Theoretical Frameworks for the Study of Structuring Processes in Group Decision Support Systems

Adaptive Structuration Theory and Self-Organizing Systems Theory

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Most theoretical perspectives used to explain the use and effects of communication and decision support technologies assume some form of technological determinism. Inconsistencies in the research findings have prompted theorists to reject the assumptions of technological determinism in favor of an emergent perspective. To date, only adaptive structuration theo y (AST) offers the promise of satisfying two requirements for explanation based on an emergent perspective: recursivify and unique effects. The current article reviews the application of AST to the study of a relatively recent technology in the work place—group decision support systems (GDSS). Next it discusses AST's challenge to capture, dynamically and precisely, GDSS processes and outcomes. In response to these concerns, self-organizing systems theory (SOST) is reviewed and applied to problematic areas in GDSS research with the aim of advancing AST.

The introduction of new communication and decision support technologies into the workplace has had significant impacts on organizational life (Johansen, 1988, 1989; Kling

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Human Communication Research, Vol. 19 No. 4, June 1993 528-563

& Scacchi, 1982; Sproull & Kiesler, 1991). These technologies are heralded by proponents as helping to make individuals, groups, and organizations more effective and productive (Hiltz, 1988). However, reviews of the research on computer conferencing (Rice, 1984; Short, Williams, & Christie, 1976), videoconferencing (Johansen, 1977), electronic mail (Panko, 1984), and group decision support systems (Hollingshead & McGrath, in press; Seibold, Heller, & Contractor, in press) have failed to find consistent support for these claims.

Malone (1985) points out that the majority of past research is based on the suspect premise that the impact of a technology is consistent across adopting individuals, groups, and organizations. However, many recent theorists reject this technologically deterministic view, proposing instead that the uses and effects of communication technologies are better studied from an emergent *perspective* (Contractor & Eisenberg, 1990; Fulk, Schmitz, & Steinfield, 1990; Markus, 1990; Markus & Robey, 1988; Poole & DeSanctis, 1990). The emergent perspective is based on the assumption that the uses and effects of communication technology emerge on the basis of complex social interactions among users. Moving toward an emergent perspective-and away from the univalent effects hypothesis associated with the technological imperative--entails at least two requirements. *First,* it requires precise longitudinal examination of the social practices involved in the use of technologies by groups and the organizations in which they are embedded. This would include articulation of the reciprocal relationships among goals, technology, actions, and interactions that constitute the appropriation of technologies (Contractor & Eisenberg, 1990). Second, the recursive interplay among goals, technologies, and actors in an emergent perspective must account for how specific groups of users assimilate technologies within their own streams of work activity. That is, an emergent perspective must be capable of explaining how groups with similar composition, working on identical tasks, perceive and use the same technologies differently (Barley, 1990; Lewis & Seibold, 1992).

In this article, we undertakefour tasks. We begin by offering a brief description of a relatively recent technology in the workplace-group decision support systems (GDSS). Second, we highlight inconsistencies in the empirical findings on its uses and effects. We note that to date only one theoretical perspective-adaptive structuration theory (AST; Poole & DeSanctis, 1990, 1992)—offers the promise of satisfying the dual requirements of an emergent perspective (recursivity and an explanation of unique effects) set forth above. Next, we identify challenges to AST for capturing precisely and dynamically GDSS processes and outcomes. In the final section, and with the hope of advancing AST, we review self-organizing systems theory (SOST) and demonstrate its application to problematic areas in GDSS research. In brief, we argue that SOST is a meaningful complement to, and extension of, AST insofar as it conceptually and empirically clarifies important areas of AST that are vague and nondynamic. We offer an SOST simulation of GDSS processes that demonstrates this potential and conclude with derivation and discussion of six empirically testable hypotheses that extend AST predictions.

GROUP DECISION SUPPORT SYSTEMS: AN OVERVIEW

The microcomputer revolution has expanded decision makers' bounds of rationality by enabling the storage and easy retrieval of large amounts of information (Zander, 1979). Initially, the microcomputer was a "stand alone" tool used primarily by individuals. In the area of decision making, for example, managers began using decision support systems (DSS) software on their personal computers to aid with semistructured decisions and to enhance judgment.

Until recently, group decision making was relatively unaffected by microcomputer technology or attendant software. However, the introduction of computer networking enabled users to communicate with one another (Kiesler & Sproull, 1992; Licklider & Vezza, 1978; Sproull & Kiesler, 1991). This capability, coupled with the increased number of personal computer users in organizations and continued pressures for better decision making, has prompted interest in the use of computer support for meetings and other group-related activities in research communities (Wulf, 1989) and in businesses (Johansen, 1989). These tools have been described in a number of ways including "groupware," computer-supported cooperative work (CSCW), electronic meeting systems (EMS), and group decision support systems (GDSS)-a label we use throughout this article.

GDSS decision makers typically have access to one or more of the following tools: software for facilitating and structuring text and graphic-based computer-mediated communication, a common electronic display (see Stefik & Brown, 1989), software for problem-solving procedures such as rank ordering alternatives (see Hiltz, Johnson, & Turoff, 1987) and decision-analysis software, and even

expert support systems (Malone, Grant, Lai, Rao, & Rosenblitt, 1989). These technologies are designed to improve group performance by providing additional channels for group members to display information and to communicate (to the entire group or to select members). The emphasis is on giving group members "access to the positive aspects for coordination-not just preventing collisions" (Greif, 1988, p. 9). Seibold et al. (in press) offer a detailed discussion of differences among current GDSSs and their respective features.

Review of Empirical Research on GDSS

Although this technology is relatively new, there has been a plethora of GDSS research. A bibliography of GDSS-related references (DeSanctis, 1989) contained over 250 published and unpublished entries. More than 75% of the (dated) citations were fewer than 5 years old. Although the majority of GDSS research has focused on exploring new options and designing prototypes (for reviews, see Dhar & Olson, 1989; Galegher, Kraut, & Egido, 1990; Greif, 1988), there is an emerging body of findings concerning GDSS effects on group members, processes, and outcomes (Culnan & Markus, 1987).

A review of this literature revealed that even studies using similar levels of computer support for group sessions did not report consistent effects (Hollingshead & McGrath, in press; McLoed & Liker, 1991; Seibold et al., in press). For example, whereas a number of investigations found that member satisfaction and group consensus was *enhanced* in GDSS groups, other studies revealed no *differences* beyond chance expectation. Further, although some studies revealed significant decreases in members' rates of participation in GDSS groups, others found that participation was significantly ***higher*** in computer-supported groups. Although some of these variations may be attributable to systematic sample and measurement differences, it was equally apparent that the hypotheses in the studies reviewed were rooted in the (flawed) premise that the impact of the technology *ought* ***to be consistent*** across groups using it.

In GDSS research, like other research on the social organization of work, the "technological imperative" assumption has been found wanting (Malone, 1985; Markus & Robey, 1988). Accordingly, Seibold et al. (in press) closed their review of GDSS research by proposing that the use and effects of GDSS be informed by the "emergent perspective."

Several theoretical perspectives have been spawned or appropriated by GDSS researchers: social presence (Short et al., 1976), media richness (Daft & Lengel, 1986), social information processing (Fulk et al., 1990). However, to date only one theoretical perspective undergirding current GDSS research offers the promise of satisfying the dual requirements (recursivity and an explanation of unique effects) set forth above: adaptive structuration theory (AST; Poole & DeSanctis, 1990). In the following section, we explicate AST and briefly review empirical findings reported by Poole and colleagues.

ADAPTIVE STRUCTURATION THEORY

Adaptive structuration theory (AST) has been discussed and tested in a number of recent articles (e.g., DeSanctis, D'Onofrio, Sambamurthy, & Poole, 1989; DeSanctis & Poole, 1991; DeSanctis, Poole, Deshamais, & Lewis, 1992; DeSanctis, Poole, Dickson, & Jackson, in press; Holmes & Poole, 1991; Poole & DeSanctis, 1989; Poole, DeSanctis, Kirsch, &Jackson, 1991; Poole, Holmes & DeSanctis, 1991; Poole, Holmes, Watson, & DeSanctis, 1990), but the most complete explication of the theory is provided by Poole and DeSanctis (1990, 1992). AST proceeds from the assumption that groups are organized around a variety of practices that are task-related and social in character, practices unlikely to be supplanted by GDSS. Furthermore, because GDSS technologies can only be analyzed in terms of the uses groups make of them, it is within these practices that GDSS must be interpreted. GDSS effects on any of these practices, including decision making, are best understood in terms of "the structures this technology promotes in the group: They provide *rules,* such as voting routines and resources, such as data bases, which can be used by groups in the structuring process" (p. 179; emphasis added). Whereas any observable system of GDSS use may be of interest, it is the analysis of structures that is therefore central to understanding how and why systems of GDSS use appear as they do.

Poole and DeSanctis (1990) distinguish between two senses of technological structure: *spirit,* or the "general goals and attitudes that the technology seeks to promote (such as democratic decision-making)", and the particular *"structural features* built into the system (such as anonymous input of ideas, or one vote per member)" (p. 179; emphasis added). These two aspects of GDSS structures typically interpenetrate but occasionally stand in contradiction to each other. The authors' account of "how these structures enter into active use" in the groups that GDSSs are intended to support-the focus of their

theory of adaptive structuration—draws heavily on British social theorist Anthony Giddens's (1979, 1984) theory of structuration. "Structuration" refers to the process by which systems are produced and reproduced through its members' uses of rules and resources. Central to AST's account of GDSS structuration is the analysis of group interaction, for it is through the variety of social processes that occur in interaction that any group "produces and reproduces its own structures-in-use" (p. 180). Any contextual factors that affect member interaction (e.g., task characteristics, group composition, time pressures, etc.) by extension can affect GDSS uses. Careful study of these contextual features and group interaction will reveal how a particular group "appropriates'‘-uses, adopts and reproduces-social and technical structures "to form its particular amalgam of structural features which it employs in its practices" (p. 180). Appropriation can be studied at the level of microlevel interaction at specific times within a (user) group (Poole & DeSanctis, 1992), and in terms of the use of GDSS over time within any particular group (Billingsley, 1991; DeSanctis & Poole, 1991; Holmes & Poole, 1991), and in terms of general norms concerning technology in the organization and society in which the group is situated (DeSanctis, Poole, Desharnais, & Lewis, 1992; DeSanctis, Poole, Dickson, &Jackson, in press).

Poole and DeSanctis (1990) thus provide a perspective on GDSS groups in which both technology and context affect group outcomes only through influence on members' (mediating) structuring processes. *This* "double contingency" is expressed as follows: Given special characteristics of the GDSS technology available to the group and specifiable **contextual** conditions, $n_1, n_2, n_3, \ldots n_k$ *and* the (anticipated) form of how a group appropriates the spirit and features of GDSS structures, then predictable outcomes of GDSS use will result. The majority of AST research has focused on the (first contingency) effects of technology and context on group appropriation processes. For example, Poole, Holmes, and DeSanctis (1988; cited in Poole, Holmes, & DeSanctis, 1991)—as predicted-found that Level 1 GDSS were less effective at managing conflict than were control groups using a manual version of the structure built into the GDSSs studied. In an extension of this research, Poole, Holmes, and DeSanctis (1991) found differences in conflict management behavior in GDSS supported versus unsupported groups, that the GDSS used had different effects on different groups (consistent with AST predictions) and that these differences contributed to consensus change. Similarly, DeSanctis, D'Onofrio, et al. (1989) reported that groups that were taught the "spirit" of GDSS technology obtained significantly higher consensus levels than did groups presented with only instructions on system uses. We conclude our discussion of AST with a critical summary of its strengths and the challenges it must confront.

Critical Review of AST

Poole and DeSanctis (1990) developed AST in such a way as to overcome many of the most frequent objections to Gidden's (1979, 1984) structuration theory. Where the original position was loose or vague, AST specifies testable propositions. Where the original theory was indicted for overemphasis of agency over structure (Archer, 1982; Barbalet, 1985; Callinicos, 1985; Fielding, 1988; Layder, Ashton, & Sung, 1991), AST underscores complex but clear constraints of technology on groups. And where structuration theory purportedly does not explain how earlier action constrains (or enables) (Haines, 1988; Thomsen, 1984), AST explicitly describes the constraining effects of specific microlevel interactions.

Notwithstanding these merits and modifications, the scope of predictions based on the current formulation of AST is limited. The reasons for these limitations reflect two additional concerns about structuration theory in general and AST in particular. First, like structuration theory, AST is a complex verbal theory that must continue to seek greater definitional precision (Turner, 1986). Further, both structuration theory and AST acknowledge the occurrences, but do not articulate the dynamics, of unintended consequences (Brewer, 1988; Sewell, 1992). The remainder of this section describes these limitations in terms of two conceptual distinctions developed by AST: faithful versus ironic appropriation and intended versus unintended consequences.

First, as discussed earlier, AST recognizes that the spirit of the technology helps structure its appropriation. Poole and DeSanctis (1992) argue that the spirit of the technology is not just the designer's intentions or the users' interpretations of the technology. Instead, Poole and DeSanctis suggest that the spirit be identified as a "text" open to multiple interpretations. Further, "the use of multiple sources of evidence lays open the possibility of contradictions; when these occur, it suggests that the GDSS in question does not present a coherent spirit" (p. 13, emphasis added). Poole and DeSanctis posit that an appropriation is considered *faithful* if the "group uses the features of a GDSS in a manner consistent with its spirit . . . assuming that the GDSS in question has a coherent spirit" (p. 13). If these conditions are not met, users will appropriate GDSS in an ironic fashion. Poole and DeSanctis have developed and demonstrated techniques to empirically identify situations where the GDSS was ironically appropriated. However, the majority of hypotheses deduced from AST are restricted to situations where the technology has a coherent spirit and it is faithfully appropriated by users.

Second, AST distinguishes between intended and unintended consequences of the appropriation process. Poole and DeSanctis (1990) note that "social system and its interconnections are often so complex that users cannot fully grasp the implications of their actions. In such cases, the system may 'get away' from members, reproducing structural features in unanticipated ways" (p. 181). Poole (1990) argues that, taking advantage of recent developments in systems theory, simulations can help researchers appreciate how "unintended consequences are generated by our lack of knowledge of the implications of our actions" (p. 3). In the present context, these simulations can help researchers identify more specifically the boundary conditions under which groups reproduce, sustain, and change existing structures or shift to a different structure. Poole and DeSanctis (1992) have taken a first step in this direction by empirically demonstrating two distinct interaction dynamics in groups: "First, there is the continuous production and reproduction of structures as they are employed in activities. . . . Second there are junctures at which major shifts in the structure occur" (p. 15). However, although AST acknowledges the potential for intended and unintended consequences and has developed techniques for identifying gradual and sudden changes in the use of structures, the hypotheses deduced from AST make predictions on the basis of stable, intended consequences.

Taken together, these two limitations suggest that the current formulation of AST is restricted to making predictions in cases where the technology is faithfully appropriated and the intended consequences are realized. These limitations do not undermine the *inherent* merits of AST. There is nothing in the conceptual framework of AST that restricts it to the deduction of hypotheses about intended consequences by groups that appropriate GDSS faithfully. For it to be less restrictive, however, AST must address the challenge of developing more explicitly and precisely the *generative mechanisms,* "the basic dynamics that generate and sustain" (Morgan, 1986, p. 235) the patterns of faithful or ironic appropriation. In its present form, AST broadly defines these generative *mechanisms* as the production and reproduction of structures resulting from the recursive interplay between structure and interaction. However, AST research must offer greater conceptual and predictive precision to (a) identify the many *forms* of production and reproduction, (b) to track the intended or unintended dynamics of production and reproduction resulting from faithful or ironic appropriation, and (c) to identify the boundary conditions under which these dynamics reflect gradual or major shifts in the structures.

We have argued here that AST has benefited from its theoretical underpinnings in structuration theory while successfully addressing some of the criticisms leveled against the latter. However, most of the hypotheses deduced from current explications of AST focus on intended consequences in groups, which appropriate faithfully a GDSS that has a coherent spirit. We argue that in order to broaden its scope AST research must explicate and consider more precisely the dynamics that are implied by the generative mechanisms of the structuration process. In the following section, we propose that self-organizing systems theory is well suited to address these challenges. In the final section, we use the theory to dynamically simulate creation of selected structures within certain interaction parameters.

SELF-ORGANIZING SYSTEMS THEORY

In general terms, self-organizing systems theory (SOST) seeks to explain the emergence of patterned behavior in systems that are initially in a state of disorganization. It offers a conceptual framework to explicitly articulate the underlying generative mechanisms and to systematically examine the processes by which these mechanisms generate, sustain and change existing structures or elaborate new structures (for technical discussions, see Nicolis & Prigogine, 1977; Prigogine, 1980; Schieve & Allen, 1982; for nontechnical overviews, see Briggs & Peat, 1984, 1989; Coveney & Highfield, 1990; Jantsch, 1980; Prigogine & Stengers, 1984; for discussion of its relevance to social systems, see Levine, Sell, & Rubin, 1992; for discussion of its relevance to communication theory, see Kincaid, 1987; Krippendorf, 1987; for discussion of its application to organizational communication theory, see Contractor, in press).

SOST is a relatively abstract position, which articulates requirements for systems to be self-organizing, then indicates a range of process patterns exhibited by systems meeting those requirements. To

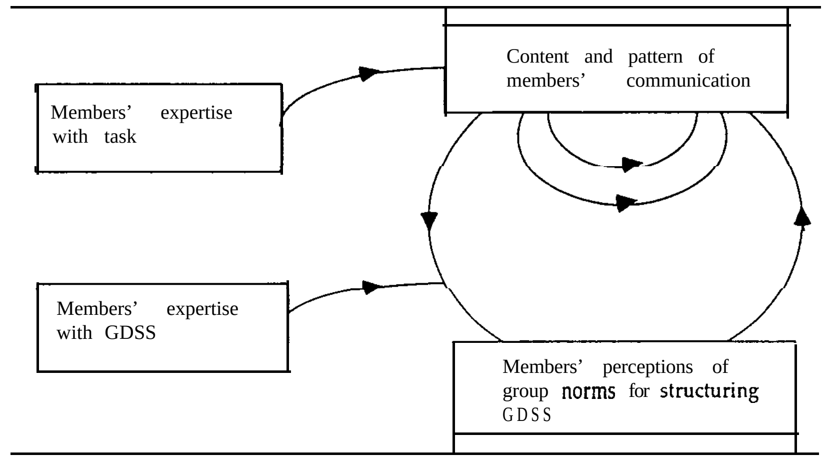

Figure 1: A Self-Organizing System Model for the Appropriation of GDSS

make our discussion as concrete as possible, we begin by describing in very general terms an initial SOST theory of GDSS interactions. We then describe the requirements for such a theory to fall within the domain of SOST and the possible process patterns this theory might generate. After that, we rewrite the theory as a specific equation system, which is used to simulate developments that the theory predicts will occur in GDSS-supported group interactions.

An SOST Model of GDSS Appropriation

We developed the conceptual SOST model for this article using two sorts of resources. First, we depended on the conceptual resources of AST for the generative mechanisms it articulates to explain group interaction processes involving a GDSS. Second, we used a typical SOST model as a template for choosing and framing the generative mechanisms so that their interrelations would constitute a self-organizing system.

Figure 1 shows an SOST model for the appropriation of GDSS that reflect the following generative mechanisms:

1. Members' expertise (or resources) with the task will reinforce the content and pattern of their communication during GDSS-based discussions.
2. The content and pattern of members' communication will reinforce their perceptions of the group's norms for structuring the GDSS-based discussion.

3. Members' expertise (or resources) with GDSS will reinforce their perceptions of the group's norms for structuring the GDSS-based discussions.
4. Members' perceptions of the group's norms for structuring the GDSS-based discussion will reinforce the content and pattern of their communication.

These generative mechanisms are analogous to those offered by AST models of microlevel structuration (Poole & DeSanctis, 1992), both in terms of root concepts and generative mechanisms. Members' perceptions of the group's norms for structuring GDSS-based discussion, their expertise with GDSS, and their task expertise correspond to AST's conceptualization of structures. Members' content and pattern of communication correspond to AST's definition of systems. Further, the generative mechanisms listed above are consistent with AST's assertion of a recursive interplay between structures and systems.

Theoretical Requirements for Self-Organizing

The SOST model extends the explanatory power of AST by making it possible to explicitly specify and to systematically examine the dynamic implications of the generative mechanisms relating structures and systems. In particular, it offers an opportunity for researchers to deduce hypotheses implied but not apparent by the generative mechanisms. The potential comparative advantage of SOST over AST is based on a Noble Prize-winning effort by Ilya Prigogine. Prigogine and his colleagues mathematically derived four theoretical requirements that are necessary but not sufficient conditions for all systems that exhibit the potential of self-organization (Glansdorff & Prigogine, 1971): First, at least two of the components in the system must be mutually causal. A system exhibits mutual causality if at least two of the components in the system have a circular relationship, each influencing the other (Maruyama, 1982). In the case of the aforementioned self-organizing model of GDSS appropriation (see Figure 1), the two components are members' perceptions of the group's norms about task communication and the members' communication activity in the group sessions. That is, members' communication activity influence, and are in turn influenced by, their perceptions of the group's norms about task communication. This requirement is analogous to AST's arguments for "technology-interaction recursivity."

Second, at least one of the components in the system must exhibit *autocatalysis.* A system exhibits autocatalysis if at least one of the components is causally influenced by another component, resulting in its own increase (Eigen & Schuster, 1979). In the case of the SOST model for GDSS appropriation, a member's communication activity during a discussion will be reinforced at subsequent sessions if it is consistent with the member's perceptions of the group norms about task communication. This requirement is analogous to AST's notion that activities in a group are "reproduced."

Third, the system must operate *in* a *far-from-equilibrium* (FFE) condition. A system is defined as being "far from equilibrium" when it imports a large amount of energy from outside the system, uses the energy to help renew its own structures-a process referred to as "autopoeisis" (Varela, Maturana, & Uribe, 1974)—and dissipates, rather than accumulates, the accruing disorder (entropy) back into the environment. This requirement to keep the system FFE implies that the SOST model must explicitly acknowledge that the members' GDSS and / or task expertise (or resources) increase as a result of activities external to their use of the GDSS. These could include, for instance, effort invested in training group members on the use of GDSS. The requirement for a self-organizing system to be FFE, while not explicitly acknowledged, addresses AST's concern with the extent to which groups faithfully appropriate GDSS. It suggests that the likelihood of faithful or ironic appropriation can be assessed directly in terms of the level of GDSS training given to the group members.

Fourth and finally, to exhibit morphogenetic changes, at least one of the components of the system must be open to *external random variations* from outside the system. A system exhibits morphogenetic change when the components of the system are themselves changed. This requirement underscores a key feature of systems that operate FFE. It implies that in the absence of random variations from the environment a system can generate, sustain, and change but not elaborate its existing structures (Jantsch, 1980). External random variations are necessary to explain the emergence of new structures or the *merger* of existing structures (analogous to AST's interpenetration of structures).

There are *two* ways in which the SOST model of GDSS appropriation responds to random variations from the outside. In most situations, the groups appropriating GDSS will be relatively impervious to random fluctuations. For instance, in a group newly introduced to GDSS technology, a random fluctuation in a member's communication activity may *not* cause long-term changes in the group member's appropriation of the technology. However, at certain boundary conditions, a random fluctuation can qualitatively change the nature of the norms manifested by the groups. For instance, in a group whose members start out with prior expertise in GDSS, a random fluctuation in a member's communication activity can result in the group evolving a new norm regarding task communication.

Empirically, the requirement for random fluctuation is the simplest to appreciate. Even if it is not made explicit in their theories, most small group researchers would concede that groups do not work in a deterministic vacuum. In traditional small group theories, random fluctuations influencing group processes are considered as noise that may detract from the theories' predictions (Steiner, 1972). Even theories inspired by the open systems paradigm, which recognize the existence of random fluctuations affecting the boundary of a system, seek ways of controlling for these fluctuations (Monge, 1977). Alternatively, like AST, they choose to make predictions only in cases where random fluctuations do not disrupt the likelihood of "faithful" appropriations. However, SOST proposes that groups appropriate new norms because, not in spite, of these random fluctuations. In the parlance of the pop management literature, SOST proposes that groups "thrive on chaos" (Peters, 1987).

We began our discussion of SOST by outlining a self-organizing model to study group members' appropriation of GDSS. Next, we enumerated the four theoretical requirements for a system to self-organize. We also showed how these theoretical requirements apply to an SOST model of GDSS appropriation; wherever possible we showed these to be analogous to AST postulates. In other cases, we indicated the potential theoretical and predictive advantage to be gained by using SOST postulates to extend AST. Over a period of time, the generative mechanisms specified by the model will predict one of a finite set of potential patterns of appropriation. In the next section, we describe the various appropriation patterns that can emerge from the SOST model outlined above. The set of appropriation patterns include those that are both faithful or ironic and intended or unintended.

Classification of Appropriation Patterns in SOST

All of the potential appropriation patterns for the SOST model outlined above can be classified into qualitatively distinguishable categories. This section describes these categories.

During the early stages of the GDSS appropriation process, there are likely to be considerable changes in members' perceptions of the group's norms about task communication and their communication activity. These initial variations represent *transient* patterns in the appropriation process. After these preliminary changes, the SOST model of GDSS appropriation predicts that the groups will display one of *three* qualitatively different appropriation patterns.

First, the group's appropriation process may reach a constant state. In these cases, the group members will experience minimal change in their perceptions of the group's norms about task communication and will not alter their communication activity Furthermore, random changes in members' perceptions of the group's norms about task communication or their communication will not in general influence their long-term appropriation patterns.

Second, in some groups, instead of reaching a constant state, the appropriation process goes through a cycle. Members' perceptions of the group's norms about task communication and their communication activity move back and forth between two or more different levels (see Bales & Strodtbeck, 1951). Even though the group members' appropriation of GDSS are not at a constant level, the appropriation patterns are stable within that cycle. Here again, the cyclical appropriation pattern is not in general influenced by external random changes.

Finally, in some groups, members may *never* be able to achieve stable appropriation. In some of these instances, the group members' perceptions of the group's norms about task communication and their communication activity continue to fluctuate in a seemingly "chaotic" manner (Gleick, 1987). In other instances, the group members' communication activity may cease, thereby terminating the appropriation process (analogously see Poole's, 1981, discussion of "activity clusters" in his efforts to track decision development in groups). Both of these instances reflect the group's inability to self-organize.

SOST posits that precise specification of the generative mechanisms and initial conditions will determine the emergence of one or the other of these three qualitatively distinct appropriation patterns.

These hypotheses will not be restricted by assumptions of faithful appropriation, as would be the case in AST for the reasons outlined above. A researcher can explicitly examine the extent to which a group's appropriation of GDSS is faithful or ironic in terms of (a) their initial levels of GDSS and task expertise and (b) the rate at which these levels are maintained FFE through external efforts, such as training. Further, the hypotheses deduced from the SOST model will not be restricted to intended consequences because running a simulation of the model augments researchers' ability to visually examine the long-term dynamics implied by the generative mechanisms. Simulations provide invaluable assistance in deducing such hypotheses because the generative mechanisms proposed by AST, like most social science theories, are nonlinear. However, although human intellect is capable of articulating nonlinear relationships, it is limited in its capacity to mentally construe the long-term appropriation patterns implied by these nonlinear mechanisms (Ham-reman, 1988). The remainder of this section provides two illustrations in support of this argument.

First, the generative mechanisms relating components of the SOST model of GDSS appropriation can be specified as time-varying coefficients that do not have *"constant relevance"* (Abbott, 1988, p. 173). That is, members' perceptions of the group's norms about task communication for structuring the GDSS-based discussion do not have a constant impact on the content and pattern of their communication, Hence we must expect that the same change in members' perceptions of the group's norms about task communication can at one point in the appropriation process increase their communication activity; at a subsequent point in time it may decrease their communication activity; and at a third point in time it may have no impact at all. This nonlinear feature of the SOST model also implies that whereas at most points in time members' activity and their perceptions of the group's norms about task communication will mutually influence each other, there are times when one is more influential than the other.

Second, the nonlinearity implicit in the generative mechanisms makes long-term appropriation of GDSS sensitive to *initial conditions.* That is, two groups that differ in their members' initial perceptions of the norms regarding the use of GDSS may demonstrate different appropriation patterns. Typically, the differences are minimal for a wide range of initial conditions. However, at certain boundary conditions, the patterns of appropriation change dramatically. In these cases, initial conditions may determine which of the three classes of appropriation patterns is more likely to emerge. Such a scenario is consistent with the "unique effects" requirement of the emergent perspective discussed at the start of this article: Two groups whose members' have differing initial levels of expertise with GDSS are likely to appropriate the technology differently, even if they are working on identical tasks and using the same technology.

The above examples suggest that a group's appropriation of GDSS is not apparent by simply inspecting the generative mechanisms From a computational standpoint, this is because nonlinear relationships often do not have closed-form solutions and are therefore analytically intractable. However, as mentioned earlier, recent developments in computational science make it relatively easy to use simulations as a convenient tool to observe these various appropriation patterns (Hanneman, 1988; Whicker & Sigelman, 1991). In the next section, we present the methodology and results of such a simulation of GDSS appropriation and use.

SIMULATION EXAMPLE

To demonstrate the rigor and potential power of SOST for explaining appropriation patterns of GDSS, we present a simulation. Although exceedingly simplified, the simulation serves to exemplify the arguments presented thus far and to demonstrate the comparative advantage of SOST over AST in providing specific, empirically testable hypotheses about the GDSS appropriation process. We begin by specifying a set of equations that represent the generative mechanisms proposed in the SOST model of GDSS appropriation discussed earlier (Figure 1). Next, we derive a set of difference equations that identify the rates at which the components in the model change over time. These difference equations are used to specify a dynamic simulation. After confirming the plausibility of the model's predictions, further simulations are carried out to examine the extent to which appropriation patterns implied by this model are sensitive to two parameters; specifically, the training received by group members and their initial awareness of the norms regarding the use of GDSS. The section concludes with a set of hypotheses deduced from the results of these simulations.

Specification of the SOST Model

The SOST model of GDSS appropriation outlined in a previous section can be represented analytically in terms of the following three equations:

$$T \xrightarrow{k_1} N, \tag{1}$$

$$2(C) + N \xrightarrow{k_2} 3(C), \tag{2}$$

$$G + C \xrightarrow{k_3} N, \tag{3}$$

where

T is the member's level of expertise in the task, rated on a scale from *0* to *50*
G is the member's level of expertise with GDSS, rated on a scale from 0 to 50
C is the amount of time (in minutes) the member communicates about task-related matters
N is the member's perception of the norm that the group must use GDSS only for task-related communication. The member's perception is rated on a scale from 0 (ignorance of the norm) to +10 (high awareness of the norm)
k_1, k_2, and k_3 are the causal coefficients set at .04, .02, and .02, respectively. The selection of these values is arbitrary. The primary criteria for their selection are the scales assigned to the three variables.

The three equations instantiate the four generative mechanisms proposed in the SOST model of GDSS appropriation. The first of the four generative mechanisms proposed that members' expertise with the task will influence their group norms about task communication (Equation 1). The second and fourth generative mechanisms proposed a mutually causal relationship between the group's norms about task communication and their task communication (Equations 2 and 3). The third generative mechanism proposed that members' expertise with GDSS will influence their group's norms about task communication (Equation 3). This system of equations corresponds to the relational pattern indicated in Figure 1. However, these equations require additions for two reasons. First, because they are based on an equation system that meets chemical conservation requirements, they describe variable relations as transformation processes that "use up" the independent variables in creating the dependent variables. For instance, Equation 1 describes a process in which the amount of diminishing task expertise precisely matches the amount by which norm perception is augmented. This is contrary to commonsense

notions of how task expertise works. Now, a model that more realistically describes the kinematics of, say, task expertise might be more complex than the purposes of this article allow. We decided to avoid declines in task expertise and GDSS expertise by introducing some exogenous variables that would supplement and correct the values of the latter. These exogenous factors would also respond to the second reason for supplementing the model: The initial equations do not meet all four SOST requirements. That is, they do not specify a system that can operate in an FFE condition or exhibit morphogenetic changes.

To operate in an FFE condition, at least one of the two exogenous elements in the model (namely, GDSS expertise and task expertise) must continually be able to increase its level by importing energy from outside the system. To specify this requirement, it is necessary to examine the rates at which the elements in the system change over time. The change of the four elements in the system from one point in time to the next can be mathematically derived from Equations 1 through 3 and are presented in Equations 4 through 7:

$$AT = -k_1 T \tag{4}$$

$$AG = -k_3 GC, \tag{5}$$

$$AC = k_1 T + k_2 NC^2 - k_3 GC, \tag{6}$$

$$\Delta N = -k_2 NC^2 + k_3 GC, \tag{7}$$

where AT, AG, AC, and AN represent the change in the level of task expertise, GDSS expertise, task communication and task norm for each time interval. Thus the level of each of the four elements in the system at time t can be specified in difference equations (Equations 8 through 11) as the sum of their respective levels at time t − 1 and the change during a unit time interval:

$$T_t = T_{t-1} + \Delta T = T_{t-1} - k_1 T_{t-1}, \tag{8}$$

$$G_t = G_{t-1} + \Delta G = G_{t-1} - k_3 G_{t-1} C_{t-1}, \tag{9}$$

$$C_t = C_{t-1} + \Delta C = C_{t-1} + k_1 T_{t-1} + k_2 N_{t-1} C_{t-1}{}^2 - k_3 G_{t-1} C_{t-1}, \tag{10}$$

$$N_t = N_{t-1} + \Delta N = N_{t-1} - k_2 N_{t-1} C_{t-1}{}^2 + k_3 G_{t-1} C_{t-1}, \tag{11}$$

where T_t, G_t, C_t, and N_t are the levels of task expertise, GDSS expertise, task communication, and task norm at time, t; T_{t-1}, G_{t-1}, C_{t-1}, and

N_{t-1} are the levels of task expertise, GDSS expertise, task communication, and task norm at the preceding point in time, $t-1$.

For the system to operate in an FFE condition, the levels of task expertise and/or GDSS expertise must be continually increased from outside the system. As mentioned earlier, training members on the use of GDSS will increase their level of GDSS expertise. Likewise, it is plausible to assume that groups will increase their level of task expertise based on information acquired outside the GDSS meetings. Hence in order to specify the SOST model as operating in an FFE condition, Equations 8 and 9 are respecified to explicitly include the contribution of information acquisition and training:

$$T_t = T_{t-1} + \Delta T = T_{t-1} - k_1 T_{t-1} + In, \tag{8}$$

$$G_t = G_{t-1} + \Delta G = G_{t-1} - k_3 GC + Tr, \tag{9}$$

where In is a constant indicating the amount by which members increase their task expertise through information acquired outside the GDSS meetings, and *Tr* is a constant indicating the amount by which members improve their GDSS expertise due to training.

The SOST model specified above does not meet the final requirement of SOST: the ability to exhibit morphogenetic change. This is because the equations do not allow for random fluctuations. Hence, although the SOST model offered in this study can be used to examine how the level of task norms are generated, sustained, and changed, they cannot offer insights into the emergence of new norms.

The difference equations presented in this section underscore two issues raised in earlier sections. First, they offer a precise statement of the manner in which the generative mechanisms specified in the SOST model of GDSS appropriation act to change the group's norms and communication from one point in time to the next. For instance, an inspection of the generative mechanisms outlined in Equations 1 through 3 does not offer a clear statement of the factors contributing to temporal changes in the level of task communication. In contrast, Equation 10, derived mathematically from Equations 1 through 3, indicates explicitly that the change in level of task communication from time $t-1$ to time tare due to three sources: It will increase by an amount proportional to their level of task expertise (the term $k_1 T_{t-1}$ in Equation 10); it will increase by an amount proportional to the product of their awareness of the task norm and the square of their task communication (the term $k_2 N_{t-1} C_{t-1}^2$ in Equation 10); and it will be reduced by an amount proportional to the product of their GDSS expertise and their task communication (the term $-k_3 G_{t-1} C_{t-1}$ in Equation 10). It is important to emphasize that these sources do not directly influence the level of communication at time t; rather, they influence the extent to which the level of communication changes from its prior value.

Second, the difference equations also make evident the nonlinearities implied by the generative mechanisms. For instance, Equation 10 indicates that the change in task communication is proportional to the square (a nonlinear function) of the level of communication in the preceding time interval (the term $k_2 N_{t-1} C_{t-1}^2$ in Equation 10). Clearly, it is not possible to mentally deduce hypotheses about the pattern of GDSS appropriation simply by examining the nonlinear difference equations presented above. Further, these nonlinear equations often do not have analytic solutions. That is, it is not possible to analytically derive a solution that permits the researcher to determine the level of task communication at t = 10, say, without computing the level of communication at each previous point in time. In such cases, it is imperative that simulations be used to help the researcher deduce hypotheses implied but not readily evident from the model specified.

Execution of the SOST Model

The computer program STELLA II (Richmond & Peterson, 1990) was used to carry out the simulations. The difference equations presented in the previous section were used to specify the model. The goal of the simulations was to observe qualitative differences in the appropriation patterns under different conditions. The appropriation patterns were observed by plotting time series of the members' time spent communicating (C) and the members' perceptions of the group's norms regarding task communication (*N*). In addition, phase maps were plotted to observe the temporal trajectory of C (X-axis) and *N* (Y-axis). Phase maps are two-dimensional scatter plots where points representing consecutive occurrences in time are connected to each other. The arrows indicate the direction of the temporal trajectory.

To validate its plausibility, a *baseline model* was run on the assumptions that (a) members had no initial GDSS expertise (G = 0), (b) members were ignorant of the group's norms regarding task communication (*N* = 0), (c) members' initial level of task expertise (*T*) was assigned an arbitrary value of 9 (on a scale ranging from a low of 0 to a high of 50), (d) the increase in GDSS expertise due to training (*Tr*) was assumed to be 0.3 (a 0.3 value implies that training helped

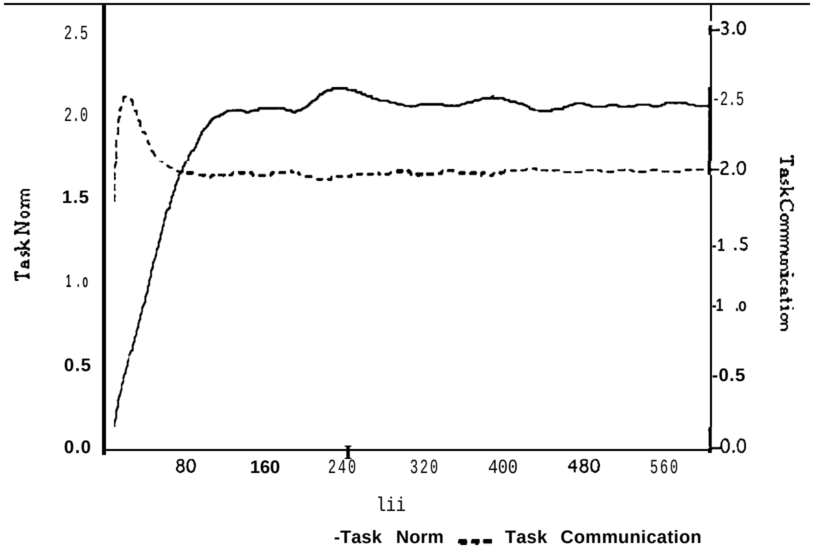

Figure 2: **Predicted Time Series of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, No Prior Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions**

increase members' level of expertise with GDSS by 0.3 in each time unit), and (e) the increase in task expertise due to acquiring information (In) was assumed to be 0.2 (a 0.2 value implies that information acquisition helped increase members' level of task expertise by 0.2 in each time unit). The appropriation patterns are shown in Figures 2 and 3.

Figure 2 indicates that under the baseline assumptions members' awareness that GDSS must only be used for task communication increased gradually for approximately the first 100 time units and then stabilized at approximately 2.05 (10 representing a high degree of awareness). Figure 2 also indicates that the time that members spent communicating increased rapidly at first, then declined slightly, before stabilizing at about 1.9 minutes.

The phase map, shown in Figure 3, provides an alternative view of the process. The plot starts at the origin because members' initial perception of the norm regarding the task communication and the initial amount of communication were both zero. The phase map initially shows a positive slope indicating that an increase in members' awareness of the norm regarding use of GDSS for task

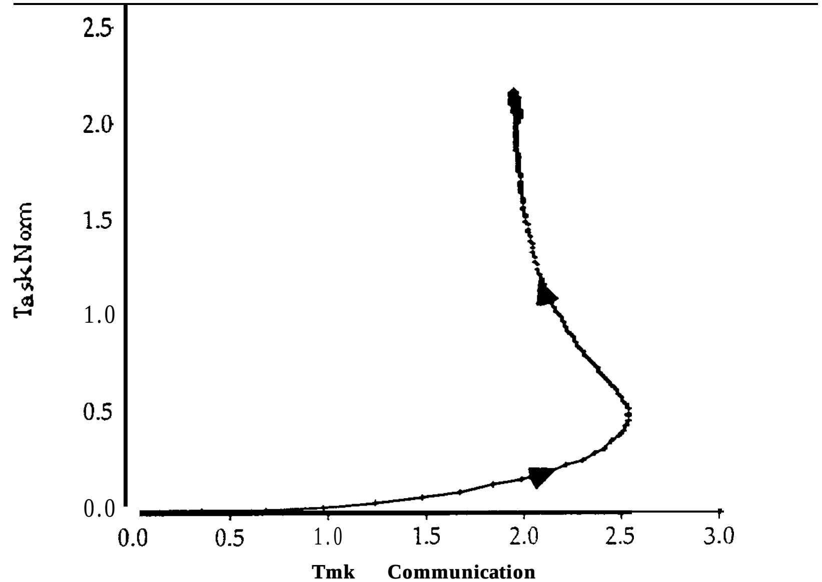

Figure 3: **Predicted Phase Map of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, No Prior Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions**

communication was accompanied by an increase in their amount of communication. However, as one continues following the curve, there is a sharp bend in the plot, and for a short while the trajectory follows a negative curve. The change in the trajectory indicates that, at this stage in the group's history, even though members continued to increase their awareness of the group's norm they actually decreased their level of communication. Finally, the phase map halts (at the point represented by Task Norm, N = 2.05, and Task Communication, C = 1.90). This indicates that after arriving at this point there was no further change over time in the group members' perception of the norm or their amount of communication.

In summary, the baseline model indicates that in the long term, under the set of assumptions postulated, group members self-organize. They appropriate a stable norm regarding the use of GDSS for task communication and stabilize the amount of time spent using the GDSS. However, in the short term, the relationship between members' awareness of the norm regarding the use of GDSS and amount of communication is complex. Initially, the relationship is positive and then turns negative. The short- and long-term dynamics exhibited here demonstrate *the plausibility* of the specified SOST model for GDSS appropriation. However, it must be emphasized that the appropriation patterns do not indicate empirical support for the specific set of equations. To test the validity of this specific formulation, the next step would be to use simulations to deduce hypotheses relating the group's initial parameters to its long-term appropriation patterns.

Deducing Hypotheses From the SOST Model

Having established the plausibility of the model, the next step was to observe how the group's appropriation patterns would change if the model's parameters were systematically altered. Specifically, two questions were addressed:

1. How would the group's appropriation patterns be influenced by increases in GDSS expertise due to increased training (higher values of *Tr*)?
2. How would the group's appropriation patterns be influenced by greater initial awareness of the norm regarding use of GDSS for task communication (higher initial value for *N*)?

Answers to these two questions would provide hypotheses that are deduced directly from the SOST model for GDSS appropriation but are not evident by simply examining the generative mechanisms specified in the model.

Question 1 is an attempt at extending AST's focus on making predictions only in cases of faithful appropriation. Changes in the level of training provided to the group on a continual basis increases the likelihood of faithful appropriation. Thus, comparing the appropriation patterns generated by different values of the GDSS training parameter, *Tr* provides researchers with an opportunity to deduce hypotheses about the likelihood and nature of faithful or ironic appropriation. Simulations were conducted by modifying the GDSS training parameter, *Tr*, and holding constant the remaining parameters at the values assigned in the baseline model. In the baseline model, *Tr* was set at 0.30, indicating that training helped increase the group members' GDSS expertise by 0.3 from one time unit to the next. Analytically, the boundary values for this parameter range from $-\infty$ to $+\infty$. That is, training could result in drastic reductions or increases in members' GDSS expertise. Substantively, we were interested in examining how the appropriation patterns would change if training

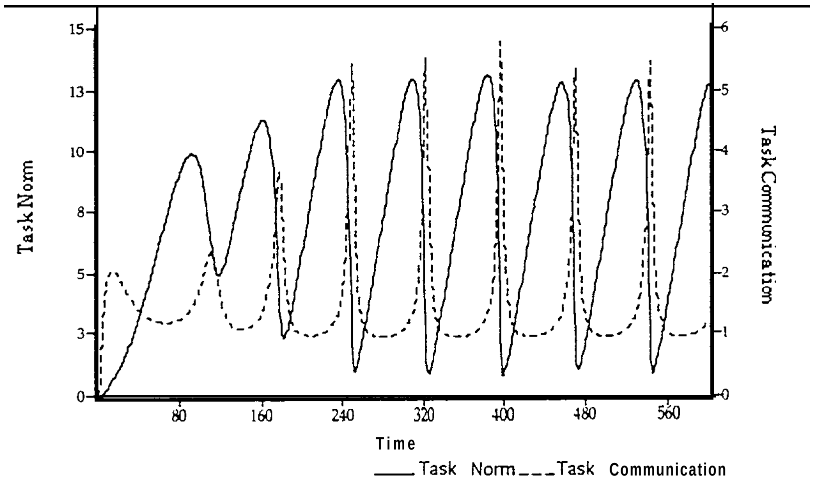

Figure 4: Predicted Time Series of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, No Prior Awareness of Norm Regarding Its Use for Task Communication, and Intensive GDSS Training Between Sessions

resulted in an increase in GDSS expertise for each time unit, ranging from 0.3 to 0.7. Hence the relevant values for *Tr* ranged from 0.30 (in the baseline model) to 0.70. This approach is consistent with the procedures of sensitivity analysis, a well-accepted strategy in simulation methodology (Hanneman, 1988).

The model was rerun 39 times, modifying the value of the GDSS training parameter in incremental steps of 0.01, from 0.30 to 0.70. Within this range there were two qualitatively distinct appropriation patterns. The appropriation patterns did not exhibit any qualitative changes until the *Tr* reached a value of 0.54. However, when *Tr* was above 0.54 (i.e., starting with 0.55) the appropriation patterns displayed a qualitatively different state of self-organization. Figures 4 and 5 plot the trajectories based on the assumption that training helped increase their GDSS expertise by 0.55 in each time interval. Figure 4 indicates that an increase in GDSS training caused members' awareness of the norm regarding task communication and their amount of communication to increase initially and then settle into a stable cyclical pattern. That is, in the long term, members' perceptions of the norms about task communication and their amount of communication always changed, but the pattern of change was repeated. The phase map in Figure 5 provides further evidence of this cyclical

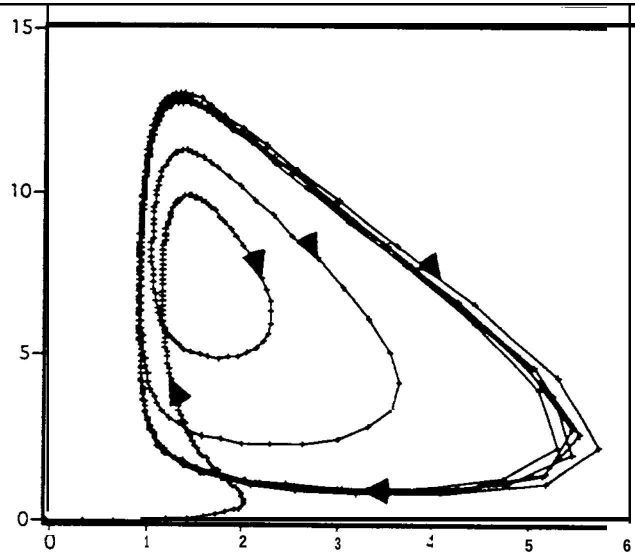

Figure 5: Predicted Phase Map of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, No Prior Awareness of Norm Regarding Its Use for Task Communication, and Intensive GDSS Training Between Sessions

behavior by providing another view of the complex relationship between members' awareness of the norm and their communication. For instance, at some points in time, members continue to increase their communication even though they do not change their awareness of the norm regarding task communication. At other tunes, a sharp increase in members' awareness of the norm is not accompanied by any change in their amount of communication.

In summary, the results shown in Figures 4 and 5 suggest that increasing the rate at which members are trained in the use of GDSS beyond a threshold point (0.54) can make a qualitative difference in their appropriation pattern. As in the case of the baseline model, here too the groups self-organize. However, the appropriation now occurs in the form of a stable cycle as opposed to a constant value. The relationship between members' awareness of the rules regarding the use of GDSS for task communication and the amount they communicate is even more complicated.

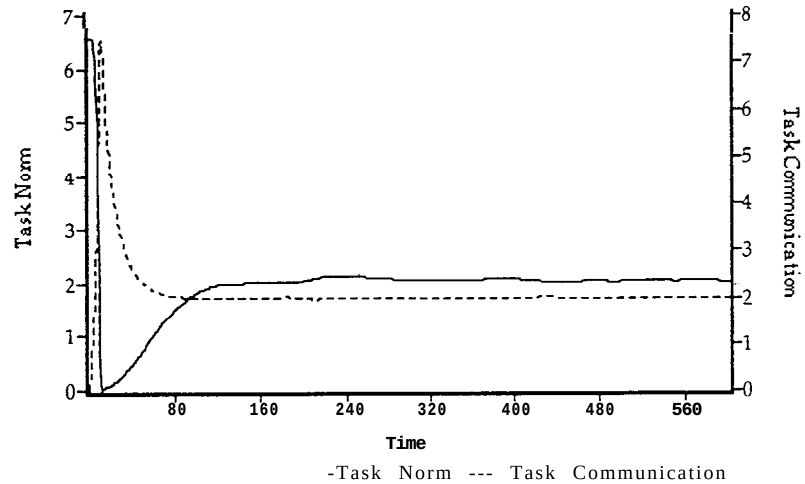

Figure 6: Predicted Time Series of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, Modest Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions

To address the second question posed at the start of this section (i.e., the effects of initial awareness of norms regarding task communication on the appropriation process), the model was rerun modifying the initial value of the task norm, N, and holding constant the remaining parameters at the values assigned in the baseline model. In the baseline model, the N was set at 0, indicating that group members were ignorant of the norm regarding use of the GDSS only for task communication. The boundary values for this parameter were specified earlier as ranging from 0 (ignorance of the norm) to +10 (high awareness). The model was rerun 99 times, modifying the value of N in incremental steps of 0.1, from 0 to 10. Within this range, there were three distinct appropriation patterns. The appropriation patterns did not exhibit any qualitative change from the baseline model until the initial value of N reached a value of 6.6. When the initial level of N was 6.6, the appropriation patterns displayed a qualitatively different state of self-organization (Figures 6 and 7).

Figures 6 and 7 indicate that members' awareness of the norm regarding use of the GDSS for task communication *falls* rapidly at first. Interestingly this decline in awareness is accompanied by an increase

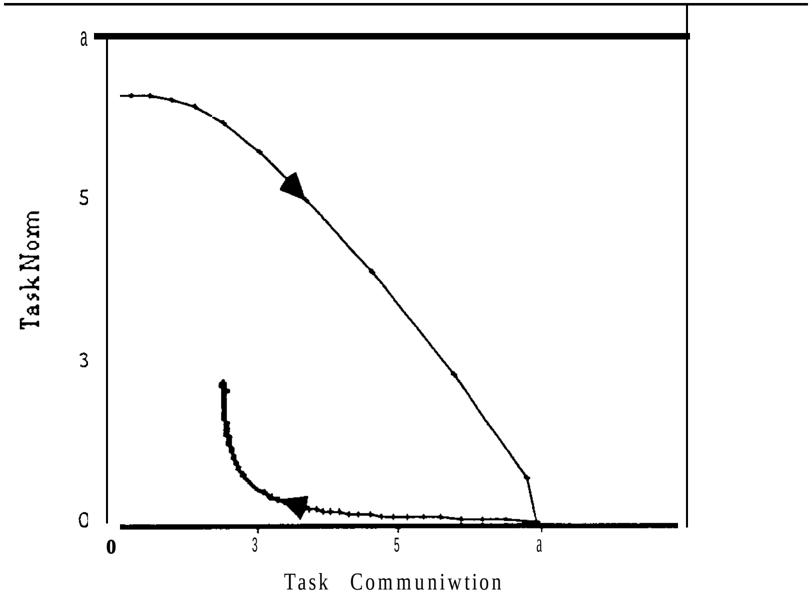

Figure 7: Predicted Phase Map of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, Modest Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions

m the members' task communication. However, after these transient fluctuations, the members' appropriation stabilizes. Significantly, in the long term the members' level of awareness of the norm and their amount of communication is identical to the baseline model. In summary, these results suggest that increasing awareness of the norm regarding the use of GDSS for task communication beyond a threshold value (in this case, N = 6.5) results in a substantial increase in task communication in the short term. However, this increased awareness has no long-term impact on the members' appropriation patterns.

Increasing the initial level of the N from 6.6 to 6.7 causes a second qualitative change in appropriation pattern (see Figures 8 and 9). There is initially a precipitous decline in the members' awareness of the norm. However, unlike the previous appropriation patterns (Figures 6 and 7), here the members' awareness of *the* norm *disappears* completely, and their amount of communication stabilizes at a very low level. These results indicate the presence of a second threshold

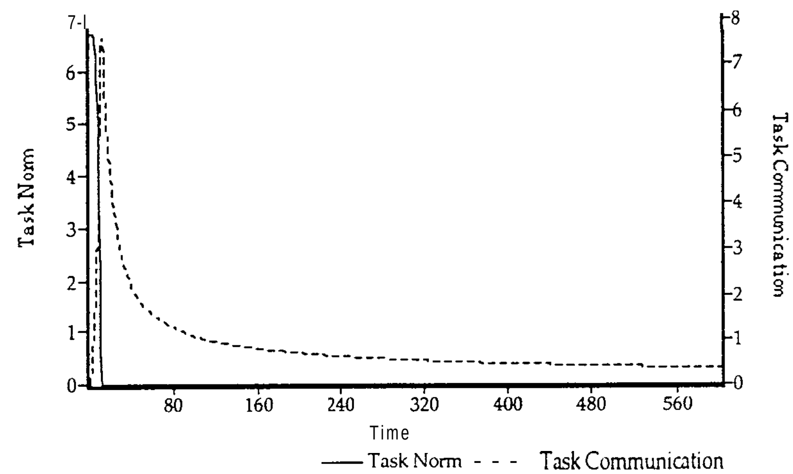

Figure 8: Predicted Time Series of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, High Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions

value for N at 6.6. If the group members' initial awareness is even slightly greater than this threshold value, there is a qualitative change in their long-term appropriation pattern. Counter to intuition, a higher initial awareness of the norm leads to its complete disappearance!

We began this section by asking two questions. They concerned the influence of GDSS training and initial levels of awareness about the group's norm on appropriation patterns. The results reported in this section, along with results obtained from the baseline model in the previous section, suggest the following six empirically testable hypotheses:

H1: Members with no prior GDSS expertise, modest GDSS training between sessions, and no initial awareness of the norms regarding the use of GDSS for task communication will show a gradual increase in their awareness of the norm that will stabilize over time (see Figures 2 and 3).

H2: Members with no prior GDSS expertise, modest GDSS training between sessions, and no initial awareness of the norms regarding the use of GDSS for task communication will show an initial increase in their use of GDSS for task-related communication followed by a slightly lower but stable level (see Figures 2 and 3).

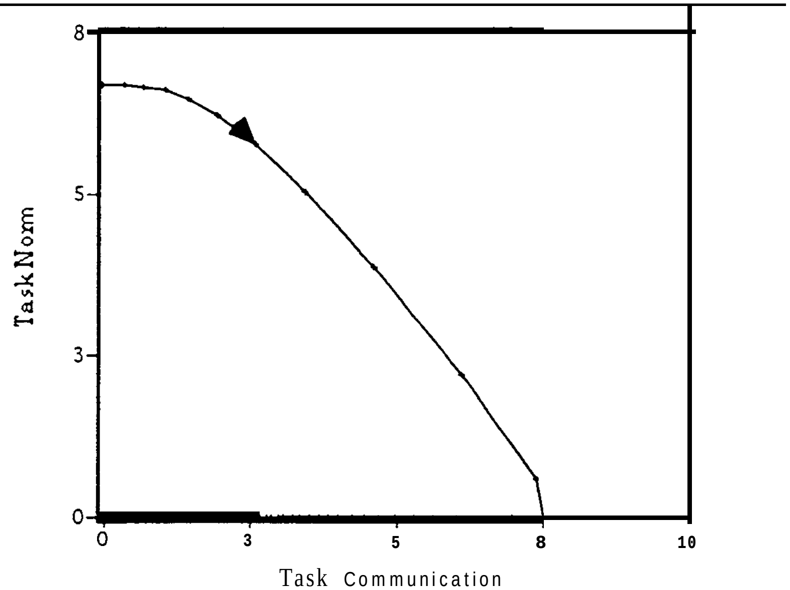

Figure 9: Predicted Phase Map of Appropriation Patterns for GDSS Usage Among Members With No Prior GDSS Expertise, High Awareness of Norm Regarding Its Use for Task Communication, and Modest GDSS Training Between Sessions

H3: Members with no pnor GDSS expertise, intensive GDSS training between sessions, and no initial awareness of the norms regarding the use of GDSS for task communication will show cyclical patterns in their awareness of the norms (Figures 4 and 5).

H4: Members with no prior GDSS expertise, intensive GDSS training between sessions, and no initial awareness of the norms regarding the use of GDSS for task communication will show cyclical patterns of communication activity (Figures 4 and 5).

H5: Members with no prior GDSS expertise, modest GDSS training between sessions, and modest initial awareness of the norms regarding the use of GDSS for task communication will show high initial communication activity in the short term but no long-term effects (Figures 6 and 7).

H6: Members with no prior GDSS expertise, modest GDSS training between sessions, and high initial awareness of the norms regarding the use of GDSS for task communication will show high initial communication activity in the short term followed by sharply lower communication activity (Figures 8 and 9).

Discussion of Simulations

It must be emphasized that the model presented in this study, and the resulting hypotheses, are offered more as an illustration of the SOST perspective than as a definitive statement of GDSS appropriation. Our goal here is not to suggest that the above simulations empirically demonstrate how groups appropriate GDSS. Instead, it serves to illustrate the manner in which SOST offers the promise to extend AST. The model of GDSS appropriation presented in this study is consistent both with the generative mechanisms proposed by AST and the theoretical requirements of SOST. We have attempted to advance AST by (a) offering precise statements of its verbal generative mechanisms, (b) demonstrating the potential of simulations to better understand their dynamic implications, and (c) extending the scope of AST to include predictions about the nature and likelihood of ironic appropriation.

There are at least two directions in which the proposed SOST model can be extended. First, a revised form of the SOST model of GDSS appropriation must necessarily include additional theoretically relevant concepts, such as the effect on appropriation of the coherence in the spirit of the GDSS design (Poole & DeSanctis, 1992). Second, to meet the fourth requirement of self-organizing systems, the model should be extended to include the possibility of external random fluctuations. Doing so would provide researchers with the ability to study morphogenetic changes, such as the creation of new norms or the merger of existing structures. Ultimately, the validity and adequacy of the proposed model will be assessed in terms of its ability to generate hypotheses that are empirically supported.

The role of computer simulations, as illustrated in this study, is to help us understand and clarify the implications of our verbal theories and propositions. Without them it is well nigh impossible for us to appreciate the long-term implications resulting from an explicit formulation of our propositions. For instance, it is very difficult to mentally construe the long-term effect of members' initial awareness of the norms regarding the use of GDSS for task communication simply by examining Equations 1 through 3 or even the difference Equations 8 through 11.

Further, the results of the simulation underscore the complex and changing relationship between members' awareness of the norm regarding the use of GDSS and the amount they communicate. A quick examination of the phase maps (see Figures 3, 5, 7, and 9) shows that depending on the time when data are collected, a researcher can conclude that members' awareness of this specific norm helps, hinders, or has no impact on their communication activity, This suggests that, according to SOST, studies testing hypotheses predicting linear relationships are unlikely to yield meaningful and consistent results. This observation may help explain the inconsistent results in past GDSS research discussed at the outset of this article. Put bluntly, accepting the assumptions of SOST implies that GDSS researchers have been asking the wrung questions. SOST, as exemplified in the above simulation, offers an alternative genre of hypotheses.

It is important to note that we are advocating the use of simulations to help theory construction as opposed to theory testing. The goal is to generate hypotheses based on the observation of *qualitative* changes in appropriation patterns, not to make numeric predictions about the level of appropriation. Hence the actual values of the parameters (or the time units) chosen are *not* sacrosanct. This more novel application of simulation in the social sciences is therefore not prone to some of the warranted criticisms of earlier applications of simulations in the social sciences (see Hanneman, 1988; Levine et al., 1992: Poole, 1990, for development of this argument).

CONCLUSION

In summary, like AST, SOST meets the dual requirements for powerful theories of GDSS effects outlined earlier: the explanation of the "technology-interaction recursivity" and of "unique effects" across GDSS groups. Like proponents of AST (Poole & DeSanctis, 1992), we disagree with structuration theorists who believe that the term recursivity in the human sciences "has only a tenuous connection with the mathematical sense of that term" (Giddens, 1991, p. 204). Extending AST, SOST specifies in a mathematical model the conditions under which stable appropriation (self-organization) can occur. SOST deemphasizes the notion that the appropriation of a specific set of GDSS-related norms be classified as faithful or ironic, as intended or unintended. Instead, the focus is simply on specifying boundary conditions under which a specific set of norms is more (or less) likely to be appropriated.

Further, SOST specifies how the group's initial conditions may influence its likelihood of appropriating a specific set of norms. AST theorists, on the other hand, as lamented by an AST proponent, "blandly throw out the notion that social structures are 'produced and reproduced' by actors, . . . [while] detailed analysis of their long-term implications is largely omitted. What determines, for example, whether a process replicates itself, changes in regular cycles over time, gradually decays, or follows some other interesting trajectory?" (Poole, 1990, p. 24). We believe that SOST is a first attempt at developing a framework that rigorously makes it possible to answer these questions. As such, it both complements and offers the promise of *extending* AST, thus far arguably the most impressive theory of GDSS use.

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