). They suggest that a *positional* view that focuses on technological and

structural constructs such as complexity, task definition, workflow integration, etc.) should be followed by a *relational* view that examines the fluid relations between technology and structure in organizations (understood to be continuous, changing, and interactive).

Research Agenda

In making recommendations for future research, each of the three reviews makes a number of specific suggestions for organization research. Barley (1988) cautions that unidirectional models of technical change are inappropriate, noting that examining a technology's ramifications across a range of occupations or organizations will reveal that single or invariant relationships do not apply. How a technology interacts with specific meanings, actions, cultures, structures, and institutional environments makes a difference, so that the same technical capacity may be used in multiple contexts to occasion quite different social structures. As a result, he suggests that researchers seek to engage (rather than reduce) the complexity and equivocality that are observed empirically in relations between technology and organizations.

In a similar vein, Orlikowski (1992) recommends that future analyses of technology in organizations should focus on the multiplicity of interpretive and institutional patterns that may be enacted in relations between different organizational structures, human actions, and technological artifacts. She emphasizes the value of attending to the structuring process through which people in particular organization contexts may produce certain kinds of technologies, and how use of these technologies in turn may reinforce or transform existing structural and work configurations over time. She also urges more focus on the unanticipated consequences that inevitably result from the interaction of technology and organizations.

Echoing Barley (1988), Roberts and Grabowski (1996) similarly caution that uniform or generalized descriptions of technology and organizational utility are no longer appropriate. Instead, they argue that what is needed is a contingency framework, along with more refined typologies of technology. They also recommend the production of more studies of decision settings characterized by increasing knowledge, complexity and turbulence. Reflecting their process orientation, they urge more temporal and longitudinal studies of organizations and technology, arguing that these are particularly necessary to account for the dual

nature of technology as process and product, and to accommodate the necessarily changing relations that exist between technology and organizations in a fluid and dynamic world.

Difficulties with the Two Streams of Research on Technology in Organizations

Whether emphasizing individual, stable entities or ongoing, interactive processes, these two streams of research have generated valuable insights into specific aspects of the relationships between technology and organizations. As with all perspectives, however, they also entail conceptual commitments that generate some distinctive blindspots in dealing with technology in organizational research. We suggest two such difficulties here.

The first difficulty concerns the focus on technology as causing or occasioning some organizational effect or change (e.g., development, diffusion, adoption, adaptation, improvement, etc.). This suggests that technology is relevant to organizational theorizing only as specific technological events or processes occur. As such, technology is seen to be of particular interest at certain times, in explicit places, and during special organizational circumstances. For example, studies of technology adoption or implementation examine the changes associated with introducing new technology into the workplace. Barley's (1986) study of the adoption and early use of CT scanning technology in the radiology departments of two hospitals is a case in point. So is Boudreau and Robey's (2005) research into the uptake of new enterprise resource planning (ERP) software within a government agency, and Sewell's (1998) study of the implications of electronic surveillance for team dynamics in a consumer electronics firm. Studies of technology design and development focus on the social dynamics associated with the production of new technology, as in Bechky's (2003) focus on occupational knowledge involved in machine fabrication in a manufacturing firm, Orlikowski's (1991) study of shifts in organizational control associated with software development in a consulting firm, and Thomas' (2004) multi-firm study of how power and politics shape new product development. Similarly, technology adaptation or breakdown are seen as particularly valuable moments to understand social phenomena, as in von Hippel's (1988) work on lead users as sources of innovation, Orr's (1996) ethnography of photocopier repair activities, and Crozier's (1964) classic study of the influence of maintenance workers in factories.

While we learn much by considering technology as a specific organizational event or process, such a view also obscures ways of seeing how organizational practices *always* entail some sort of technological (or material) mediation. As we discuss below, to the extent that technology is treated as an occasional or specific organizational phenomenon, we lose the possibility of seeing how it is an integral part of all organizing at all times, places, and circumstances.

The second difficulty is associated with positing the technology–human (or organizational) relationship as involving distinct entities or processes that interrelate in some way. What becomes relevant to study in this logic is the nature of the relationship entailed, whether understood as a unidirectional causal influence (e.g., in the technological imperative or strategic design perspectives) or as a mutual interaction (as in the process perspective) (Markus and Robey 1988). For example, in studies of the business value of information technology (Bryjolfsson and Hitt 1996; Aral and Weill forthcoming), researchers conceptualize technology as the independent variable (measured in terms of dollars spent on hardware and/or software) and assess changes in these dollar expenses with changes in such dependent variables as firm performance and capabilities (e.g., revenues, profit, market valuation, digital processes, technical skills, open information environment, etc.). Other studies focus on technology as a malleable resource that can be shaped, deployed, and used in various ways with various effects depending on organizational strategies, managerial ideologies, or political dynamics (e.g., Child 1972; Noble 1984; Thomas, 1994; Zuboff 1988). Studies adopting a process perspective focus on how technology and organizations mutually influence each other over time. Thus, structurational studies of technology in organizations (e.g., Barley 1986; DeSanctis and Poole, 1984; Orlikowski 1992; Walsham 1993) explore how technology is shaped by the users who engage with it in the workplace, while also examining how users' work is shaped by the features inscribed into the technologies.

By studying how technology and humans (or organizations) influence each other, this set of studies has shed important light on the impacts, interactions, and unanticipated consequences of technology design and use in organizations. But what is not questioned in this logic is the assumption that technology and humans (or organizations) are separate in the first place. As we will discuss below, work in the sociology of technology challenges this presumption of ontological separation embodied in the two research streams,

arguing instead for a relational ontology that sees humans and technologies as inextricably entwined (Knorr Cetina 1997; Latour 2005; Pickering 1995).

LESSONS FROM THE SOCIOLOGY OF TECHNOLOGY

Initially born out of the science studies literature (Williams and Edge 1996), the sociology of technology shares a similar underlying tenet of "interpretive flexibility" (Pinch and Bijker 1984). Scholars uphold the premise that the development process of technological artifacts is multidirectional rather than linear, and constituted by processes of negotiation between social groups who vie to achieve specific outcomes during phases of controversy. Analyzing the relationships among these groups and the technological artifacts in which their interests are embroiled is presented as a way to understand the various meanings that shape emerging agendas and artifacts, and that result in contingent outcomes.

Over time, some of the scholars working with these ideas became convinced that the relationships of interest could not be neatly divided into the technological and the social because they represented achievements that were dependent on both. Hughes (1987), for example, maintains that it is the interaction of different mutually dependent agencies that we should find worthy of study. For him: "Technological systems also include organizations, such as manufacturing firms, utility companies, and investment banks, and they incorporate components usually labeled scientific, such as books, articles, and university teaching and research programs. Legislative artifacts, such as regulatory laws, can also be part of technological systems" (Hughes 1987, p.51). Recognizing the inherent inseparability of the technological and the social led scholars to search for an alternative ontology. What emerged was an ontological relationality, which posits that entities have no inherent properties, but acquire their form and attributes only through relations with others. It gives us our third research stream on technology.

Research Stream III: *Relationality*

In this stream of research, people and things are not seen to be, first of all, self-contained entities, which then influence each other (Slife 2005), either through impacts (Research Stream 1) or interactions (Research Stream II). Rather, people and things only exist in relation to each other. As Slife (2005, p. 159)

puts it: "They start out and forever remain in relationship," a condition that Barad (2003) refers to as a constitutive entanglement. Within the sociology of technology, this ontological relationality produced a body of work that transcends both the individuality of the first research stream and the duality of the second. Table 5 depicts its primary characteristics in relation to the other two research streams.

Table 5: Three Streams of Research on Technology and Organizations

	Research Stream I	Research Stream II	Research Stream III
Ontological Priority	Individuality	Duality	Relationality
Key Mechanisms	Impacts	Interaction	Performativity
Main Concepts	Technological Imperative Technology Effects	Structurational perspectives Social Constructivism	Actor-Network Theory Sociomateriality
Logical Structure	Variance	Process	Relationships
View of Social and Technical Worlds	Humans/organizations and technology are assumed to be discrete, independent entities with inherent characteristics	Humans/organizations and technology are assumed to be interdependent systems that shape each other through interaction	Humans/organizations and technology are assumed to exist only through their entangled intra-relating
Examples	Blau et al. (1976) Huber (1990)	Barley (1986) Prasad (1993)	Callon (1986) Suchman (2007)

A prominent example of a perspective that embraces a relational ontology with respect to technology is Actor Network Theory (ANT), originally developed by sociologists Michel Callon (1986) and Bruno Latour (1987). In this view, as Law (1999, p. 1) explains: "an object is an effect of an array of relations," in which humans and technologies are not only reciprocally interdependent, but also symmetrically relevant. From an ANT perspective, there are no distinct and separate social or technological elements that interact with each other; rather, technological artifacts are considered as equivalent participants in a network of human and non-human agencies that (temporarily) align to achieve particular effects.

In ANT studies, relationships are no longer seen as a concept with which to frame some aspect of the research, but instead become the theoretical foci and central explanatory vehicle of the research. The

analytical goal in such studies is to present "society, organizations, agents, and machines [as] effects generated in patterned networks of diverse (not simply human) materials" (Law 1992, p. 380). In one of the influential papers often cited in support of this approach, Callon (1986) famously blurs the human and non-human agencies at work on a beach: "Scallops make the fisherman do things just as nets placed in the ocean lure the scallops into attaching themselves to the nets and just as the data collectors bring together the fisherman and the scallops in oceanography."

In the area of technology and organizations, the use of ANT has been used to shed light on technological relations in the workplace (Monteiro and Hanseth, 1996; Walsham and Sahay 1999). For example, Scott and Wagner (2003) use ANT to discuss a case in which the ambitions of a university vice president to elevate his organization to the status of "gold standard" combined with the concerns of the financial controller regarding their top rated (AAA) audit compliance to drive the adoption of a particular technical accounting method during the implementation of an enterprise resource planning (ERP) package. This accounting method was written into the programming code during the customization of the ERP software and subsequently manifested in the graphical representation and calculative processes of reports that the university administrators were told they must use. In this way, the social life worlds of university ranking, claims regarding expert accounting knowledge, government regulation, and the practices of credit rating agencies were entangled with the technological agencies of the ERP package and routine conversations among administrators and academics about how much money they had left in their grants. In their paper, Scott and Wagner (2003) show that while these changes were presented by the human actors as "merely" a shift in the temporal features of work practices and "an inevitable and necessary part of switching to ERP," they triggered intense organizational controversies over values, identities, and community within the university.

Difficulties Associated with Actor-Network Theory

ANT's symmetrical treatment of humans and technology has revealed some important insights that have been overlooked by other theoretical lens. As Suchman (2007, p. 268) notes this approach "has been tremendously valuable as a corrective for the entrenched Euro-American view of humans and machines as

autonomous, integral entities that must somehow be brought back together and made to interact." But the approach has also raised some difficulties, particularly for organization research. First, ANT does not account very well for the role and influence of institutions, in particular, for how institutional conditions shape recurrent action, even as they are constituted by them. Second, the nature of intentions and how they are to be treated is quite ambiguous within ANT. The principle of symmetry would require attributing intentionality to technological artifacts, a move that some critics (Collins and Yearley 1992; Pickering 1995; Schatzki 2002) find problematic. Extending this critique, Suchman (2007, p. 268; emphasis in original) observes that the notion of symmetry precludes seeing more generally that "persons and artefacts do not constitute each other *in the same way*."

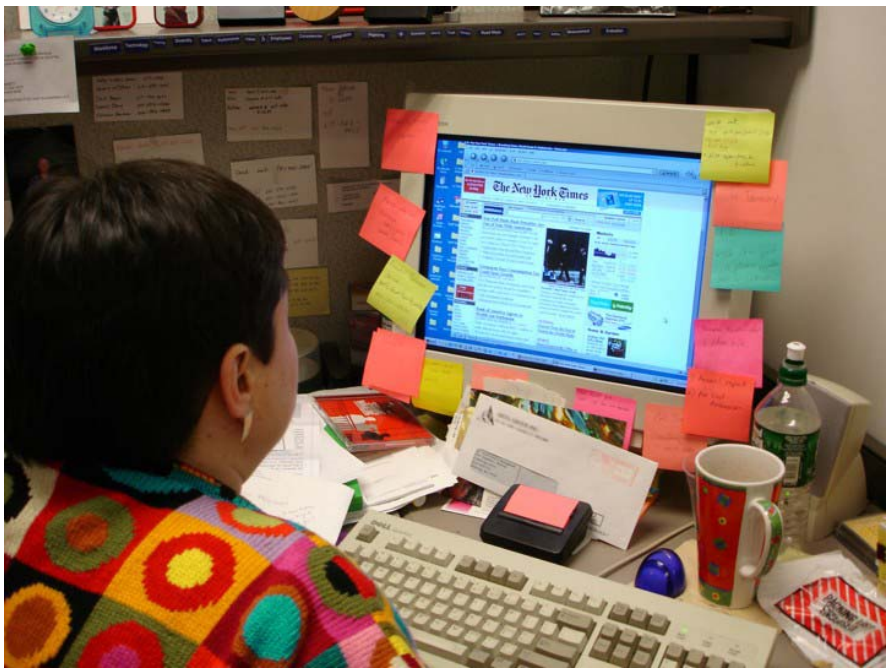
Third, while ANT research claims to treat technological and social actors equally, many of the studies tend to privilege one form of agency over the other, thus defeating their founding goal. For example, Grint and Woolgar (1997) argue that in some cases ANT treats technologies as having "actual properties," thus reintroducing a "residual essentialism" emphasizing the technologies. Finally, there are some nontrivial methodological difficulties with attempting an ANT analysis. It often proves challenging to turn the methodological aim of tracing ties between social groups into a workable fieldwork design. What defines the formation of a network? Where does a network start or finish? As a consequence, we are presented with narratives from a subset of actors that the researcher may or may not define in scope. In particular, identifying delegates to represent technological agents takes us into less well-charted territory. The credibility of such data sets tends to be hard won.

Thus, while ANT represents an important part of the palette of ideas for studying technology and work, we want to develop the relational ontology of the third research stream in a somewhat different direction. In so doing, we acknowledge that these efforts do not represent a radical departure than those already forged in this research stream, but rather express a commitment to be part of the continuing scholarly effort to develop ways of overcoming the social/technological separations discussed above.

TOWARDS A SOCIOMATERIAL PERSPECTIVE ON TECHNOLOGY AND WORK

The approach that we propose here is grounded in an ontology of relationality, which like in ANT, emphasizes the "constitutive intertwining and reciprocal inter-definition of human and material agency" (Pickering 1995, p.26). However, rather then turning to the metaphor of networks as a way of ordering relational interactions, we seek to analyse them in terms of the *sociomateriality* (Mol 2002; Suchman 2007). This alternative framing shifts the epistemological and methodological orientation away from tracing ties in a network towards an examination of performativity and (re)configuration (Barad 2003; Suchman 2007) in situated practices. Furthermore, rather than treating human and material agency symmetrically, the focus is on recognizing their mutual (albeit different) constitution and the performed or enacted nature of the boundaries between them (Suchman 2007, p. 260). Thus, all practices are (re)configured by some specific sociomateriality. Consider, for example Figure 1, which shows at a glance how office work is inextricably, and at the same time, tied up with the social and material. We see the physical hub of a person's work practices composed of an array of materiality imbued with multiple logics and capabilities (programmes, reminders, sources, and connections) all poised to form part of the pattern of her work flow, ready to be actively configured into a situated work performance.

Figure 1: Example of Sociomateriality in Office Work



The notion of sociomateriality posits the entangled relations between humans and technologies as performed, that is, not pre-given or fixed but enacted in practice. The practice lens is particularly helpful in grounding this notion of performed relations. Practice studies—or more accurately what has been referred to as "the practice turn" (Schatzki et al. 2001)—has received growing attention in recent management and organization studies research (e.g., *Organization Studies* 2006, volume 17, number 5). The term "practice" in this context does not refer to rendering pragmatic insights from management research for a practitioner audience, nor is it meant to imply separation of academic theory from practice. Rather, it is the scholarly effort of understanding how social orders (such as organizations) are produced through recurrent human activities. As Reckwitz (2002, p. 252) notes, the routinized way in which "bodies are shaped, objects are handled, subjects are treated, things are described, and the world is understood." In this view, an organization is held to be a recurrently enacted and patterned set of relations, reproduced over time and space. Attempts to identify a encompassing, systematic "practice theory" (Friedmann 1987, p.186) have largely given way to the suggestion that the concept of practice is most effectively used as a way of framing research (Schatzki 2001, p 4.).

The "practice lens" marks out a distinctive way of thinking about organizations and activities of organizing (Gherardi 2006; Orlikowski 2000; Whittington 2006). Organization studies that have adopted this approach analyze the flow of situated action as expressed through, for example, organizational routines (Feldman and Pentland 2003), global product development (Orlikowski 2002), interactive strategizing (Jarzabkowski 2005), and communities of practice (Wenger 1998). Ironically, as Duguid (2005) notes, once the unit of analysis has been framed, the idea of practice is theoretically bracketed by many scholars, As he put it when critiquing community of practice studies: there is often more emphasis on the community than the *practice*. Our observation is that, since technology is constitutively entangled with contemporary work practices, further effort to theorize practice must encompass technology in organizations. Our proposal for a way to achieve this is with the notion of sociomateriality.

Since any approach influences the way phenomena are framed from the outset of a study, it might help if we compare a sociomaterial framing to that of the previous research streams of work and technology discussed above. As we saw, both research streams I and II have tended (in different ways) to objectify the

technical and to sequestrate the social, creating two distinct domains within the research (whether conceived as a dualism or a duality). This presumption of separation is then inscribed in the priorities of the study and most importantly, in its analytical gaze, producing, for example, the following sorts of research questions:

What are the impacts of the technology on organizations?
How and why do people make sense of the technologies they design and use?
What renders the technology available, meaningful, and knowable to people?
What organizational outcomes are caused/enabled by the technology, and with what consequences?

This way of formulating research questions about technology and work guides the process of data gathering and analysis so that the findings are necessarily split between two categories: the technological artifacts and the social (context, activities, meanings, outcomes). Thus, the language and assumptions of separation lead conceptually and methodologically to a realm of possible findings that are already configured. That is, by design, the questions and findings entail impacts or interactions of the social and the technical. We lose the possibility of seeing the technical and social as inextricably intermingled. Part of the problem, as Suchman (2007, p. 263) points out is that "our language for talking about […] persons or artefacts presupposes a field of discrete, self-standing entities."

The notion of sociomateriality attempts to preclude the possibility of seeing the social and material worlds as distinct. By definition, they are constitutively entangled, and such a conceptual configuration leads to a different set of research questions, for example:

When and why is sociomateriality (re)configured?
How is sociomateriality performed in practice?
When do people make sense of the sociomaterialities of which they and their practices are a part?
What consequences arise out of the multiple sociomaterial (re)configurations performed in ongoing practices?

In this framing of the phenomenon of interest, there is no separation of the technical and the social. Rather all practices are always sociomaterial, and this sociomateriality is integral, inherent, and constitutive, shaping the contours and possibilities of everyday organizing. As Barad (2003, p. 818) puts it, "Agencies are not attributes [of either humans or nonhumans] but ongoing reconfigurations of the world."

As a way of outlining the kinds of research studies entailed by a sociomaterial perspective, we discuss two cases that illustrate the forms of sociomateriality that constitute part of the fabric of socio-economic life: searching the web and making financial decisions. These entanglements are particularly important because they

are taken for granted in the processes of knowing and organizing, and yet they are profoundly influential in patterning contemporary work practices. After briefly describing each case, we use the research questions posed above to offer a sociomaterial analysis.

The Sociomateriality of Web Search: *Google Search Engine*

Searching the world wide web has become a commonplace activity. A recent estimate suggests that about 213 million web searches are performed on a typical day in the United States (Sullivan 2006). A central technology with which this activity is accomplished is the web search engine, and the activity of web searching with a search engine represents a particularly interesting example of sociomateriality, as it is performed through an ongoing entanglement of human and technological activities.

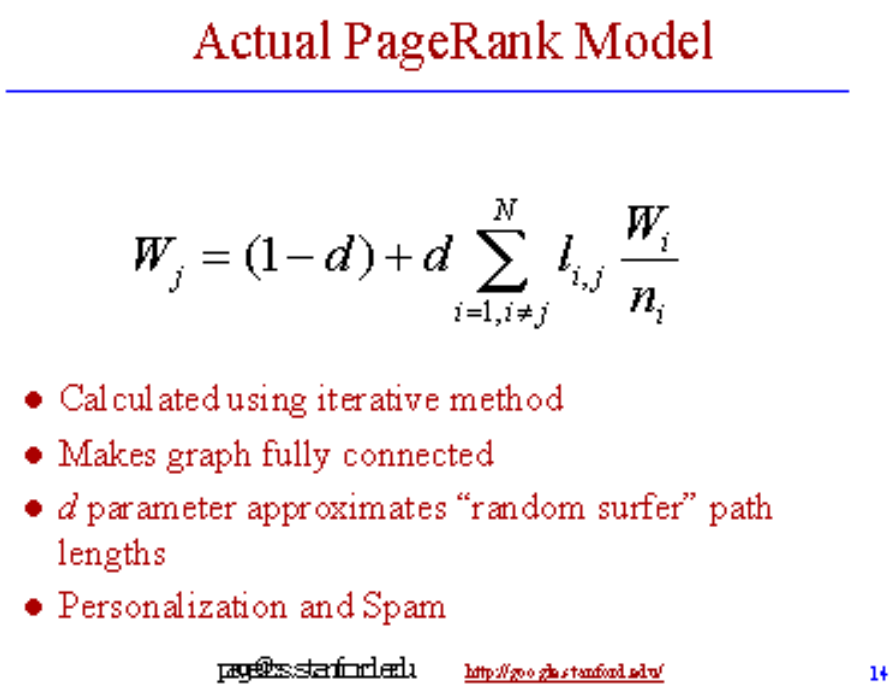
The process of designing and managing a search engine service (such as that provided by Google, Yahoo!, or Ask) involves making a number of choices about what data to include and exclude in the reference database, and how to sort and rank these data in the database. These choices then become embedded in the design specifications and program code of the search engine software such as the web crawling heuristics and webpage ranking algorithms. When this software "runs" or is executed, these choices-as-embedded-in-code shape the operation of the search engine, the databases and indexes that are built and maintained, and the results that are returned to users.

Let us look at this in a little more detail by examining the case of Google. Google, by most estimates, is the most popular search engine in use today. A recent study found that 43 percent of the searches performed on a typical day in the US are done on Google, with Yahoo! coming in second at 28 percent (Sullivan 2006). One of the reasons for Google's popularity is that its searches tend to yield more precise results for most queries than many of the other search engines (Butler, 2000). Google is able to achieve this because of a particular algorithm—the PageRank algorithm—that sorts the billions of records in its database. This algorithm was created (and subsequently patented) by the two Google founders, Lawrence Page and Sergey Brin when they were doctoral students in computer science at Stanford University (Brin and Page 1998a). In operation, the PageRank algorithm assesses the importance of a web page based on the number of other web pages that link to it, as well as their relative importance. Thus, for each page in Google's database, the algorithm computes a

score (known as a "page rank") based on the number and kind of links that point to that particular webpage (its incoming links, or "backlinks"). And this score is then used to rank the page within Google's indexes, and to order the results returned to users in response to a query (see Figure 2). Google describes the PageRank algorithm on its website in this way:

> PageRank relies on the uniquely democratic nature of the web by using its vast link structure as an indicator of an individual page's value. In essence, Google interprets a link from page A to page B as a vote, by page A, for page B. But, Google looks at considerably more than the sheer volume of votes, or links a page receives; for example, it also analyzes the page that casts the vote. Votes cast by pages that are themselves "important" weigh more heavily and help to make other pages "important." (http://www.google.com/technology/)

Figure 2: PageRank Algorithm (Bin and Page 1998b)



Google's page ranking system has been compared to the citation count analysis produced for published articles in academia. Pages with many backlinks—akin to articles that are heavily cited—are seen as "more important" and are ranked higher in the search results. Web pages that have few or no links pointing to them—akin to poorly cited articles—are not seen as "important," and are thus poorly ranked in the Google ranking system. Google thus relies on the web itself to rank the importance of pages. And as the web is continually changing (with content, links, and pages being added, changed, and deleted daily), Google's

assessment of the importance of web pages is also changing, as the Google software constantly updates its databases, indexes, and page rank scores to reflect the changing content and link structure of the web. Thus, a particular Google query posed today may yield quite different search results when posed tomorrow or next week. The operation of Google is dynamic, or in Pickering's (1995) terms, "temporally emergent" in ongoing practice.

Using the research questions we proposed above, we now offer a (necessarily brief) account of the web search phenomenon from the perspective of sociomateriality.

When and why is sociomateriality (re)configured?

The performance of web search via search engines cannot be simply understood as people "using" a given or instrumental technology to get some work done. Google's performance and any search results it returns are not dependent on either the technical aspects of the search engines or on the human choices and actions that design and operate the software and submit search criteria. Neither do they depend on some interaction between the putative social and technical domains. A web search conducted with the Google search engine is sociomaterial "all the way down," entailing computer code written and updated by software engineers, executing on computers (configured with particular hardware and software elements which were designed and built by computer engineers and production workers), and whose operation depends on the millions of people who use computers to create and update web pages everyday, and the millions of people around the world who enter particular search criteria into their web browsers running on still other computers designed and built by yet other people, and so on. The resulting sociomaterial configuration represents the dense and dynamic entangling of the material and social in many different places and times, and in various ways. And this configuration is actually a reconfiguration because the web is dynamic and emergent, and these ongoing changes in web content and structure are reflected in Google's continually updating databases and indexes.

The sociomateriality that configures any particular web search is thus never given or stable, but always performed. That is, it is an enacted accomplishment, which can and does change. Thus, when Google engineers change their views about how best to do web searching and update their crawling heuristics and ranking

algorithms accordingly, the sociomateriality of the performed web searches will change. For example, given the popularity of the Google search engine, getting a good "page rank" on Google has become highly coveted by people owning websites and seeking to "increase traffic" to them. In practice, the PageRank concept has proven vulnerable to manipulation, and websites have sprung up promising to "improve your Google ranking" (http://www.opentracker.net/en/articles/improve-google-ranking.jsp). PageRanks may also be manipulated, often for humorous or political intentions, via "Google bombs," a technique that artificially influences the rankings of the webpages that Google returns when people search for certain phrases. For example, the first known Google bomb was the one that led the search term "more evil than Satan himself" to bring up the Microsoft homepage as the top result (http://en.wikipedia.org/wiki/Google_bomb). Initially defending its algorithms against the disruptive influence of such manipulation tactics, Google now claims that they have developed algorithms to minimize the impact of these techniques. Each of these moves, attacks, and responses represent reconfigurations of the particular sociomateriality that is performed when accomplish web searching.

How is sociomateriality performed in practice?

In practice, Google's "page rank" score is dynamically computed by an algorithm executing in one of Google's computers that reflects the (ongoing) choices that millions of web users make in deciding what set of web pages they want to link to from their own web pages. It also reflects the relative status of websites within the web, as links from popular or official websites such as portals (e.g., MSN, AOL) or institutional sites (e.g., the UK Government, The New York Times) are weighted more heavily by the algorithm than links from other web pages (e.g., individuals' personal home pages). In this, as Introna and Nissenbaum (2000) point out, the search engine gives preference to larger, wealthier, and more prominent sites, affording "systematic prominence for some sites, [… and] systematic invisibility for others." As a result, many pages in the web are not indexed at all, or appear so far down in the ranking results that they are rarely "found" through a web search.

The performance of web search sociomateriality is thus both inclusive and exclusive—including well-linked and highly-connected web sites, and excluding poorly-linked and less-connected web sites. This has considerable political and epistemic implications because it means that a part of the world wide web is

completely unavailable to most people. A study conducted by researchers from IBM (Butler 2000) found that the web includes considerable constellations of web sites that are difficult to navigate and thus inaccessible by links. Known as the "bow tie theory" of the web (referring to the four distinct regions that make up approximately 90 percent of the web — the "bow tie"), the researchers found that about 10 percent of the web is completely disconnected from the entire bow tie, and thus not reachable via conventional web searches. As such, the performativity of web search engines powerfully shapes how the web is configured for the users. And as Introna and Nissenbaum (2000, p. 170) note, in this way search engines "are political … constitut[ing] a powerful source of access and accessibility within the Web."

When do people make sense of the sociomaterialities of which they and their practices are a part?

In the discussion above, we have already drawn attention to times when the sociomateriality of a web search is of interest for economic or political reasons. However, this perspective also draws attention to the way in which sociomateriality slips from view and dissolves into everyday practices. Introna and Nissenbaum (2000, p.176) note that not only are most users are unaware of the biases patterning their searches on the web, they also seem to be "unaware that they are unaware." This invisibility is compounded when a particular search engine is set as default and textures the sociomateriality of both corporate intranets and personal sensemaking at home. Search engine providers respond by arguing that they do not operate a monopoly and "participants are free to express their preferences through the choices they make among alternatives" (Introna and Nissenbaum 2000, p.176). Although know-how does circulate among communities, there is a certain matter-of-fact-ness achieved when 43 percent of searches are conducted with a particular engine and it is not clear that most people understand how search engines work or by what means they yield their results, nor do many know how to reset a default option. In the context of such sociomaterial taken-for-grantedness, sensemaking is only disrupted when there is a controversy or breakdown, during which time we are made aware of the implications of a particular configuration or performance of sociomateriality.

What consequences arise out of the multiple sociomaterial (re)configurations performed in ongoing practices?

The performed sociomateriality of web searching has important consequences. Consider for example, the controversy that surrounded Google's entry into China in January 2006 (BBC News 2006). In order to gain

greater access to the fast-growing Chinese market, Google agreed to censor the search services it made available within China. This censored version—Google.cn—is strongly regulated by the Chinese authorities and restricts access to thousands of sensitive terms and web sites. For example, the BBC news website is unavailable; so too are any websites related to the Taiwanese independence movement and the 1989 Tiananmen Square protests. A search for the banned Falun Gong spiritual movement produces only web pages that denounce it (e.g., articles such as "Outlawing the Falun Gong Cult" and the "Campaign against the Falun Gong"). And Chinese residents cannot simply access other Google search services (e.g., Google.com) to bypass these restrictions. The so-called "Great FireWall of China" blocks access by Chinese residents to many sites on the web, including alternative Google search services.

As it turns out, similar albeit less visible restrictions are occurring elsewhere on the web. For example, as Zittrain and Edelman (2002) highlight, the French and German versions of Google omit search results deemed inappropriate or unlawful by the respective governments. Censorship and its inscription within technologies is not new, but the Google example powerfully highlights how the sociomateriality of web searches is (re)configured in real time depending on the location of the web users, and how this significantly shapes the resulting information that people rely on to do their work. And as we have noted, this is potentially quite insidious because most users are not even aware that the results returned to them have been censored or are biased towards particular web sites.

For many of us, web search engines have become part of our everyday sensemaking and acting whether because they are now integral to an internal organizational intranet or are used as a reflex during our personal information gathering on the Internet. Our next field study provides an example of how sociomateriality is bound up in the way contemporary economic life is conducted through the routine work practices that pattern how core business competencies are accomplished.

The Sociomateriality of Financial Decision-Making: *Lending Advisor*

Scott (1998) describes the historical development of corporate lending practices within a major UK retail bank. The origins of the bank in the study (referred to as "UK Bank") date back to 1896 when twenty family-owned, private banks amalgamated. The bank's prosperity was founded on the private wealth of the

families involved and profitable credit arrangements. The latter were based on personal connections with members of the banking families and the capacity of applicants to convince the bank that they had both the material means and character to warrant a loan.

After World War II, lending practices changed as centralised "professional training" began to slowly overtake the norm of inherited positions. Lenders developed a variety of formats in which risk assessment experience could be formed into formulae, empirical heuristics, methods for interpreting categories on balance sheets, policy guidelines, regulatory criteria, *aide memoires*, notes or "crib sheets" for specialist areas (such as agriculture). As a retired bank manager explained:

> Every branch manager was required to keep an information sheet. The front side would have details of the company and a summary of the balance sheets produced by their accountant. The other side would have a narrative, often hand-written, at the end of which the loan or overdraft facilities undertaken were noted…The outcome was all very much contingent on how you performed as a manager and how each business that you had on your books performed. That was the stuff of our daily lives.

In the early 1990s, UK Bank experienced major losses due to loan defaults and made a very public commitment to improving both lending practices and organizational portfolio analysis capability. In the past, loan defaults on this scale had resulted in fingers being pointed at various individuals or groups deemed to have accumulated an unacceptable level of "bad and doubtful debts," The managing director appointed to address the crisis reflected on this and decided to take a different approach. Instead of, as he put it, "Wearing a hair shirt and blaming the management of four years ago," he explored options for systematic change by incorporating a decision support system called Lending Advisor (LA) into the work practices of bank managers.

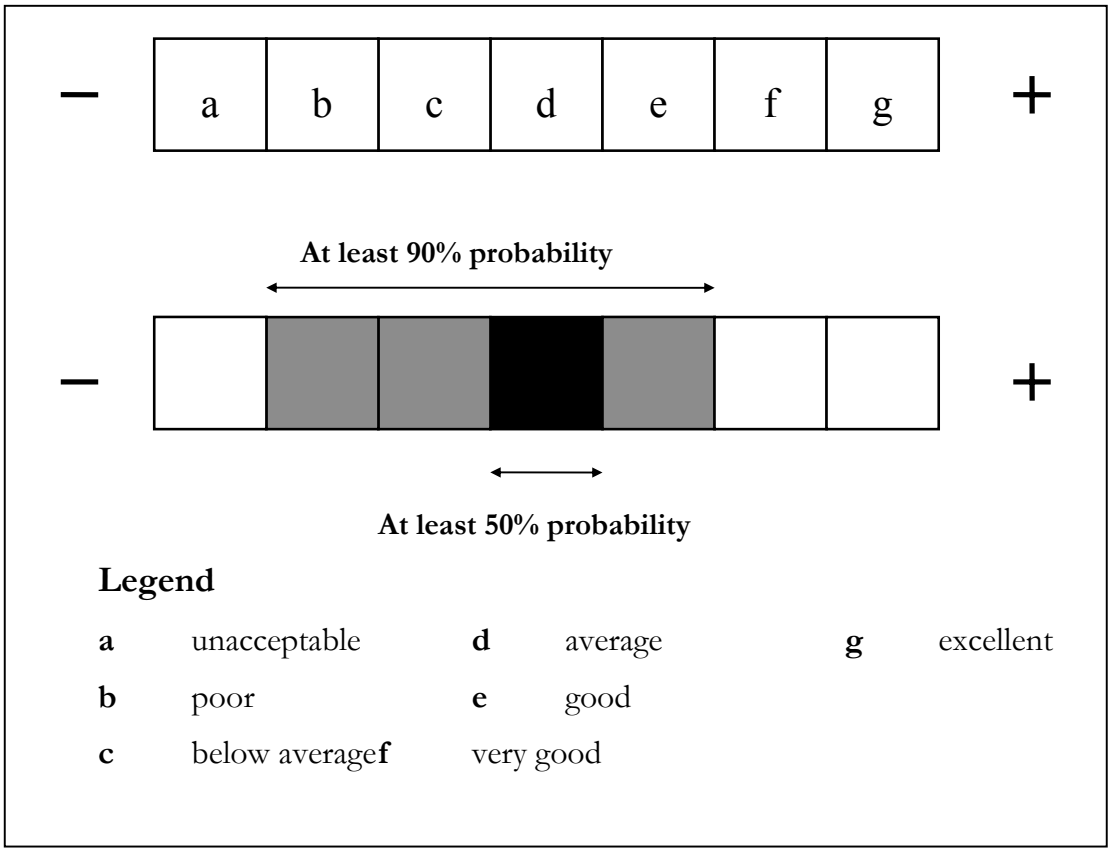
The knowledge engineering process that ensued focused on gathering "best practices." The basis for this was "mutual education" in which internal and external lending specialists translated the processes and procedures involved in a loan into weighted criteria scored out of 100. As a programmer explained:

> The experts very rarely agreed completely, but small deviations were not a problem as the knowledge engineers were still able to make a judgement on what represented the modal point...The system was calibrated between experts.

The project fused together insights into how professional lenders worked with a variety of new resources (information sources from rating agencies, catalogues of business industry codes) and the algorithms

associated with the LA inference engine to form a probability-based system that would become part of decision-making on corporate loans. The form chosen to represent this combination of logics for the new loan assessment was a meter (see Figure 3).

Figure 3: Lending Advisor Assessment Meter



The 1995 training manual to the Lending Advisor describes the assessment meters as follows:

> Meters are designed to illustrate a measure of risk and to indicate how confident the system is in its assessment. The system does this by showing meters ranging from **–** (or unacceptable) on the left, to **+** (or excellent) on the right [as shown in Figure 3]. All meters have seven points ... shaded with black, dark grey and white. The shading corresponds to different degrees of certainty; the wider the segment of shading, the greater the degree of doubt, conversely, the narrower the shading the greater the certainty.

During training sessions, some trainers handed out "pathways" through the 52 screens of the system, however, as one noted: "this was just to get them started…after a year's use of the system, they will develop their own pathway…[and] use of Lending Advisor will become almost subliminal, second nature." Scott's

(1998) study describes how at first when managers got back to their branch, they "played" with these meters, altering their input to move the meters and overriding them with lengthy "footnotes" to correspond with the decision they would have recommended using the former method of assessment. However, this changed over time, and when asked twelve months later if the Lending Advisor assessments still corresponded to the decisions they would have made using the paper-based method, managers replied, "It's difficult to say now because these days I'm actually thinking LA rather than paper, and I've lost the ability to compare my decision making processes between the two." The lending professionals had moved beyond translating from the paper to the electronic work practice in an effort to equate them, and had begun appropriating Lending Advisor into the sociomateriality of their professional performance. This had become so much the case that, as one manager observed: "When you talk to analysts at regional level, they discuss cases more in terms of meters and [UK Bank] business grades, nowadays."

Scott (2000) concludes by noting that whereas the interpretation of previous revisions to lending practices had been managed locally, the implementation of new credit risk assessment and portfolio management practices associated with Lending Advisor achieved a different level of system-ness, a globality. The implications of this are considerable when the portfolio in question represents approximately 23 percent of the UK domestic market (as in the case of UK Bank). Such a percentage has the potential to shift the trajectory of national economic development. As above, we now offer a brief analysis of this case in terms of the research questions about sociomateriality posed earlier.

When and why is sociomateriality (re)configured?

UK Bank's loans assessment and portfolio management are now both the subject of and subject to the new form of sociomateriality that has emerged and continues to be performed. The knowledge engineering undertaken during the Lending Advisor project fused the qualitative judgement of human managers with the expert system inference engine. Typically, these rational and non-rational components of decision-making have been framed as two very different categories. However, Callon and Law (2005) suggest re-framing this duality within the term "qualculation," and we maintain that the sociomateriality of the

lending practices described here illustrates this well. In the revised work practice, the loan assessment is neither purely technical, nor solely subjective; it is a fusion of both.

How is sociomateriality performed in practice?

Reflexivity is an important part of the mutual configuration at work in forms of sociomateriality. As customer cases are loaded onto Lending Advisor they become part of a cumulative reasoning feedback; they are not static data buried in a file, they perform a key role in the on-going configuration of work practices. For example, the ability of one plastic goods producer to have its corporate loan approved is dependent upon the performance of all the other businesses located within the same business industry code. Its bid thus becomes entangled in the skill level of multiple elements: the specialists producing business industry codes; the lending professionals within UK Bank; the managers at other plastics companies; the experts producing industry reports; and the updates to the weightings and algorithms of the Lending Advisor to bring them in line with corporate strategy and regulatory policies. If any one of these under-perform, for example, if a prosthesis producer is put in the same category of assessment as a household gutter moulding company, the loan outcome will be compromised. As a consequence of all these interdependencies, the resulting performance of UK Bank's lending decisions is temporally emergent from ongoing practice.

When do people make sense of the sociomaterialities of which they and their practices are a part?

By the end of Scott's (1998) study, some managers had taken early retirement, while others relished this new way of articulating their professional performance, both to customers and at home. Lending Advisor had been appropriated into lending managers' situated performances to the extent that they were thinking and talking "meters." This level of familiarity was an achievement, but it was hard won in the case of some managers who experienced what might be seen as breakdowns in the version of sociomateriality that they were being told to integrate into their work practices. For example, there were managers who accepted thinking in meters, but who refused to "do data entry," which they regarded as "for the girls and boys in the back office." As one manager put it: "I dictate, giving the secretary the name of the case and my [Lending Advisor] password… The only one [screen] that she needs to know is the Credit Analysis Comments screen.

So, I sat down and wrote an idiot's guide for her." Although some lending professionals attempted to insert distance between parts of the loan application process, eventually the two became seen as inseparable. In follow-up interviews, attitudes had shifted. As one manager noted:

> Lending Advisor input is not delegatable. When you are loading or working on a case, you are going through an inter-related thought process. I am a two-finger typist, advancing to being a three-finger typist. Despite that, I don't let anyone type my input. I am familiar with what I want to say, so I'm more focused and end up with less waffle. I have found that the end result is better if I work on it myself.

What consequences arise out of the multiple sociomaterial (re)configurations performed in ongoing practices?

When the Lending Advisor project began, the design and development team envisioned it as augmenting human expertise and went to considerable lengths to differentiate "decision support" from "credit scoring." The training courses that managers went on were designed around this principle: trainers told managers to "find their own best practice" and discover the most effective way through the 52 screens as they constructed the loan application for themselves. They encouraged lending professionals to "look behind the figures… [because] unless you do this, Lending Advisor is just a number cruncher. It relies on the user challenging the figures and knowing where they come from. Lending Advisor gives the numbers context" This strategy, however, was later revised and a programme of major organizational restructuring took place. A third of the managers in Scott's study were made redundant or given early retirement. A younger generation of bank personnel with global job titles (for example "corporate loans manager" rather than "Mettleton branch manager") and performance related contracts arrived, and for them meters were just the way loans were done, rather than an interpretive challenge to an already existing stock of knowledge. Scott (2000) raises concerns about this organizational re-calibration and notes that in effect the definition, assessment and management of credit risk in a major financial services institution had been changed without debate. She points to the problems that the design and development team had with particular modules and the compromises that were made to meet deadlines in order to alleviate the crisis of confidence in UK Bank during the economic recession of the early 1990's. This was all the more significant because the modules in question affected sectors that many regarded as critical in the British economy: small businesses, media/film companies, and agriculture. Scott (2000) concludes by suggesting that through the everyday routinizing of the

Lending Advisor's sociomateriality, the future British economic landscape may have been changed without anyone's consent.

CONCLUSION: WHITHER TECHNOLOGY IN MANAGEMENT RESEARCH?

We began this paper by highlighting a paradox in the management literature. Despite the considerable empirical evidence of technology's central role in organizational affairs, technologies remain largely understudied in organizational research. Whatever the reasons, we believe that such an absence of attention to technological issues in organizational research is a serious concern.

It is important that we appreciate that it is not a question of whether technology forms part of organizing or not; technology is an integral part of the fact of work and its performance in the world. If we do not take this into consideration in the way that we study organizations, we may not arrive at an understanding of how work is "made to work." Indeed, we believe that to the extent that the management literature continues to overlook the ways in which organizing is critically bound up with material forms and spaces, our understanding of organizational life will remain limited at best, and misleading at worst.

We have proposed sociomateriality as part of a palate of approaches that we believe may advance the way we study technology. We do not intend this as a successor theory. We believe a range of different tools is appropriate when studying such an important, dynamic, and emergent phenomenon. There will be studies for which existing theory and approaches will be suitable, but there will be many more that necessitate a fresh perspective. Our call for research to move on from atomized variance studies or perpetual dualities makes the research challenge ahead of us a richer one. This is a fast moving field; just as what we study changes over time, so the theoretical lens or tradition that we use to approach it needs to be develop over time. The approach that we have proposed resonates with the status and nature of technologies in contemporary organizations. These are increasingly multiple, emergent, dynamic, and unprecedented. To understand these we will need a flexible array of notions and approaches. As Weick (1996) reminds us, we should "hold our concepts lightly and update them frequently."

While the significance of management instruments and canonical practices (Brown and Duguid 1991) has been recognized in organization studies, attention has tended to focus on technological effects, occasions of change, or processes of sensemaking and interaction with little recognition of the deeply constitutive entanglement of humans and organizations with materiality. The evidence from the field studies that we presented depicted work practices as composed of an array of agencies, including configurations of space, technical heuristics, algorithms, qualitative expert judgement, physical mechanisms, categories, and so on. As a thought experiment, consider doing anything in the world (whether at home or in an organization) that does not in some way or another entail material means (e.g., bodies, clothes, food, spectacles, buildings, classrooms, devices, water pipes, paper, telephones, email, etc.). Latour's (2004, p. 227) provocative quote makes this point particularly well:

> To distinguish a piori "material" and "social" ties before linking them together again makes about as much sense as to account for the dynamic of a battle by imagining, first, a group of soldiers and officers stark naked; second, a heap of paraphernalia – tanks, paperwork, uniforms – and then claim that "of course there exists some (dialectical) relation between the two." No! one should retort, there exists no relation whatsoever between the material and the social world, because it is the division that is first of all a complete artefact. To abandon the division is not to "relate" the heap of naked soldiers with the heap of material stuff, it is to rethink the whole assemblage from top to bottom and from beginning to end.

We make our proposal for the way forward in the spirit that ideas have currency and we use them when they help us to explicate the world around us. It has become commonplace for studies of technology in organizations to combine metaphors of networks and infrastructures with the language of mediation and enabling. However, if we let go of the methodological assumption that we should think of relationships as moulded into networks and frame our analysis in terms of practices instead, we can more effectively examine the specific forms of sociomateriality that are entailed in performing everyday work. We suggest that this is a particularly relevant perspective in an era when sociomateriality is so much part of our everyday organizational experience that it becomes taken-for-granted. Work practices are inherently sociomaterial, and so to understand work, we must understand its sociomaterial configuration. The implications for organizations are particularly important; these practices don't just mediate work, they perform organizational realities.

In exploring the sociomaterial perspective, we re-worked some specimen research questions to show the pivotal conceptual shifts we are proposing. The cases that we have worked with here point to a subtly different range of phenomena. In both the financial decision support system (Lending Advisor) and the web search engine (Google), we have shown how different forms of sociomateriality in practice not only increase the capacity for transactions to be disembedded from time and space, but also disappear from the attentions of users and observers. Such increased invisibility in the technological entailments of everyday work practice are troubling, as they limit our capacity to understand, monitor, reflect on, and change them. It suggests that additional and alternatives ways of examining these are urgently required in organization studies. We believe that a sociomaterial perspective may offer one promising approach for reconsidering the status of technology in organizational research, and that a grounding in relationality (rather than either individuality or duality) may afford some empirical and conceptual innovations that will increase our understandings of the practices of contemporary organizational life.

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