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Beyond socio-technical systems: introduction to the special issue

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Abstract

This article serves as an introductory essay to this special issue of *Journal of Technology and Management*. It identifies and articulates the broad themes of the five papers included in this issue. Additionally, it outlines areas where further research is likely to make considerable contributions to the field of socio-technical systems. © 2001 Elsevier Science B.V. All rights reserved.

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1. Role of socio-technical systems in engineering and technology management

Since the 1950s, researchers and (some managers) have acknowledged that the technical and social factors interact to influence organizational outcomes. Work prior to the 1950s (and even some work today) often argued for technological determinism where technology implementations were expected to have direct effects, for example, if a robotic welding system is introduced on an assembly-line, production throughout will increase.

One of the first counters to the deterministic approach was made by Trist and Bamforth (1951). They noted that human and organizational outcomes could only be understood when social, psychological, environmental and technological systems are assessed as a whole. This approach has come to be known as a socio-technical systems (STS) perspective. This perspective assumes that organizations are "made up of people (the social system) using tools, techniques and knowledge (the technical system) to produce goods or services valued by customers (who are part of the organization's external environment). How well the social and technical systems are designed with respect to one another and with respect to

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the demands of the external environment determines to a large extent how effective the organization will be" Rogers (1995).

Research building from STS continues even today. A recent special issue of *Human Relations* (in 1987) focuses on organization innovation and STS as a work design process (i.e. to be compared with reengineering). Spender (1996) uses the ideas of social construction and STS to discuss a knowledge theory of the firm. He concludes that STS "is unsuitable as the basis for a theory of the firm because it adopt(s) too naïve a view of social systems and ignore(s) economic interactions" (p. 55).

By contrasting Spender's comment with that of prior STS researchers it is possible to see that the concept of STS is being used in two different ways. Much STS work focuses on designing work for both organizational and human good. There is a normative slant, in that the work suggests people should be involved in designing the relationships between technology and work. Quality of work life is a key consideration (e.g. Emery, 1969; Molleman and Broekhuis, 2000). The other perspective of STS is more theoretical. STS provides critical insights to understand the relationships between people, technology and organizational outcomes, and as Majchrzak and Borys (2000) note, was originally developed from open systems theory (von Bertalanffy, 1950). In is this perspective that Spender and others have indicated a limited, but interesting, approach to understanding organizational outcomes.

This special issue is a further step in this dialog. While the early steps were taken in the 1950s, traditional organization theory (and, unfortunately, some current models) have treated "technology" as some kind of monolithic entity that lurked in the environment (Blau, 1955), or as a general representation of how the work of an organization gets done (cf. Woodward (1965) — small batch, mass production, continuous flow; Thompson (1967) — long linked, mediating or intensive technologies). However, technology is not a "disembodied force afoot in the land", to paraphrase Gouldner (1954) characterization of organization and institutional thinking in the 1950s. Both STS thinking and most technology researchers understand technology as an actual system of physical, social and cognitive elements that are built, used and rebuilt by people in everyday practise. We can observe, manipulate, change and make sense of technology (however complex it might be) and its relationships to the social setting.STS thinking complements our field's attention to these practical dynamics of technology development, from the early days of R&D research (e.g. Schon (1963) use of product champions to overcome "dynamically conservative" tendencies of organizations; Pelz and Andrews (1966) analysis of creative tensions in managing R&D; Allen (1977) studies of patterns of communication within and among project teams); to present concerns in concurrent engineering, design for manufacturing or CAD/CAM (Adler, 1995). These general concerns with socio-technical interactions are also found in studies of manufacturing innovations and their interactions with organizational structure (Ettlie, 1983; Leonard-Barton, 1988). In MIS, Sproull and Hofmeister (1986) unravel the interactions of individual cognition and technology use, such as with e-mail systems and the relationships between social roles, networks and technology adoption. Still others (e.g. Weick, 1995) consider the co-evolution of social values and technological systems.

With this explosion of STS-like work in technology management, at all different levels of analysis and focused on such a variety of problems, we think it is time to explore the theory that they may, or may not, have in common use. Do any or all of these relationships embody similar or different dynamics? Can we build a broad socio-technical theory that explains the linkages at so many levels and/or for so many technology issues, or are there different kinds of socio-technical connections that require different theories? Perhaps, a comprehensive theory is not possible — instead of that only subsets of levels, problems and other dimensions should be considered. Alternatively, future work may find that a comprehensive theory is possible and provides a new approach to our understanding.

This special issue presents papers that go beyond STS as a rather vague description to develop more explanatory theories of technology–organizational outcomes. Each of these papers move theory and research forward by explicating more clearly the what (what factors), how (how are the factors related) or why (why do these dynamics exist) of STS. In several instances, the authors of the following papers note that the description, "socio-technical systems", is not adequate for the new conceptualizations.

Each of the authors within this special issue explore whether and how insights from STS inform theory development in technology and innovation management. The authors also present discussions of what it means to go beyond STS to grapple with critical developments in technology studies. We argue that STS thinking fits work in technology and innovation for two reasons: its general premises regarding the nature of technology mirror the perspectives of most *Journal of Engineering and Technology Management*readers; and its specific theory regarding the dynamics of socio-technical interactions prompts us to do a better job of articulating particular research dynamics, thus going beyond STS. The five articles in this special issue among them summarize the basic STS principles and their historical development.

2. Crystallizing themes

Our purpose in this introduction is to use the STS perspective as a lens into the current and future developments in technology and innovation management, rather than to elaborate upon STS thinking per se. We found in the process of putting together this special issue that three themes about socio-technical dynamics crystallize some of the rather amorphous thinking in our far-flung, multi-disciplinary fields into central thrusts for research and theory development. The three themes are: *Beyond Technological Determinism*, *Beyond Industrial Efficiency* and *Beyond Rational/Functional Thinking*. We summarize below how STS thinking took the study of management beyond the fairly limited, deterministic understandings in these three areas. We also draw upon the articles to suggest how technology studies can go further beyond these early STS breakthroughs, either by extending STS itself or by leaping beyond the STS paradigm entirely.

We think it is time for technology researchers to delve more systematically into these dynamics, and to explore the differences in kind or degree among the connections and relationships, so we can develop sharper, clearer theories about technology development and change. However, while many technology and innovation management researchers take for granted that the social interacts somehow with the technological, the actual nature of these relationships remain confusing, under-explored or unarticulated across our large, multi-disciplinary literature. The STS perspective specifies particular dynamics, so the process of considering which dynamics fit or do not force us to flesh out our thinking in technology management. The themes outlined below highlight three kinds of dynamics in technology study, which we believe need more development: (1) our various definitions of the technology system, and how these might conflict with, complement or challenge alternate views; (2) our understandings of work itself, which sits at the center of the socio-technical interaction; and (3) our views of the social side of the overall process, and how these shape work and technology.

3. Beyond technological determinism

The original STS thinkers made a critical contribution by breaking decisively with the notion of technological determinism. Technological determinism says that "technology is the major causal factor affecting other organizational attributes, intraorganizational activities and interorganizational behavior" (Katz and Kahn, 1978, p. 279). Thus, technological determinism presumes that if one knows the state of technical advance in any given industry, one can predict the organizational consequences. More specifically, it presumes that the introduction of a particular technology such as a robotic welding system on an assembly line, an automated accounting system or an improved method for mining coal, will improve productivity or efficiency. Social scientists have long argued against these simplistic notions (Weber, 1947), but the STS studies grounded the question of technology and social organization in the everyday world of work, making their ideas particularly relevant to management scholars. They also vividly illustrated the interactions between the technology, and the psychological, social–psychological and sociological conditions of the work group, making their ideas also particularly relevant to technology and innovation scholars.

The STS perspective went beyond technological determinism in two ways: (1) by opening up the technology "black box',' so technology could be studied in detail; and (2) by bringing notions of systems theory that were in the air at the time, down to earth, so that the implications of systems thinking became more comprehensible (cf. von Bertalanffy, 1950). First, Trist and Bamforth (1951) analysis of technological change in coal mining showed that the old method of mining coal depended on intensive collaboration between two or three skilled miners, who worked with extensive autonomy over specific methods such as how they used explosives, extracted coal or built roof supports. The new long wall technology was designed to maximize the potential of the machine in extracting large quantities of coal in a long horizontal seam. However, the new design was not as efficient as predicted, and led to a number of serious problems because the worker's knowledge was not properly used. Workers could not coordinate effectively despite the extreme interdependence among tasks introduced by the new method, and they were left with no way to deal with the inherent dangers of the work. Trist and Bamforth argued that the technological integration required social integration, that authority over work needed to fit the task, and that if the situation called for adaptation as this one did, the technological system had to be adaptable.

The STS view came to focus in a particular way that social and technical go hand in hand: "The technical demand places limits on the type of work organization possible, but a work organization has social and psychological properties of its own that are independent of technology" (Rice, 1958, p. 4), or since STS includes people as well as tools, it is appropriate to ask how well a STS utilizes tools, utilizes the abilities of people and meets their needs

(Katz and Kahn, 1972). This focus has remained a foundation of STS approaches, but as will be seen in this issue, has received new and extended interpretations.

3.1. Going further beyond technological determinism

Several of the authors in this special issue suggest that technology studies can go beyond the traditional STS perspective in both the technology and the social system areas. The traditional STS perspective does not delve into the technology system as fully as they delved into the social system, so the particular dynamics within technology as a system and how this system is itself developed remain underexamined. Indeed, many STS writers focus only on production technology (see Heller, this issue, for notable exceptions).

We suggest that technology researchers explore the perception of technology more deliberately, so researchers can elaborate better upon technology's various aspects, dynamics and development paths. For example, Orlikowski (1992) outlines distinct perceptions of technology that each have different dynamics: technology as a product of ongoing human action, which downplays its material nature; technology as a material object whose meaning is defined by the context of use, which downplays its adaptive nature; technology in the Marxist tradition, which downplays its appropriation by workers or users. Other views define technology as a system of core versus peripheral components and their linkages (Tushman and Murmann, 1998); as knowledge and the outcome of collective sensemaking; or as an architecture of modules and interfaces (Sanchez, 1995). Each of these views focus on certain dynamics but perhaps overlook others or perhaps provide a particularly insightful way to understand certain issues.

As alluded to above, research on social construction of technology meaning/perceptions may be especially valuable for future research. Social construction speaks of the duality (Orlikowski, 1992) of technological design. According to Weick (1990) notes, there is a technology in the head and a technology on the floor. The technology on the floor is designed and redesigned by a process of social construction — the technology's design and meaning is enacted (Weick, 1979) within a social system. Likewise, the organizational structure relating to the technological system is socially constructed (Barley, 1986). Thus, even before an STS organizational design process can begin, the understanding and meaning of the "S" and the "T" must be constructed. Indeed, within each particular group, the use and meaning of the socio-technical system will be negotiated (DeSanctis and Poole, 1994; DeSanctis et al., 2000). This is the extreme opposite of a belief in technological determinism. Not only does the technology not independently determine organizational outcomes, but even the technology itself must be considered in its social context to be fully understood.

It was interesting for us that only two of the papers in this special issue have strong connections to the concepts of social construction. Kaghan and Bowker present actor network theory (ANT) as an approach to understanding large socio-technical systems. ANT speaks of the relationships between human, non-human and "hybrid" human/non-human actors and how these relationships are negotiated over time. They argue that STS is often unrecognized precursor to perspectives such as ANT. One of their conclusions is that the pragmatist/culturalist perspectives such as STS and ANT can learn from more rationalist/functionalist approaches — a powerful conclusion when considered in context with Majchrzak and Borys' attempt to do just that.

Heller presents the second paper making a strong connection to social construction. He raises issues related to social construction through his focus on joint optimization — that is, both the social and the technical systems (e.g. the mining machinery and social/organizational arrangements of a coal mine, Trist and Bamforth, 1951) must be managed as an interaction. Interestingly, the tightness of the interaction, the dual nature of technology as both socially constructed in design and in use, were not a clear part of the early thinkers' models. Heller provides the following quote: "socio-technical systems, however, are composed of two distinct systems which, although correlative, are governed by different laws" (Trist and Murray, 1993, p. 588).

While we believe it is true that joint optimization has largely been left out of critical STS presentations, it has been widely used in research, even if not by name. Katz and Kahn (1972) note in describing STS, "two questions of goodness-of-fit are thus raised: the fit between the social and the technical aspects of an organization, and the fit between the resulting socio-technical structure and the human characteristics of the people who enter it" (p. 701). Barley (1986) remarks that "... since technologies exist as objects in the realm of action, one cannot hope to understand a technology's implications for structuring without investigating how the technology is incorporated into the everyday life of an organization's members" (p. 81). DeSanctis and Poole (1994) write, "there is a 'duality' of structure (Orlikowski, 1992) whereby there is an interplay between the types of structure that are inherent to advanced technologies ... and the structures that emerge in human action as people interact with these technologies" (p. 122). Joint optimization, though not in those words, is addressed in the context of a group support system information technology: "... the social components of an organization are combined with the technical components in an attempt to create a balanced and synergistic relationship" (Griffith et al., 1998, p. 21).

Part of the issue may be with the difficulty of explicating these issues. Only recently have more fine-grained methods been presented for studying what is becoming known as the adaptive structuration process (DeSanctis and Poole, 1994; DeSanctis et al., 2000; Griffith, 1999). Adaptive structuration theory posits that groups' structure, task, and appropriation of a technology are jointly involved in determining the outcomes of a group's technology use (DeSanctis and Poole, 1994). However, there is a fine line between effective explication and assuming away critical processes and appropriate care should be taken.

Three of the papers take an additional tack going further beyond STS' break with technological determinism. These authors indicate that basic STS thinking can no longer address the socio-economic-political environment of organizations. Hirschhorn, Noble, and Rankin argue that the shift from mass production to mass customization changes the technology, the work, and thus the features of the social system that should be optimized. Kaghan and Bowker suggest that STS thinking fails to address the social and political dynamics of technology as a large system that spans both distance and time (e.g. train systems, major science). They suggest that actor network theory provides a better systems approach because it incorporates key social dynamics for reducing ambiguity and openness, and for mediating among parts of the system. Molleman and Broekuis discuss the shift in organizational outcomes relating to price, quality, and flexibility in innovation, and how this subsequently affects the importance of STS practices. A theme of organizational learning (Argote, 1999) also runs, in varying amounts, through each of these papers. This highlights the dynamism that may, or may not be, changing in organizational design.

A central challenge to technology and innovation management researchers is to keep their understanding of technology and work real and grounded in actual practice, but to also push our thinking about relationships and social interactions. It is essential that we raise our core presumptions and taken-for-granted ideas about dynamics out of the background, and examine alternate aspects of and explanations for them.

4. Beyond industrial efficiency

The STS perspective also breaks significantly from the notion of "industrial efficiency", which says that well-informed managers or industrialists need only develop the right factors of production and arrange them in the right way to create profit. A significant contribution, we think, of the STS perspective is that it highlights the work itself and those who do it. However, as some authors in this special issue indicate, STS became increasingly focused on a particular kind of work, the factory floor, and so countered "industrial efficiency" with the principle of "industrial democracy". Despite its limited focus, the STS approach has developed specific techniques for diagnosing, analyzing, and designing factory work, and the article by Hirschhorn, Noble, and Rankin reminds us of how useful these techniques can be. The article by Majchrzak and Borys develops a series of propositions on the efficacy of these techniques. These authors propose a midrange theory about configurations of techniques that are constrained rather than ideal, so that some gaps in ideal organization design features can be compensated for by the combination of other features.

Additionally, Majchrzak and Borys note, and then refute, that the primary benefit to STS is its values. This perspective may be held by many researchers and practitioners who have been frustrated by the abstractness of STS principles. While many of the principles of STS are related to critical issues of organizational and technological system design, these principles have begged for more specific definition and testing. However, Principle 8 (at least in Cherns presentation, 1987, 1976), presents an idea that we are better able to grasp without "niceties" of empirical support — that an objective of organizational design should be to provide quality of work life (QWL). Thus, perhaps given the difficulty of empirically demonstrating the other aspects of STS, QWL has been a focal point for many perceptions of STS in general.

4.1. Going further beyond industrial efficiency

Studying technologists, engineers, scientists, and technicians at work has always been a strong thread in technology and innovation management work (e.g. Katz 1988; Bailyn, 1993; Thomas 1994). However, the fact that STS has become, as Hirschhorn, Noble, and Rankin state, a technical, moral and political discipline, perhaps, is off-putting to technology researchers who do not wish to subscribe to a particular ideology. We think that another key theme in technology research that now "floats" rather amorphously in the larger technology literature is something akin to QWL, but extended beyond the factory floor. Thus, technology researchers not only study the working lives of scientists and engineers (Pelz and Andrews, 1966), but also of customer support personnel (Pentland, 1995), technicians (Barley, 1996), product innovators (Dougherty, 2001), female engineers (Bailyn, 1987), telecommuters

(Bailyn, 1993), nuclear plant workers (Carroll, 1998), and flute makers (Cook and Brown, 1999). While these studies vary in intent and focus, they all concern work, people at work, and the various social dynamics of autonomy, control, and meaningfulness that the STS perspective emphasizes. We think that technology studies can go beyond STS to develop a more coherent understanding of work and the quality of work life to fit the broader groups of workers and professionals that we study. Ideas such as communities of practice, lateral coordination, and process organizing all go along with the study of work, and provide useful ways to frame the work system so that we can examine its socio-technical dynamics.

We also wonder about the outlook for STS in information focused, volatile settings. None of the following papers explicitly investigated the role of electronic commerce. At least one company, the computer sales company Egghead, has closed the doors to its “brick and mortar” stores in favor of pure electronic commerce. At the same time, the pure electronic commerce company (books, electronics, etc.), Amazon.com, is being challenged with the possibility of a physical presence. Clearly the issues of electronic commerce are related to the point raised by the some of the authors regarding the information age. Yet, given the historical awareness of STS researchers regarding the social side of organizational design, it is surprising that the social aspect of working within a pure electronic commerce organization are not mentioned.

5. Beyond the rational/functional assumptions

The rational/functional perspective, or what Burrell and Morgan (1979) term the structural/functional epistemology, is a third variation on the deterministic thinking that STS broke with. In this variation, it is assumed that once social structures such as teams, legitimate authority, formality of rules, divisional organizational designs, routines and so on are in place, the predicted social action occurs without problem (other than rational communication gaps). Thus, teams share work, people routinely follow the commands of senior managers, formal procedures are executed with fidelity, and so on. As Kaghan and Bowker argue in this Special Issue, the STS perspective explicitly acknowledged how people understand a structure or how a technology matters a great deal. These authors argue that according to Trist and Bamforth (1951), a more sensitive rethinking of socio-technical organization of work can lead to genuinely productive innovations, in which the social and psychological costs incurred by miners can be decreased while organization performance can be increased. STS theorists recognized that humans are more than thinking machines, that can be expected to adapt to economic or technological imperatives. One central premise is that some of the knowledge necessary to do the work is held by the workers, and is not in the purview of management. STS research assumes that peoples’ everyday thinking and acting is affected by their socio-cultural milieux: by the norms, perceptions, and understandings that they develop or acquire as they interact with others.

5.1. Going further beyond the rational/functional

Technology research today goes well beyond the STS idea that people are more than thinking machines who perform as expected, but instead bring their own needs, own understandings, indeed their own constructions of the situation, to bear. We can again draw on a rich palette of "social constructionist" ideas, ranging from the institutional dynamics developed by Berger and Luckmann (1967) analysis of the sociology of knowledge, Strauss (1978) dynamics of negotiated order, Weick (1979) enactment and double interacts, and Giddens (1979) thesis of structuration, which emphasizes the dual nature of social structures: they both constitute and are constituted by social action (or, social action mediates and is mediated by social structure). All of these views go beyond STS because the latter tends to ignore the technology once it is in place, while the social constructionist views embrace the dynamics of ongoing evolution, emergence, mutual constitution, appropriation, and interpretation of technology.

However, as with the areas of technology and quality of work, technology researchers use a variety of incommensurate or conflicting approaches about the so-called processes of social construction, which muddies our theories of the social dynamics involved in technology. As mentioned above, Kaghan and Bowker in this issue develop the implications of actor network theory for technology studies to advance our STS thinking. Other sociologists of technology and information technologists have developed another view of social construction that is not represented in this Special Issue but certainly informs our understanding of the social side of the socio-technical world (Bijker, 1995; Newman and Rosenberg, 1985). More recently, and as described earlier, DeSanctis and Poole (DeSanctis and Poole, 1994) present adaptive structuration theory. This approach brings the role of group process and function into the foreground, as well as the social construction of technology more generally.

Going further beyond the rational/functionalist views allows us to develop improved theories of organization and organizing, for example-the notion of "self-organizing" systems is that a manager or other knowledgeable person does not have to create and impose an order, because social order emerges as people interact and create a common understandings and routines.

6. Summary

Reviewing these papers provided us with the opportunity to study the history and development of STS theory from a safe distance and the diversity to gain a new perspective on the field. To us, a critical insight is that STS has not only continued to grow "beyond" its original boundaries, but may even be "beyond" some of the most cutting-edge theories in development today. We suggest that there are three categories of research open for further consideration — research that continues to move beyond technological determinism, beyond industrial efficiency, and beyond rational/functional thinking.

The following papers present a broad perspective on both the history and future of STS. We have outlined in this introduction, areas, where even further research is likely to make considerable contributions to the field. Is STS a theory? It would seem that in a constrained definition the answer is yes. Majchrzak and Borys show that it is possible to define aspects of STS with enough clarity to create testable theory. However, it is also apparent from the papers presented here that there remain widely disparate view of what STS actually is. While we agree with Molleman and Broekhuis' assessment that Cherns (1987) principle of incompletion applies to the study of STS itself, we also believe that several of the authors have taken profitable approaches by segmenting particular sections of STS for study.

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Beyond socio-technical systems: introduction to the special issue

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Abstract

This article serves as an introductory essay to the special issue of *Journal of Technology and Management* 18 (3–4). It identifies and articulates the broad themes of the five papers included in that issue. Additionally, it outlines areas where further research is likely to make considerable contributions to the field of socio-technical systems. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Socio-technical systems; Organizational design; Social construction

1. Role of socio-technical systems in engineering and technology management

Since the 1950s, researchers (and some managers) have acknowledged that technical and social factors interact to influence organizational outcomes. Work prior to the 1950s (and even some work today) often argued for technological determinism where technology implementations were expected to have direct effects, for example, if a robotic welding system is introduced on an assembly-line, production throughput will increase.

One of the first counters to the deterministic approach was made by Trist and Bamforth (1951). They noted that human and organizational outcomes could only be understood when social, psychological, environmental, and technological systems are assessed as a whole. This approach has come to be known as a socio-technical systems (STS) perspective. This perspective assumes that organizations are "made up of people (the social system) using tools, techniques and knowledge (the technical system) to produce goods or services valued by customers (who are part of the organization's external environment). How well the social and technical systems are designed with respect to one another and with respect to

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the demands of the external environment determines to a large extent how effective the organization will be" Rogers (1995).

Research building from STS continues through today. A recent special issue of *Human Relations* (in 1987) focuses on organization innovation and STS as a work design process (i.e. to be compared with reengineering). Spender (1996) uses the ideas of social construction and STS to discuss a knowledge theory of the firm. He concludes that STS "is unsuitable as the basis for a theory of the firm because it adopt[s] too naïve a view of social systems and ignore[es] economic interactions" (p. 55).

By contrasting Spender's comment with that of prior STS researchers it is possible to see that the concept of STS is being used in two different ways. Much STS work focuses on designing work for both organizational and human good. There is a normative slant in that the work suggests people should be involved in designing the relationships between technology and work. Quality of work life is a key consideration (e.g. Emery, 1969; Molleman and Broekhuis, 2001). The other perspective of STS is more theoretical. STS provides critical insights for understanding relationships between people, technology and organizational outcomes, and as Majchrzak and Borys (2001) note, was originally developed from open systems theory (von Bertalanffy, 1950). It is this perspective that Spender and others have indicated is a limited, but interesting, approach to understanding organizational outcomes.

This special issue is a further step in this dialog. While the early steps were taken in the 1950s, traditional organization theory (and, unfortunately, some current models) have treated "technology" as some kind of monolithic entity that lurked in the environment (Blau, 1956), or as a general representation of how the work of an organization gets done (cf. Woodward (1965)—small batch, mass production, continuous flow; Thompson (1967)—long linked, mediating or intensive technologies). However, technology is not a "disembodied force afoot in the land," to paraphrase Gouldner's (1954) characterization of organization and institutional thinking in the 1950s. Both STS thinking and most technology researchers understand technology as an actual system of physical, social, and cognitive elements that are built, used, and rebuilt by people in everyday practice. We can observe, manipulate, change, and make sense of technology (however complex it might be) and its relationships to the social setting.

STS thinking complements our field's attention to these practical dynamics of technology development, from the early days of R&D research (e.g. Schon's (1963) use of product champions to overcome "dynamically conservative" tendencies of organizations; Pelz and Andrews' (1966) analysis of creative tensions in managing R&D; Allen's (1977) studies of patterns of communication within and among project teams); to present concerns in concurrent engineering, design for manufacturing or CAD/CAM (Adler, 1995). These general concerns with socio-technical interactions are also found in studies of manufacturing innovations and their interactions with organizational structure (Ettlie, 1983; Leonard-Barton, 1988). In MIS, Sproull and Hofmeister (1986) unravel the interactions of individual cognition and technology use, such as with e-mail systems and the relationships between social roles, networks, and technology adoption. Still others (e.g. Weick, 1995) consider the co-evolution of social values and technological systems.

With this explosion of STS-like work in technology management, at all different levels of analysis and focused on such a variety of problems, we think it is time to explore the theory that they may, or may not, have in common. Do any or all of these relationships embody similar or different dynamics? Can we build a broad socio-technical theory that explains the linkages at so many levels and/or for so many technology issues, or are there different kinds of socio-technical connections that require different theories? Perhaps, a comprehensive theory is not possible—that instead only subsets of levels, problems, and other dimensions should be considered. Alternatively, future work may find that a comprehensive theory is possible and provides a new approach to our understanding.

This special issue presents papers that go beyond STS as a rather vague description to develop more explanatory theories of technology–organizational outcomes. Each of these papers moves theory and research forward by explicating more clearly the what (what factors), how (how are the factors related), or why (why do these dynamics exist) of STS. In several instances, the authors of the following papers note that the description, “socio-technical systems”, is not adequate for the new conceptualizations.

Each of the authors within this special issue explores whether and how insights from STS inform theory development in technology and innovation management. The authors also present discussions of what it means to go beyond STS to grapple with critical developments in technology studies. We argue that STS thinking fits work in technology and innovation for two reasons: its general premises regarding the nature of technology mirror the perspectives of most *Journal of Engineering and Technology Management* readers; and its specific theory regarding the dynamics of socio-technical interactions prompts us to do a better job of articulating particular research dynamics, thus, going beyond STS. The five articles in the special issue among them summarize the basic STS principles and their historical development.

2. Crystallizing themes

Our purpose in this introduction is to use the STS perspective as a lens into the current and future developments in technology and innovation management, rather than to elaborate upon STS thinking per se. We found in the process of putting together this special issue that three themes about socio-technical dynamics crystallize some of the rather amorphous thinking in our far-flung, multi-disciplinary fields into central thrusts for research and theory development. The three themes are: *beyond technological determinism, beyond industrial efficiency,* and *beyond rational/functional thinking*. We summarize below how STS thinking took the study of management beyond the fairly limited, deterministic understandings in these three areas. We also draw upon the articles to suggest how technology studies can go further beyond these early STS breakthroughs, either by extending STS itself or by leaping beyond the STS paradigm entirely.

We think it is time for technology researchers to delve more systematically into these dynamics, and to explore the differences in kind or degree among the connections and relationships, so we can develop sharper, clearer theories about technology development and change. However, while many technology and innovation management researchers take for granted that the social interacts somehow with the technological, the actual nature of these relationships remain confusing, under-explored, or unarticulated across our large, multi-disciplinary literature. The STS perspective specifies particular dynamics, so the process of considering which dynamics fit or do not forces us to flesh out our thinking in technology management. The themes outlined below highlight three kinds of dynamics in technology studies that we believe need more development: (1) our various definitions of the technology system, and how these might conflict with, complement, or challenge alternate views; (2) our understandings of work itself, which sits at the center of the socio-technical interaction; and (3) our views of the social side of the overall process, and how these shape work and technology.

3. Beyond technological determinism

The original STS thinkers made a critical contribution by breaking decisively with the notion of technological determinism. Technological determinism says that "technology is the major causal factor affecting other organizational attributes, intraorganizational activities, and interorganizational behavior" (Katz and Kahn, 1978, p. 279). Thus, technological determinism presumes that if one knows the state of technical advance in any given industry, one can predict the organizational consequences. More specifically, it presumes that the introduction of a particular technology, such as a robotic welding system on an assembly line, an automated accounting system, or an improved method for mining coal, will improve productivity or efficiency. Social scientists have long argued against these simplistic notions (Weber, 1947), but the STS studies grounded the question of technology and social organization in the everyday world of work, making their ideas particularly relevant to management scholars. They also vividly illustrated the interactions between technology, and the psychological, social–psychological, and sociological conditions of the work group, making their ideas also particularly relevant to technology and innovation scholars.

The STS perspective went beyond technological determinism in two ways: (1) by opening up the technology "black box" so technology could be studied in detail; and (2) by bringing notions of systems theory that were in the air at the time, down to earth, so that the implications of systems thinking became more comprehensible (cf. von Bertalanffy, 1950). First, Trist and Bamforth's (1951) analysis of technological change in coal mining showed that the old method of mining coal depended on intensive collaboration between two or three skilled miners who worked with extensive autonomy over specific methods such as how they used explosives, extracted coal, or built roof supports. The new long wall technology was designed to maximize the potential of the machine in extracting large quantities of coal in a long horizontal seam. However, the new design was not as efficient as predicted, and led to a number of serious problems because the workers' knowledge was not properly used. Workers could not coordinate effectively despite the extreme interdependence among tasks introduced by the new method, and they were left with no way to deal with the inherent dangers of the work. Trist and Bamforth argued that the technological integration required social integration, that authority over work needed to fit the task, and that if the situation called for adaptation as this one did, the technological system had to be adaptable.

The STS view came to focus on a particular way that social and technical go together: "the technical demand places limits on the type of work organization possible, but a work organization has social and psychological properties of its own that are independent of technology" (Rice, 1958, p. 4). Or since STS includes people as well as tools, it is appropriate to ask how well a STS utilizes tools, utilizes the abilities of people, and meets their needs

(Katz and Kahn, 1972). This focus has remained a foundation of STS approaches, but as will be seen in the special issue, has received new and extended interpretations.

3.1. Going further beyond technological determinism

Several of the authors in the special issue suggest that technology studies can go beyond the traditional STS perspective in both the technology and the social system areas. The traditional STS perspective does not delve into the technology system as fully as the social system, so the particular dynamics within technology as a system and how this system is itself developed remain underexamined. Indeed, many STS writers focus only on production technology (see Heller, 2001, for notable exceptions).

We suggest that technology researchers explore the perception of technology more deliberately, so researchers can elaborate better upon technology's various aspects, dynamics and development paths. For example, Orlikowski (1992) outlines distinct perceptions of technology that each have different dynamics: technology as a product of ongoing human action, which downplays its material nature; technology as a material object whose meaning is defined by the context of use, which downplays its adaptive nature; technology in the Marxist tradition, which downplays its appropriation by workers or users. Other views define technology as a system of core versus peripheral components and their linkages (Tushman and Murmann, 1998); as knowledge and the outcome of collective sensemaking; or as an architecture of modules and interfaces (Sanchez, 1995). Each of these views focuses on certain dynamics but perhaps overlook others or perhaps provides a particularly insightful way to understand certain issues.

As alluded to above, research on social construction of technology meaning/perceptions may be especially valuable for future research. Social construction speaks of the duality (Orlikowski, 1992) of technological design. According to Weick (1990), there is a technology in the head and a technology on the floor. The technology on the floor is designed and redesigned by a process of social construction—the technology's design and meaning is enacted (Weick, 1979) within a social system. Likewise, the organizational structure relating to the technological system is socially constructed (Barley, 1986). Thus, even before an STS organizational design process can begin, the understanding and meaning of the "S" and the "T" must be constructed. Indeed, within each particular group, the use and meaning of the socio-technical system will be negotiated (DeSanctis and Poole, 1994; DeSanctis et al., 2000). This is the extreme opposite of a belief in technological determinism. Not only does the technology not independently determine organizational outcomes, but even the technology itself must be considered in its social context to be fully understood.

It was interesting to us that only two of the papers in the special issue have strong connections to the concepts of social construction. Kaghan and Bowker (2001) present actor network theory (ANT) as an approach to understanding large socio-technical systems. ANT speaks of the relationships between human, non-human and "hybrid" human/non-human actors and how these relationships are negotiated over time. They argue that STS is often an unrecognized precursor to perspectives such as ANT. One of their conclusions is that the pragmatist/culturalist perspectives such as STS and ANT can learn from more rationalist/functionalist approaches—a powerful conclusion when considered in context with Majchrzak and Borys' (2001) attempt to do just that.

Heller (2001) presents the second paper making a strong connection to social construction. He raises issues related to social construction through his focus on joint optimization—that is, that both the social and the technical systems (e.g. the mining machinery and social/organizational arrangements of a coal mine, Trist and Bamforth, 1951) must be managed as an interaction. Interestingly, the tightness of the interaction, the dual nature of technology as both socially constructed in design and in use, was not a clear part of the early thinkers' models. Heller provides the following quote: "socio-technical systems, however, are composed of two distinct systems which, although correlative, are governed by different laws" (Trist and Murray, 1993, p. 588).

While we believe it is true that joint optimization has largely been left out of critical STS presentations, it has been widely used in research, even if not by name. Katz and Kahn (1972) note in describing STS, "two questions of goodness-of-fit are thus raised: the fit between the social and the technical aspects of an organization, and the fit between the resulting socio-technical structure and the human characteristics of the people who enter it" (p. 701). Barley (1986) remarks that "... since technologies exist as objects in the realm of action, one cannot hope to understand a technology's implications for structuring without investigating how the technology is incorporated into the everyday life of an organization's members" (p. 81). DeSanctis and Poole (1994) write, "there is a 'duality' of structure (Orlikowski, 1992) whereby there is an interplay between the types of structure that are inherent to advanced technologies ... and the structures that emerge in human action as people interact with these technologies" (p. 122). Joint optimization, though not in those words, is addressed in the context of a group support system information technology: "... the social components of an organization are combined with the technical components in an attempt to create a balanced and synergistic relationship" (Griffith et al., 1998, p. 21).

Part of the issue may be with the difficulty of explicating these issues. Only recently have more fine-grained methods been presented for studying what is becoming known as the adaptive structuration process (DeSanctis and Poole, 1994; DeSanctis et al., 2000; Griffith, 1999). Adaptive structuration theory posits that groups' structure, task, and appropriation of a technology are jointly involved in determining the outcomes of a group's technology use (DeSanctis and Poole, 1994). However, there is a fine line between effective explication and assuming away critical processes and appropriate care should be taken.

Three of the papers take an additional tack going further beyond STS' break with technological determinism. These authors indicate that basic STS thinking can no longer address the socio-economic-political environment of organizations. Hirschhorn, Noble, and Rankin (2001) argue that the shift from mass production to mass customization changes the technology, the work, and thus, the features of the social system that should be optimized. Kaghan and Bowker (2001) suggest that STS thinking fails to address the social and political dynamics of technology as a large system that spans both distance and time (e.g. train systems, major science). They suggest that actor network theory provides a better systems approach because it incorporates key social dynamics for reducing ambiguity and openness, and for mediating among parts of the system. Molleman and Broekhuis (2001) discuss the shift in organizational outcomes relating to price, quality, and flexibility in innovation, and how this subsequently affects the importance of STS practices. A theme of organizational learning (Argote, 1999) also runs, in varying amounts, through each of these papers. This highlights the dynamism that may, or may not be, changing in organizational design.

A central challenge to technology and innovation management researchers is to keep their understanding of technology and work real and grounded in actual practice, while also pushing our thinking about relationships and social interactions. It is essential that we raise our core presumptions and taken-for-granted ideas about dynamics out of the background, and examine alternate aspects of and explanations for them.

4. Beyond industrial efficiency

The STS perspective also breaks significantly from the notion of "industrial efficiency", which says that well-informed managers or industrialists need only develop the right factors of production and arrange them in the right way to create profit. A significant contribution, we think, of the STS perspective is that it highlights the work itself and those who do it. However, as some authors in the special issue indicate, STS became increasingly focused on a particular kind of work, the factory floor, and so countered "industrial efficiency" with the principle of "industrial democracy." Despite its limited focus, the STS approach has developed specific techniques for diagnosing, analyzing, and designing factory work, and the article by Hirschhorn, Noble, and Rankin (2001) reminds us of how useful these techniques can be. The article by Majchrzak and Borys (2001) develops a series of propositions on the efficacy of these techniques. These authors propose a midrange theory about configurations of techniques that are constrained rather than ideal, so that some gaps in ideal organization design features can be compensated for by the combination of other features.

Additionally, Majchrzak and Borys (2001) note, and then refute, that the primary benefit to STS is its values. This perspective may be held by many researchers and practitioners who have been frustrated by the abstractness of STS principles. While many of the principles of STS are related to critical issues of organizational and technological system design, these principles have begged for more specific definition and testing. However, Principle 8 (at least in Cherns presentation, 1987, 1976), presents an idea that we are better able to grasp without "niceties" of empirical support—that an objective of organizational design should be to provide quality of work life (QWL). Thus, perhaps given the difficulty of empirically demonstrating the other aspects of STS, QWL has been a focal point for many perceptions of STS in general.

4.1. Going further beyond industrial efficiency

Studying technologists, engineers, scientists, and technicians at work has always been a strong thread in technology and innovation management work (e.g. Katz 1988; Bailyn, 1993; Thomas 1994). However, the fact that STS has become, as Hirschhorn, Noble, and Rankin (2001) state, a technical, moral and political discipline, perhaps, is off-putting to technology researchers who do not wish to subscribe to a particular ideology. We think that another key theme in technology research that now "floats" rather amorphously in the larger technology literature is something akin to QWL, but extended beyond the factory floor. Thus, technology researchers not only study the working lives of scientists and engineers (Pelz and Andrews, 1966), but also of customer support personnel (Pentland, 1995), technicians (Barley, 1996), product innovators (Dougherty, 2001), female engineers (Bailyn, 1987), telecommuters (Bailyn, 1993), nuclear plant workers (Carroll, 1998), and flute makers (Cook and Brown, 1999). While these studies vary in intent and focus, they all concern work, people at work, and the various social dynamics of autonomy, control, and meaningfulness that the STS perspective emphasizes. We think that technology studies can go beyond STS to develop a more coherent understanding of work and the quality of work life to fit the broader groups of workers and professionals that we study. Ideas such as communities of practice, lateral coordination, and process organizing all go along with the study of work, and provide useful ways to frame the work system so that we can examine its socio-technical dynamics.

We also wonder about the outlook for STS in information focused, volatile settings. None of the following papers explicitly investigated the role of electronic commerce. At least one company, the computer sales company Egghead, has closed the doors to its "brick and mortar" stores in favor of pure electronic commerce. At the same time, the pure electronic commerce company (books, electronics, etc.), Amazon.com, is being challenged with the possibility of a physical presence. Clearly the issues of electronic commerce are related to the point raised by some of the authors regarding the information age. Yet, given the historical awareness of STS researchers regarding the social side of organizational design, it is surprising that the social aspects of working within a pure electronic commerce organization are not mentioned.

5. Beyond the rational/functional assumptions

The rational/functional perspective, or what Burrell and Morgan (1979) term the structural/functional epistemology, is a third variation on the deterministic thinking that STS broke with. In this variation, it is assumed that once social structures such as teams, legitimate authority, formality of rules, divisional organizational designs, routines, and so on are in place, the predicted social action occurs without problem (other than rational communication gaps). Thus, teams share work, people routinely follow the commands of senior managers, formal procedures are executed with fidelity, and so on. As Kaghan and Bowker (2001) argue in the special issue, the STS perspective explicitly acknowledged that how people understand a structure or a technology matters a great deal. These authors argue that according to Trist and Bamforth (1951), a more sensitive rethinking of socio-technical organization of work can lead to genuinely productive innovations, in which the social and psychological costs incurred by miners can be decreased while organization performance can be increased. STS theorists recognized that humans are more than thinking machines that can be expected to adapt to economic or technological imperatives. One central premise is that some of the knowledge necessary to do the work is held by the workers, and is not in the purview of management. STS research assumes that peoples' everyday thinking and acting is affected by their socio-cultural milieux: by the norms, perceptions, and understandings that they develop or acquire as they interact with others.

5.1. Going further beyond the rational/functional assumptions

Technology research today goes well beyond the STS idea that people are more than thinking machines who perform as expected, but instead bring their own needs, own understandings, indeed their own constructions of the situation, to bear. We can again draw on a rich palette of "social constructionist" ideas, ranging from the institutional dynamics developed by Berger and Luckmann's (1967) analysis of the sociology of knowledge, Strauss' (1978) dynamics of negotiated order, Weick's (1979) enactment and double interacts to Giddens' (1979) thesis of structuration, all of which emphasizes the dual nature of social structures: they both constitute and are constituted by social action (or, social action mediates and is mediated by social structure). All of these views go beyond STS because the latter tends to ignore the technology once it is in place, while the social constructionist views embrace the dynamics of ongoing evolution, emergence, mutual constitution, appropriation, and interpretation of technology.

However, as with the areas of technology and quality of work, technology researchers use a variety of incommensurate or conflicting approaches about the so-called processes of social construction, which muddies our theories of the social dynamics involved in technology. As mentioned above, Kaghan and Bowker (2001) develop the implications of actor network theory for technology studies to advance our STS thinking. Other sociologists of technology and information technologists have developed another view of social construction that is not represented in this special issue but certainly informs our understanding of the social side of the socio-technical world (Bijker, 1995; Newman and Rosenberg, 1985). More recently, and as described earlier, DeSanctis and Poole (1994) present adaptive structuration theory. This approach brings the role of group process and function into the foreground, as well as the social construction of technology more generally.

Going further beyond the rational/functionalist views allows us to develop improved theories of organization and organizing. For example, the notion of "self-organizing" systems is that a manager or other knowledgeable person does not have to create and impose an order, because social order emerges as people interact and create common understandings and routines.

6. Summary

Reviewing these papers provided us with the opportunity to study the history and development of STS theory from a safe distance and the diversity to gain a new perspective on the field. To us, a critical insight is that STS has not only continued to grow "beyond" its original boundaries, but may even be "beyond" some of the most cutting-edge theories in development today. We suggest that there are three categories of research open for further consideration—research that continues to move beyond technological determinism, beyond industrial efficiency, and beyond rational/functional thinking.

The following papers present a broad perspective on both the history and future of STS. We have outlined in this introduction areas where even further research is likely to make considerable contributions to the field. Is STS a theory? It would seem that in a constrained definition the answer is yes. Majchrzak and Borys (2001) show that it is possible to define aspects of STS with enough clarity to create testable theory. However, it is also apparent from the papers presented here that there remain widely disparate views of what STS actually is. While we agree with Molleman and Broekhuis' (2001) assessment that Cherns' (1987) principle of incompletion applies to the study of STS itself, we also believe that several of the authors have taken profitable approaches by segmenting particular sections of STS for study.

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