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THESIS

SOCIOTECHNICAL SYSTEMS AS APPLIED TO KNOWLEDGE WORK

by

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June, 1998

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SOCIOTECHNICAL SYSTEMS AS APPLIED TO KNOWLEDGE WORK

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ABSTRACT

This study examines the logic behind choosing variances and the design of forums during the planning of deliberations in non-routine work environments using a Sociotechnical System design approach. This study was accomplished through review and comparison of literature on sociotechnical applications of non-routine, knowledge work environments. The traditional sociotechnical application applied to factory settings with linear and routine work tasks analyzes unit operations within an open system, identifying technical variances that contribute to problems and social roles that control the variances. A new sociotechnical approach has been developed for systems involved in non-routine, knowledge work environments. This approach focuses on deliberations formed around topics, establishes variances that lead to poor deliberations, designs forums that minimize variances and gives control of variances to discretionary coalitions. These results generally support that variances contributing to poor deliberations are well established and that organizations need only identify the key variances that contribute to problems in their system. Organizations need to understand how the key variances effect the development of knowledge and how forums can be designed to enhance deliberations. This study places specific focus on the design of information technology forums that enhance knowledge development.

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I. INTRODUCTION

A. BACKGROUND

Sociotechnical system design has traditionally been applied to factory settings with linear and routine work tasks. The traditional sociotechnical application analyzes unit operations within an open system, identifying technical variances that contribute to problems and social roles that help control the variances. A new sociotechnical approach has been developed for systems involved in non-routine, knowledge work environments. The new approach analyzes the deliberations formed around topics, establishing variances that lead to poor deliberations, designing forums that minimize variances and giving control of variances to discretionary coalitions. The variances that contribute to poor deliberations are well established, and organizations need only identify the key variances that contribute to problems in their system and design the right forums to enhance the deliberation process.

Organizations need to understand how the key variances and forums affect the development of knowledge and how forums can be designed to reduce the effect of barriers to knowledge development. Sociotechnical systems design has three basic tenets: holistic system view, joint optimization of technical and social subsystems and throughput focus. These tenets form the foundation of all sociotechnical applications. This research examines the logic behind choosing variances and designing forums during sociotechnical systems deliberation planning in knowledge work environments. It places

specific focus on the design of information technology forums that enhance knowledge development.

B. OBJECTIVE OF RESEARCH

This research will explore literature and studies of Sociotechnical System design application in non-routine, non-linear, knowledge work environments. It will examine the logic behind the identification of variances and design of forums during deliberation planning. It will identify the forums that enhance the development of knowledge, with specific focus on information technology forums. The research will compare earlier studies of variations and forums to new studies involving intellectual capital, knowledge bases, knowledge development and innovation. After reviewing these studies the researcher will draw conclusions about the choice of variances and forums in deliberations of knowledge work.

C. RESEARCH QUESTIONS

1. Primary Research Question

How can sociotechnical systems design enhance the ability of an organization engaged in knowledge work to establish the correct variances and the best mix of forums for the development of knowledge?

2. Secondary Research Questions

a. *What is the new paradigm of knowledge work?*

b. *What is the sociotechnical systems deliberation approach?*

c. *What are the appropriate root variances from which to choose key variances?*

d. *How should forums be evaluated and designed to enhance the development of knowledge?*

e. *What is the best application for information technology forums like e-mail, chat rooms or groupware in a knowledge work environment?*

D. SCOPE

The scope of the study is to provide information, analysis and conclusions on the logic and choice of variances and forums in sociotechnical systems designs using a deliberation approach in non-routine, knowledge work environments. The study will include comparison of traditional and conventional sociotechnical systems. The study will review the analysis of variations to establish a complete variation base and will analyze and make recommendations on the design of forums during deliberation planning, with specific emphasis on the design and implementation of information technology forums such as e-mail, chat rooms and groupware.

E. METHODOLOGY

The methodology to be used in this research is as follows:

- Conduct a comprehensive review of existing literature and a search for the latest available information on sociotechnical systems applications to non-routine, knowledge work environments.
- Conduct a review of sociotechnical systems applications, past and present, to determine the appropriate choice of variances and design of forums that lead to successful knowledge development.

F. ORGANIZATION OF THESIS

This thesis contains five chapters. Chapter I is made up of a general introduction, objective, scope, methodology and organization of the thesis. It establishes the framework and guiding principles of the thesis.

Chapter II is a literature review of past and present sociotechnical systems design applications. The review concentrates on the development of sociotechnical systems design in non-routine, knowledge work organizational environments. The chapter also includes literature on knowledge development, intellectual capital and collaborative software.

Chapter III details the development of the sociotechnical systems deliberation approach. It defines deliberations, forums, discretionary coalitions and the commonly associated variances. The chapter outlines the logic behind previous choices of variance and new perspectives on variances and forum choices in the deliberation process. The chapter discusses the design and applicability of forums during the four phases of the knowledge development process. It also analyzes recent work on knowledge

development and intellectual capital to determine consistency among the variances and forums that contribute to barriers in the deliberation process. It also summarizes the logic behind the choice of variances and forums during knowledge development.

Chapter IV analyses the researcher's conclusions the researcher has made on the choice of variances and forums in the knowledge development process. Specific conclusions are made regarding the applicability of information technologies forums such as e-mail, chat rooms and groupware during knowledge development.

Chapter V summarizes the thesis, makes recommendations for adoption and offers answers to the questions listed in Chapter I. It also present specific recommendations for areas of further research.

II. LITERATURE REVIEW

Sociotechnical designs have been applied and studied in industrial organizational settings with linear, routine and sequential work processes, since the late 1940s. Applications of sociotechnical designs in organizational settings with non-routine, non-linear and non-sequential work processes have been applied and studied only since the 1980s. This review concentrates on the development of sociotechnical systems design in non-routine, knowledge work organizational environments. This chapter also includes literature on knowledge development, intellectual capital and collaborative software. It specifically focuses on the logic behind the choice of variations and forums in designing deliberations.

A. SOCIOTECHNICAL SYSTEMS AND ROUTINE WORK

The origins of sociotechnical system design can be traced to the 1949 field studies involving British coal miners conducted by Trist and Emery at the Tavistok Institute. The authors presented the basic principles developed from the studies in several publications, between 1969 and 1981. The basic principles of sociotechnical design as presented by Trist and Emery include:

- Viewing the work system as a whole unit;
- Centering the system work flow around work groups;

- Allowing work groups to regulate the system;
- Designing redundant functions instead of redundant parts;
- Valuing discretionary roles;
- Treating individuals as complementary to machines; and
- Joint optimization of social and technical subsystems and increasing work variety for individuals and the organization. (Trist, 1981)

Taylor and Fenten (1993) examine applications of sociotechnical systems in North American companies. These two authors refine the basic principles of sociotechnical design, based on the earlier works of Trist, Emery, Pava and Pasmore, as four pillars: holistic system thinking, power of information, product or throughput focus, and organizational purpose. The authors break the six classical sociotechnical steps into four phases: discovery, understanding, design and implementation. The discovery phase includes learning about the basic principles. In this phase, an organization normally sends people to workshops and retreats and establishes a steering committee to administrate the analysis and design teams. In the understanding phase, the analysis teams conducts a scan of the system, which is followed by a technical and social analysis. In the system design phase, the design team jointly optimizes or matches the technical and social subsystems, producing a provisional design. In the final phase, implementation, the

system design is approved by the steering committee. The design is implemented and there undergoes a reiterative improvement process.

Taylor and Fenton apply the basic sociotechnical principles and methods to both routine and non-routine work, using the concept of unit operations in the technical analysis. Technical analysis, in routine work, is defined as breaking the throughput or product conversion process into unit operations. Each unit operation has inputs, a state-change operation and outputs. Unit operations help focus on the throughput and enable comprehension of the conversion process. The unit operations are linked in linear sequential chains or conversion process [Fig. 1].

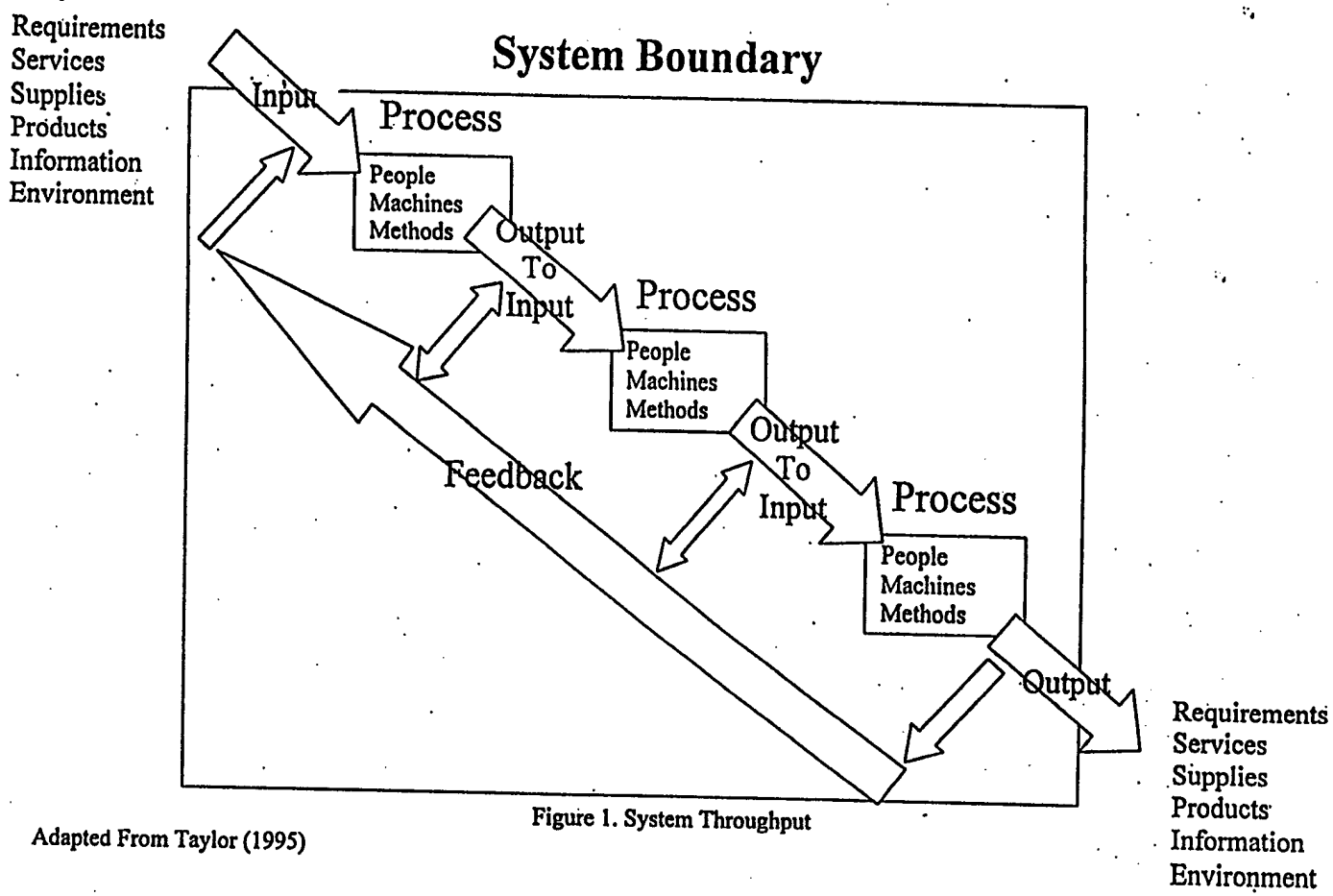

Figure 1. System Throughput

Adapted From Taylor (1995)

During the routine conversion process, normal, expected or specified standards produce the desirable outcome. If the specified standards are exceeded, or if they vary from the norm, a less desired output is produced. These variances can result from differences in the inputs or from the inability to control the conversion process. Unit operations help identify variances and establish which key, or critical, variances have the greatest impact on the output, or product. The technical analysis typically produces a variance matrix of linear unit operations associated with variances. A variance matrix helps to establish system boundaries by maximizing control of variances at the unit operations where the variances originate.

The authors use unit operations to break up the throughput in the technical analysis of non-routine work, but the unit operations encounter problems due to ambiguous inputs and non-linear flow. The ambiguous inputs are key issues to be resolved. Deliberations among those in focal roles provide resolution of key issues in initial unit operations. Cooperation and coordination among focal roles contribute to the control of variances in the remaining unit operations. The throughput is viewed as accumulated information and knowledge. The variance matrix now includes unit operations and key issues to be resolved with both routine and non-routine variances.

The authors describe the social analysis, of both routine and non-routine work systems, as analyzing the division of labor, and the methods of coordinating activities among people and their social roles. A role is different from a job in that it focuses on a

person's behavior and relationship to others rather than on a set of specific task descriptions. Analysis of social roles helps to establish and define the networks of human interaction. It tells us who communicates with whom, what the relationships are and how people cooperate and coordinate with each other. In designing the social system, control over problems is given to the people closest to the root causes.

Taylor and Fenton propose that routine sociotechnical applications are yielding autonomous work groups based on cross-trained workers and overlapping skills, but professional knowledge workers are often too highly trained to develop overlapping skills. They describe parallel or reticular organizations involving temporary structures, similar to discretionary coalitions, which are established to complete a project and parallel the permanent structure. Pava's (1983) The authors conclude that the organization design should ensure people have the proper information, technology, incentives, controls and coordination to ensure accomplishment of overall objectives. Like technical subsystems, social and organizational subsystems are subject to design choices, and they should be designed to fit the environment.

B. SOCIOTECHNICAL SYSTEMS AND NON-ROUTINE WORK

Pava (1983) provides a sociotechnical framework for studying non-linear systems and develops analytical methods for studying non-linear and non-routine conversion processes in office settings. The author reaffirms the basic principles presented by Trist and Emery (1981), refining the system principle as an open system with input, output,

comparison and feedback. Pava emphasizes the need for organizational learning and change to make full use of new office technology. The author also develops a six-step sociotechnical design process for routine and non-routine work that includes start-up, initial scan, technical analysis, social analysis, work system design and enhancement. The non-routine process has an additional step of mapping and identifying the target system prior to start-up. The primary differences between the routine and non-routine design processes are in the analysis and design steps. Technical analysis of routine work involves breaking the work process into unit operations and identifying variances. Technical analysis of non-routine work involves deliberation mapping, or listing deliberations that occur around topics and the forums in which they occur.

The author defines deliberations as reflective and communicative behaviors concerning topics. Gaps in information are identified as variances caused by poor deliberations or forums. Social analysis of routine work involves analyzing roles and interactions. Social analysis of non-routine work involves analyzing networks, network roles and values built during key deliberations, and outlining discretionary coalitions. Both routine and non-routine work system designs try to optimize or match the technical and social subsystems. Routine work system design improves the system operation by establishing boundaries that facilitate control of variances where they occur. Non-routine system design charts the deliberations, discretionary coalitions and forums. Non-routine design also tries to establish boundaries to facilitate the control of variances. Pava

concludes that the steps must be combined or mixed for office or knowledge work that includes both routine and non-routine work.

Pava (1983) further develops his sociotechnical non-routine framework by discussing the limited development of systematic models for analysis and design of knowledge work. He proposes that traditional sociotechnical design analysis of sequential conversion processes and fixed roles has lead to Tayloristic thinking, over optimization of technology and reliance on industrial settings. He describes office and knowledge work as having routine and non-routine tasks, linear and non-linear tasks with unstructured or semi-structured problems, a disjointed, and non-sequential conversion process and unclear beginnings and variable endings. The author further explains how topics are deliberated in forums by discretionary coalitions to handle non-routine work. He reformulates his earlier non-routine technical and social analysis steps to include the establishment and planning of "key" deliberations and "key" discretionary coalitions. The author proposes that office work requires a reticular form of organization that enables people to form and dissolve coalitions as required, while complementing the formal hierarchical structure. He concludes that information systems can genuinely augment key deliberations and forums.

Pasmore and Gurley (1988) discover and define the differences between routine and non-routine work [Fig. 2].

	Routine	Non-Routine
Nature of work	Defined	Undefined
	Repetitive	Non-repetitive
	One right way	Many right ways
	Clear, shared goals	Multiple, competitive goals
	Information readily available	Information hard to obtain
	Forecasting helpful	Forecasting difficult
Nature of success	Efficiency	Effectiveness
	Technical perfection	Human perfection
	Productivity measurable	Productivity unmeasurable
	Physical technology	Knowledge technology
	Standard information	Non-standard information
Nature of decision making	Rules applicable	Rules inhibiting
	Experience counts	Experience may be irrelevant
	Authority-based	Consensus-based
	Complete operational specs	Incomplete operational specs
	Authority by position	Authority by virtue of expertise
Nature of context	Short-time horizon	Long-time horizon
	Stable environment	Unstable environment
	Predefined outcomes	Emergent outcomes
Nature of variances	Obvious	Hidden

Figure 2. Differences Between Routine and Non-Routine Work

From Pasmore and Gurley (1986)

The authors propose that work method decisions are made during the project evolution based on politics and intuition. The authors find non-routine work to be measured by effectiveness, task completion and human perfection rather than by traditional metrics. Their research finds expertise to be widespread in non-routine work environment rather than concentrated at the top, as it is in routine work environments. The authors also find that fewer rules in the non-routine process lead to consensus building, because the individually developed pieces must eventually fit together. The authors explain that non-routine work outcomes exhibit emergent behavior with a chaotic flow, and that the variances or problems that influence output quality or quantity are hidden.

C. THE SOCIOTECHNICAL DELIBERATION APPROACH

In 1986, Pava redesigned his sociotechnical non-routine framework, reaffirming his earlier work and focusing his study and analysis on accurately defining deliberation topics and forums. In his 1986 work the author identifies three conditions present in non-linear work: (1) entwined, multiple conversion processes, compounded by imprecise inputs and outputs, (2) topic uncertainty, having no clear or final solution leading to non-sequential conversion flow and (3) coalitions involving key players who are extensively trained, individualistic and specialized professionals with hard-to-share skills who are less likely to be a source of cohesion for work groups.

The author focuses the social analysis of coalitions on identifying and studying the roles and divergent values of coalition members. He describes a case study of a computer company and proposes the following: (1) designs should make better use of computer-based systems; (2) "deliberation support systems" should be designed based on sociotechnical principles; (3) designers should be more familiar with market research ideas and technology; (4) advances in artificially intelligent expert and decision support systems could capture some of the organizational heuristics to augment deliberation support; (5) technical and social areas need to merge further; (6) entrepreneurial initiative needs to be cultivated. The author concludes that the deliberation approach can harness telecommunication and computing technology, providing a hospitable medium for deliberations and discretionary coalitions, and that the emergent design of deliberations is better than uninformed default, or allowing deliberations to form on their own.

D. VARIANCES THAT INFLUENCE DELIBERATION

Purser (1990) conducts an in-depth study of sociotechnical design applied to the non-routine work environment of research and development, analyzing deliberations and discovering variances and key variances in the non-routine work flow. The author discovers factors that delay research projects and analyzes them to uncover the variances and key variances in the work flow. Purser finds that delays occur when there is (1) a lack of critical knowledge or information for decision making, (2) inadequate time schedule inputs from workers and (3) missing relevant information from previous

projects due to poor documentation. He emphasizes increasing communications and planning, and he proposes two important factors in knowledge work: (1) the development, availability and utilization of conceptual knowledge and (2) continuing professional development and update of knowledge interdependencies. Purser uses these factors to uncover variances, and to map the relationship of root variances to derivative variances [Fig. 3].

Root Variances	Derivative Variances	Key Variances
Lack of Knowledge	Lack of technical documentation Unclear procedure Lack of planning Under-structured forums Unrealistic time frames	Established for each organization based on the derivative variances that have the greatest impact on knowledge development
Lack of Knowledge Sharing	Lack of cooperation Language barriers Divergent values Over-structure forums Unrealistic time frames	
Lack of Utilization of Knowledge	Lack of internal consulting Lack of external consulting Missing parties Wrong parties Diffused responsibilities Unrealistic time frames	

Figure 3. Relationship of Root Variances, Derivative Variances and Key Variances

Adapted from Purser (1990)

From this variance map, organizations can analyze their own deliberations to determine which of the derivative variances are key in the development of knowledge in their systems.

Purser (1992) collaborated on a case study of a research and development (R&D) organization in which non-routine sociotechnical systems methods were applied as part of an effort to improve R&D operations. The authors analyzed deliberations using both quantitative and qualitative methods and their findings describe the impact of variances on the product development cycle. The results of their study indicate that knowledge-related variances in the non-routine work flow of this R&D organization were more severe during the initial stages of product development. Survey results indicate the key sources of variance were knowledge-related, which in turn inhibited organizational learning. Specifically, key sources of variances are identified as lack of knowledge, unrealistic time frames, poor technical documentation, and a lack of internal technical consulting. Interviews indicated that: (1) technology was implemented without adequate conceptual knowledge, (2) under the pressure of time, convergence upon a technical approach occurred too soon, (3) lacking technical documentation, experimenters could not access the organization's knowledge base, (4) and the decisions were often made without consulting or taking into account all the relevant information.

The authors propose that a knowledge base is essential to developing knowledge, enabling acquisition, sharing, interpreting and retrieving knowledge. An organization

with a knowledge base is better informed on technical problems during decision making. The authors present the organizational learning process, or knowledge development, as sharing, integration, distribution, acceptance, validation, clarification and interpretation of insights, knowledge and mental models. The authors use factor analysis to find four factors that obstruct knowledge development in deliberations. These factors are: (1) knowledge sharing and planning barriers, (2) knowledge frame-of-reference barriers, (3) knowledge retention and handling procedure barriers and (4) knowledge acquisition barriers. The authors found that these barriers to learning were attributed to poorly designed and mismanaged deliberations. The authors recommend five solutions: (1) allying the most useful skills of participants with deliberations, (2) ensuring reward systems emphasize knowledge sharing, (3) implementing a participative learning system, (4) allocating more time in the early stages of product development to learning and (5) designing deliberations according to the influences of knowledge development and learning. The authors believe this will ensure relevant parties are present at key deliberations and that they will develop a common language to enhance sharing and provide adequate time for deliberations to occur.

Hull (1993) explores the relevant literature on sociotechnical design and non-routine work. The author conducts a sociotechnical analysis of government acquisition process using Purser's deliberation methodology. Hull's case study includes collection of empirical data from interviews and questionnaires, followed by statistical analysis to identify key variances and delays. The author uses the seventeen variances developed by

Purser as a base to determine the key delays, variances and barriers in his system. Hull identifies the key variances associated with the government contract cases studied as: (1) inadequate time schedule input from relevant parties, (2) lack of preparation and planning of important tasks and discussions, (3) the unavailability of required information when needed for tasks or decision making, (4) lack of documentation, causing relevant past work to be inaccessible and (5) withholding of important knowledge information because of conflict or mistrust. The author then uses factor analysis to link the sources and impacts of the key variances and delays to the development of knowledge. The author reaffirms Purser and Gurley's findings that earlier deliberations are more affected by variances and require increased attention and support. The author also finds technology has been designed without adequate planning, coordination, knowledge-sharing or time. He concludes that the lack of deliberation planning, improper forums, employee involvement and time pressures were the major barriers to learning and knowledge development in this case.

Pasmore (1994) builds on his earlier work, associating non-routine knowledge work with research and development environments and emphasizing the need to understand how social and technical systems influence the development and use of knowledge. The author proposes that the difference between variances in routine and non-routine work are so profound that understanding them requires new sociotechnical thinking. "In knowledge work you must make certain that people and teams are adequately prepared for the tasks they have been given, that the problem has been framed

properly, and to help people organize themselves to answer the critical questions they have identified."

Pasmore references Pava's 1983 work on sociotechnical design as a series of deliberations, rather than discrete decisions, as a way to understand the development of knowledge. He proposes managing knowledge development by making the learning and influence process of an organization more explicit. He characterizes effective deliberations and describes eleven variances that contribute to ineffective deliberations [Fig. 4].

Effective Deliberations	Ineffective Deliberations
Knowledge highly developed and available	Lack of knowledge
Knowledge utilized fully and without bias	Failure to use knowledge
Apolitical discussion of facts and alternatives	Lack of cooperation
People with most knowledge present	Missing parties in key discussions
Disruptive or inappropriate people absent	Wrong parties in key discussions
Discussion held at key choice points	No key discussions at all
Goals clear and shared	Lack of goal clarity
Challenging but realistic time frames	Time frame too short or too long
Decision-making procedures clear	Procedures unclear or non-existent
Appropriate attention to external environment	Inadequate attention to external environment
Minimum bureaucracy	Too much bureaucratic structure

Figure 4. Effective and Ineffective Deliberations

Adapted from Pasmore (1994)

The first variance, lack of knowledge, can also be lack of relevant knowledge. This often results in wrong decisions or in the delay or avoidance of decisions. This variance is the simplest to detect, but it is the most difficult to control. Exposing the issue and involving people with the appropriate expertise in the decision usually controls it. The second variance, failure to use knowledge, is harder to detect and results from failure to use existing knowledge to make a proper decision. This variance is hard to control. The third variance, lack of cooperation, results when people deliberately withhold knowledge due to competition, antagonism, opposing objectives, politics or resistance to other ideas. This variance is controlled through culture and reward systems. The fourth variance, missing parties in key discussions, often occurs when people with authority or status fail to solicit opinions and exclude colleagues with crucial ideas from the decision process. Planning who has input during important decisions often controls this variance. The fifth variance, wrong parties in key discussions, occurs when people who do not possess relevant information are included in the decision process. Planning who has input during important decisions also controls this variance. The sixth variance, no key discussions at all, occurs when people make decisions without input from others due to time constraints, distaste for meetings or a desire to avoid discussions. This variance is controlled by adequately planning the deliberation process. The seventh variance, lack of goal clarity, occurs when goals are unclear, change, are displaced or conflict with other goals. This variance is often controlled by stating goals clearly, ensuring they remain viable and prioritizing them when they conflict. The eighth

variance, a too-long or too-short time frame, occurs when insufficient, or excess, time is allotted to a project. Using time-schedule inputs from the right workers to plan the project often controls this variance. The ninth variance, unclear or non-existent procedures, occurs when procedures are not clearly stated and the informal system drives the decision process. The tenth variance, inadequate attention to external environment, occurs when contact with the customer or external environment is less than it should be. The eleventh variance, too much bureaucratic structure, occurs in traditional hierarchical organizations and interferes with knowledge generation and utilization.

The author explains that the only way to improve the quality of knowledge work is to increase the availability and use of knowledge. The author concludes by offering three principles to follow to improve deliberations; (1) designs must prevent aligning knowledge with authority (non-hierarchical), (2) organizations should maximize the freedom of movement, reducing role and boundary restrictions and (3) knowledge should be widely shared and easily accessible.

E. THE DEVELOPMENT OF KNOWLEDGE

Crawford (1991) discusses the development of talent, intelligence and knowledge as organizational learning and productivity. He defines human capital as skilled, educated people. He outlines the characteristics of knowledge as (1) expandable, self-generating, and exhibiting increasing returns, (2) substitutable, replacing land, labor and capital as the primary factors of production, (3) easily transportable or capable of transfer

by electronic means and (4) sharable or capable of use by multiple users at once. The author breaks knowledge development into (1) acquisition through professional or personal experiences, (2) rendering through electronic, audio, video or personal expression, (3) new development through research and design efforts and (4) transmission through education and training. The author proposes that the largest barrier to knowledge development is a lack of a common language, which inhibits communication. He believes that technology can offer a method to establish a common language for knowledge development. He further explains that knowledge development requires both routine and non-routine methods, combining logical analysis and judgment.

Nanoka and Takeuchi (1995) propose that the success of Japanese firms is due to their ability to create and utilize knowledge. The authors define organizational knowledge creation as the ability to create new knowledge, disseminate it throughout the organization and embody it in products, services and systems. The authors describe human knowledge as either explicit or tacit [Fig. 5].

Explicit Knowledge (Objective)	Tacit Knowledge (Subjective)
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (here and now)	Sequential knowledge (then and there)
Easily articulated and formalized, in language, mathematical expression and manuals	Hard to articulate, formalize or communicate with language
Easily transmitted to other individuals	Embedded in individual experience and not easily transmitted, personal and context specific
Involves tangible factors, such as rules, operating procedures and guidelines	Involves intangible factors such as beliefs, perspectives and values
Dominant western or US mode of knowledge	Dominant Japanese mode of knowledge

Figure 5. Differences Between Explicit and Tacit Knowledge

Adapted from Nanoka (1995)

They define innovation as the process of creating new knowledge, and they propose knowledge is created or converted by the interaction between tacit and explicit knowledge.

The authors present four modes of knowledge conversion: socialization, externalization, combination and internalization. Socialization is the conversion of one person's tacit knowledge to another person's tacit knowledge, in which experiences, mental models and skills are shared. Externalization is the conversion of tacit to explicit knowledge, in which personal tacit knowledge is articulated into explicit knowledge to others through metaphors, models, analogies, concepts and hypothesis. Combination is the conversion of one person's explicit knowledge to another person's explicit knowledge, in which individuals exchange or combine bodies of explicit knowledge through documents, media or electronic means. Internalization is the conversion of explicit to tacit knowledge, in which individuals internalize the tacit knowledge and mental models of others. The authors diagram organizational knowledge creation as a spiral that moves through the four modes of knowledge conversion [Fig. 6].

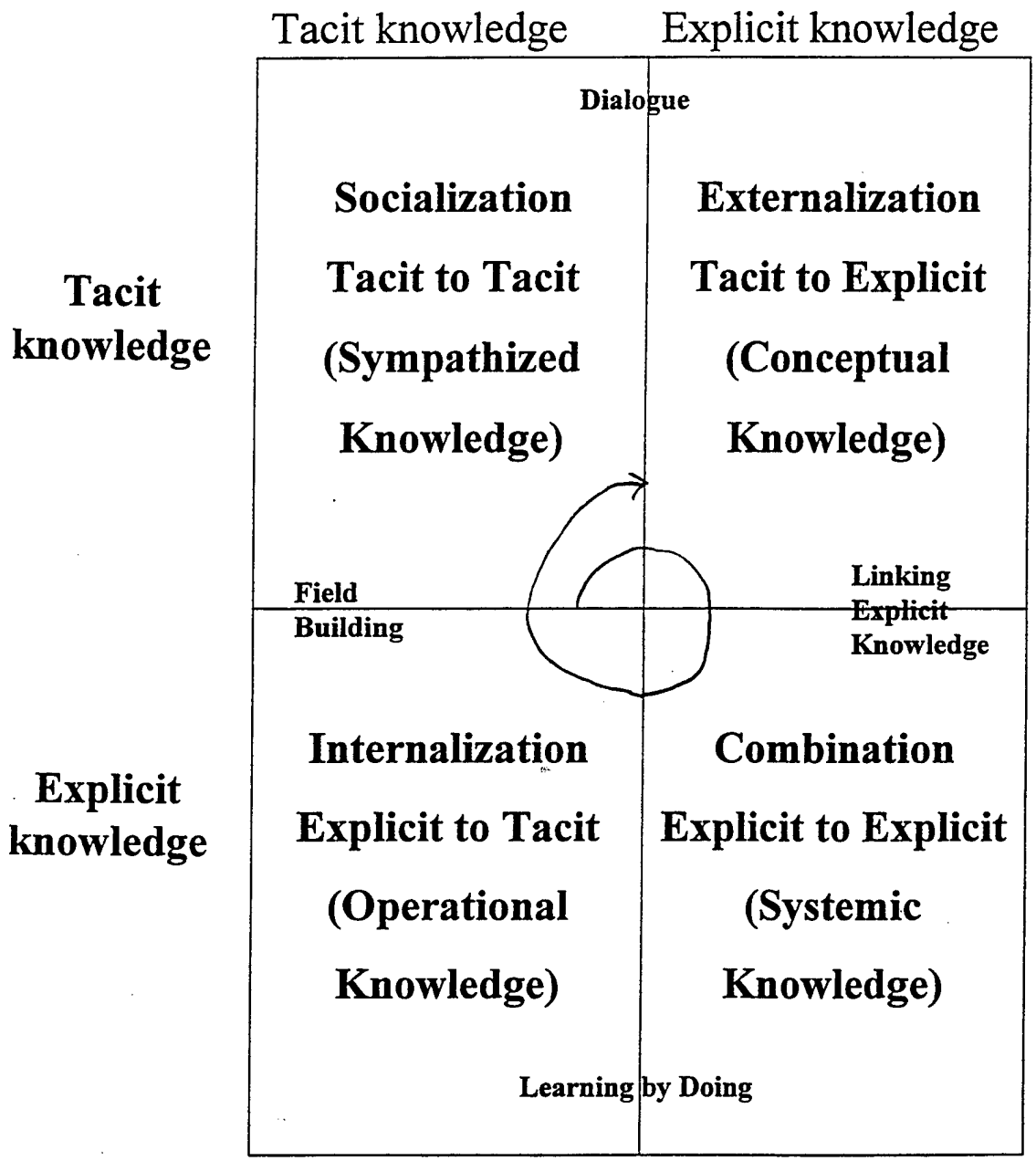

Figure 6. The Knowledge Development Spiral

From Nanoka and Tekeuchi (1995)

The authors' knowledge spiral starts with an individual having explicit knowledge. An individual socializes the knowledge by sharing experiences, mental models and skills. The model moves into externalization when the sharing of knowledge triggers meaningful dialog or collective reflection. Other members now conceptualize and can explicitly articulate the tacit knowledge that was shared. The people in the organization begin networking and combining explicit knowledge into systemic knowledge, which triggers the combination phase. Finally, the new explicit knowledge becomes part of the organization and is internalized, becoming part of the operation. The process continues as a spiral, with the new tacit knowledge being used in the next socialization phase.

The authors conducted case studies using this model knowledge conversion and determined three important organizational issues associated with knowledge creation. First, organizations need to leverage the tacit knowledge base of their individuals, making use of socialization to transfer tacit knowledge throughout the organization. Second, knowledge creation should be amplified across the various levels of the organization. Third, organizations need to create new knowledge continually. The authors also present a larger model of organizational creation that takes this basic spiral model and spans it across individual, group, organizational and inter-organizational levels.

The authors now looks at five enabling conditions that promote the knowledge-creation spiral. First, a complex environment requires a flat, flexible organizational

structure, linked with an information network. Second, organizational intention is linked to strategy goals and vision. An organization needs to foster employee commitment by formulating and sharing its intentions. Third, individual autonomy means individuals are allowed to set their own task boundaries and pursue goals with minimal specification. Creative chaos occurs from fluctuation in the environment and focuses members on defining and resolving the problem, or on externalizing tacit knowledge. Fourth, redundancy is the intentional overlapping of information about the organization, or sharing of tacit and explicit knowledge with individuals who may not need the concepts immediately. This can create information overload and requires information management. Finally, requisite variety means that an organization's diversity, variety and complexity must match its environment.

Edvinsson and Malone (1997) propose a new way to bridge the gap between traditional systems and the intellectual capital of values, skills, knowledge and information. The authors propose the true value of a company is no longer determined by physical, hard or book-value assets alone, but instead by a combination of material and nonmaterial resources. These intellectual assets are typically three to four times a company's tangible value. The authors develop a systematic model for determining, measuring and reporting these hidden assets centering on five basic focuses: customers, processes, renewal and development, human factors and finance. The authors explain that intangible assets are conceptualized best in markets or "knowledge exchanges." These markets use key indicators to measure and manage the indirect assets hidden

within organizations, such as corporate brainpower, organizational knowledge, customer relations, ability to innovate and employee morale. The author concludes that an intellectual capital or knowledge exchange must be created by establishing a common medium and a language structured to exchange all forms of organizational knowledge in an open market.

Davenport and Prusak (1998) propose that learning to identify, manage and foster knowledge is vital for companies in today's fast-moving global economy. The authors propose that most organizations have a casual or unconscious approach to knowledge development, and that they have no real idea how to manage value-added information. The authors explain that a casual approach to managing knowledge often causes knowledge support to be inefficient, relying on hit-or-miss conversations. This kind of support is disorganized, with slow, unreliable searching and reliance on local connections.

The authors reference Nanoka and Takeuchi (1995), who define knowledge development as generation, codification, coordination and transfer. The generation of knowledge is accomplished through acquisition of employees, buying knowledge from others, renting knowledge from consultants, dedicating resources to research and development, fusing of divergent people and forcing a joint answer. The authors emphasize the need for "requisite variety" of members and the "creative chaos" that formalizes brainstorming and generates new solutions. Knowledge generation needs

adequate time and space to occur. Knowledge codification occurs when members understand, internalize and develop mental models of tacit knowledge, thereby making it explicit. Coordination involves mapping and using knowledge maps. Knowledge transfer involves the networks, structure, systems and forums of knowledge exchange. Transfer occurs in meetings and talk rooms, at water coolers, through e-mail, phone conversations, knowledge fairs and numerous other mediums.

The authors propose that because of the unique way knowledge is developed, it is best thought of as a market with buyers, sellers and brokers. Knowledge buyers search for knowledge, insights, judgment and understanding. Knowledge sellers have knowledge and either give it away or hoard it. Knowledge brokers are gatekeepers and boundary spanners that make connections by using meta-knowledge, knowledge maps or logic trails. Information technology can be an effective augmentation to the infrastructure of a knowledge market or exchange. Organizations engaged in knowledge work can create "forums of physical and virtual marketplaces for knowledge exchange," by developing resources like e-mail, groupware, intra/internets, video teleconferencing, multimedia, workshops, training sessions, meetings, conversations, chat rooms, reflections and knowledge fairs. Management's role is to increase productivity by increasing knowledge flow and market efficiency. These forums are the pipelines of communication. They facilitate the flow of information, but not necessarily the development of knowledge.

Davenport and Prusak identify three key factors that cause markets to operate inefficiently in organizations: incomplete information about the knowledge market, asymmetry of knowledge and localness of knowledge. Incomplete information is caused by the lack of explicit information or knowledge maps about where the explicit information is located. Asymmetry occurs when departmental boundaries and structures group and isolate knowledge into organizational areas. Localness is caused by people's tendency to seek for and obtain knowledge only from their neighbors. Knowledge from distant sources may be unavailable, inaccessible or too difficult to obtain. The authors further describe market problems caused by knowledge monopolies, knowledge scarcity and trade barriers. These problems are associated with hoarding knowledge, losing knowledge as people leave the organization, and class and political barriers among workers. When new-car developers at Ford Motor Company wanted to learn why the original Taurus design team was so successful, no one could tell them. No one remembered, or had recorded, what made that effort so special; the knowledge gained in the Taurus project was lost forever.

The authors find that building trust throughout a company is the key to creating a knowledge-oriented corporate culture and a positive environment in which employees are encouraged to make decisions that are efficient, productive and innovative. The authors include numerous examples of successful knowledge projects at companies such as British Petroleum, 3M, Mobil Oil, and Hewlett-Packard. The authors examine how different types of companies can effectively understand, analyze, measure and manage

their intellectual assets, turning corporate knowledge into market value. They conclude that the human qualities of knowledge, experience and intuition are precisely the most valuable and difficult to manage and maximize in any organization.

Shien (1998) describes managing knowledge as capturing and preserving intellectual capital. This is accomplished by document management, search and retrieval of information and workflow enhancement. The author studied a small production company and found that implementing a knowledge base enabled fewer employees to provide better and quicker service to customers. The organization archives its secrets, shortcuts, experiences and old knowledge in the knowledge base. This makes accumulated knowledge available to all the problem solvers, leveraging the best thinking that has already been done about the problem. The author presents a graph that ranks five areas of knowledge management and the emphasis they receive in organizations. The number one area of knowledge management is organizing existing corporate knowledge, followed by new ways to share tacit knowledge, support for research and knowledge generation, new ways to share explicit knowledge and smart tools that aid decision making [Fig. 7].

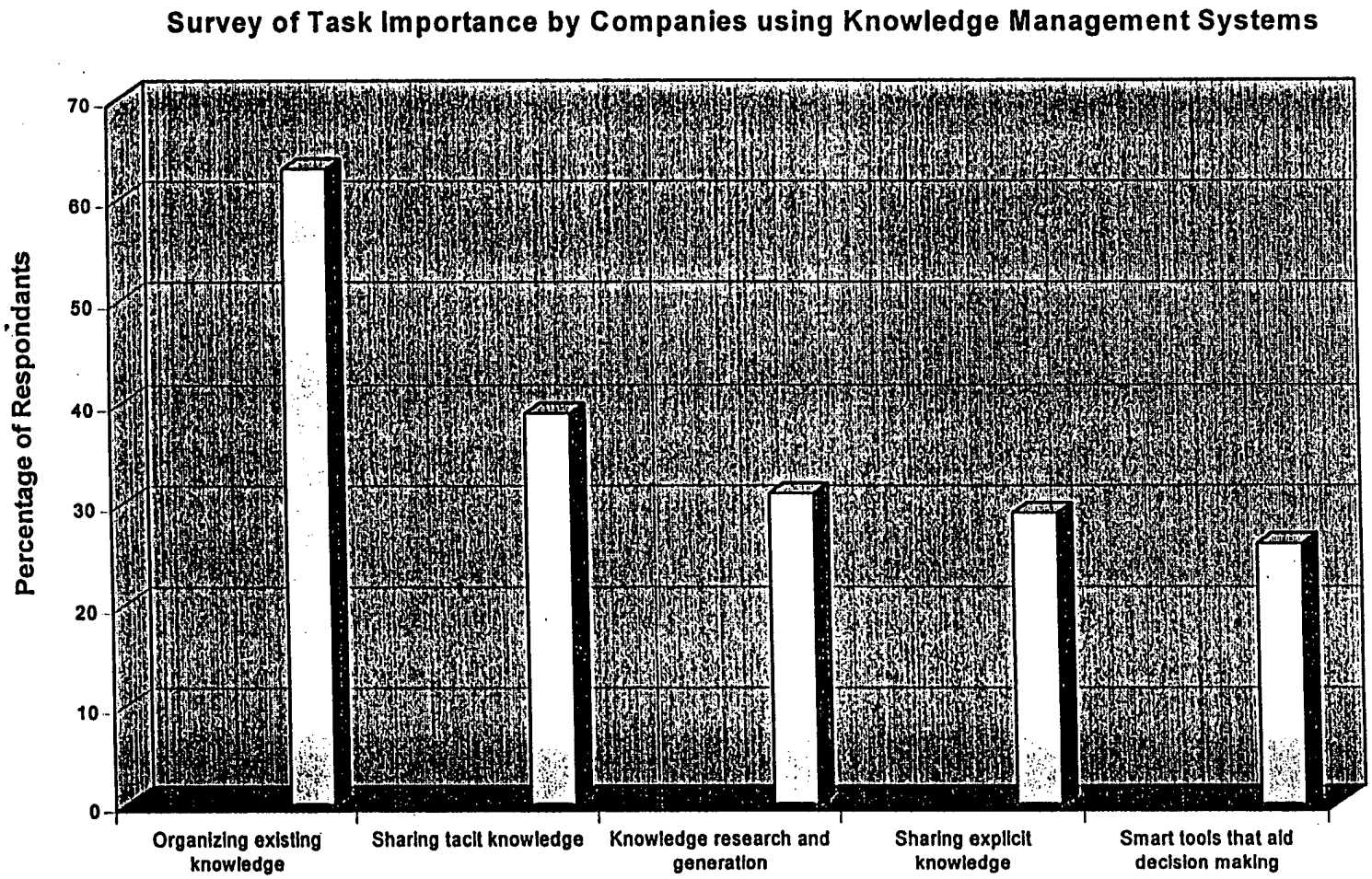

Figure 7. Knowledge Management Tasks

From the Delphi-Group Inc (1998).

Boland and Tenkasi (1995) propose that knowledge development within an organization is a process of making and taking perspectives. They use models of language, communication and cognition to assist in designing electronic communication systems to support making and taking perspectives in knowledge-intensive organizations. The authors identify communities of highly specialized knowledge workers as communities of knowing. They use the pharmaceutical industry as an example of a knowledge-intensive industry that combines specialized communities of knowing molecular biology, physiology, biochemistry, synthetic chemistry pharmacology and molecular kinetics to develop knowledge. The communities of specialized knowledge workers interact to create patterns of sense-making within the organization. The concept of specialized communities of knowing, with different funds of knowledge, interacting in an organization to make sense of issues and problems is similar to Pava's 1983 deliberation process, in which discretionary coalitions are built, from participants with divergent values, to reach trade-offs and make sense of topics.

The authors argue that designing effective electronic communications requires an appreciation for how the communities of knowing interact through prospective making and taking. Electronic communication systems can mediate how communities of knowing emerge, develop, elaborate, suffer crisis, transform, interact and take perspectives. The authors give an example of a product development team that uses a voting system within a groupware product to reach consensus on new drug test subjects. The groupware voting system focuses on consensus and does not allow the group

members to strengthen and represent their perspectives in dialogue. This perspective making and relationship building through dialogue is similar to Nanoka and Takeuchi's socialization phase of knowledge development in which reflection, dialogue and unstructured forums allow relationship building. The authors further parallel Nanoka and Takeuchi's concept of knowledge development by describing the need for members within communities of knowing to reflect and express themselves through narrative structures similar to internalization and socialization phases. The authors conclude by describing five classes of electronic communication forums and how they enhance perspective making and taking of knowledge development.

F. INFORMATION TECHNOLOGY FORUMS

Hamalainen et.al. (1992) discuss the design of computer-based technical systems that support the collaboration of scientists during research projects involving non-routine knowledge work. The authors explore computer and electronic communication technology that makes collaboration more economical and creative by improving the pace and quality of discourse among the collaborative participants. The authors emphasize the understanding of both the social organization of collaboration and the technology used to support it. This is in keeping with the basic tenets of sociotechnical systems developed by Trist (1981). The authors represent collaboration in this knowledge-intensive environment as a process of dialectical discourse or logical debates between participants.

This view is similar to Pasmore's 1991 view of collaborative participants with divergent values forming discretionary coalitions to deliberate issues and reach informed trade-offs.

The authors identify the architecture of a collaboration system that establishes a communication structure and records the flow of argumentation. They review collaborative computer-based systems from areas such as group decision support systems (GDSS) and computer-supported cooperative work (CSCW) systems such as QUILT and WHAT. The GDSS systems support brainstorming, remote communications and computer conferencing. "For example, Object Lens incorporates communication structuring and message filtering into an electronic mail system" (Lai and Malone, 1988). The CSCW systems support collaborative document production. For example, "QUILT allows multi-participant writing, editing, annotation, and labeling of documents while preserving access integrity" (Fish, Kraut, and Leland, 1988), and "WHAT, a hypertext-based writing tool, uses an argumentative approach to help researchers document their wor." (Hashim, 1990). The authors identify four minimum general features that a successful collaborative system should have:

- A capacity for remote and asynchronous collaboration;
- A method that facilitates the collaborative analysis of complex problems;
- A project management component; and
- A reporting component than can produce diverse reports.

The authors consider the features of three collaborative system bases; structured electronic mail (e-mail) systems, issue based information systems and dialectic logic systems. They conclude, by developing a collaboration system for researchers that incorporates the best features of the three system bases they studied. These features include: structured e-mail to support communication, a structured issue-based discourse facility and a facility for report production, project management, decision support and negotiation support. This collaboration system should support remote communication, coordination, discourse tracking and dialectic analysis.

Lucas (1996) describes how managers can use information technology (IT), combined with conventional approaches to organizational design, to create a technologically based organization. The author views IT as a new set of tools for organizations involved in knowledge work to enhance flexibility and responsiveness. The author discusses designing new organizations using IT in a twelve-step process. The twelve steps are: (1) recognizing the physical and logical structures of an organization are separate, (2) developing a corporate strategy, (3) identifying processes, (4) integrating classical design steps with IT variables, (5) designing the local structure of the organization, (6) designing the physical structure of the organization, (7) planning for temporary task force and matrix management, (8) focusing on key decisions that provide choice in organization, (9) designing tasks, (10) building or buying a technological infrastructure, (11) using compensation policy to achieve goals, and (12) trusting workers and leading through influence. Steps seven through nine resemble the sociotechnical

deliberation design of deliberation mapping and discretionary coalitions. Lucas views the new technology-based organization as having a flat structure made possible by technological leveling. The new organization will use technological matrixing to form temporary task teams focused on specific projects. The author proposes that group-based electronic communications can link work flows, enabling work coordination and improvement. The author defines five categories of professional work: scheduled meetings, unspecified desk work, walking around an area, unscheduled meetings and telephone calls. He proposes the activities of communication and information processing as central to all five categories. The professional worker communicates by receiving and disseminating information from people, letters, memos, tours, meetings, phone calls, e-mail and other electronic means. The information is then processed to make decisions, allocate resources and settle problems. The majority of the professional's time is currently spent on communication and not on processing.

The author describes groupware as coordination software that provides a shared environment, supporting managers and professionals in a common task. Most groupware provides access to shared databases, an internal e-mail system and application development tools. The author studied several companies that use IBM Lotus Notes groupware, and found that most firms used groupware to improve administration, with a few applying the resource to the entire business. Groupware is viewed as a forum that makes information easy to share across many traditional boundaries. The authors proposes that groupware provides an intelligence base, making organizational intelligence

available where it is needed. Groupware also leverages other technologies, such as expert and decision support systems, making it easier for these systems to be integrated by providing a common link to data. The author proposes that groupware enhances the communication capability of the people in the organization, and increases their access to information, freeing up time for them to process the information.

This chapter has presented some of the important work in sociotechnical design as applied to knowledge work environments. First, the basic tenets of sociotechnical systems apply to both routine and non-routine work. Second, the deliberation approach has been more successful at capturing the complexity of the non-routine environment of knowledge worker than has the traditional sociotechnical approach. Third, to design effective deliberations, one must understand the development of knowledge. Fourth, the variances in deliberations that cause barriers to knowledge development are well established and can be used to identify key variances within individual organizations. Fifth, the forums used by discretionary coalitions during deliberation of topics must change to meet the changing needs of the knowledge development process. Sixth, forums should be designed to enhance the phases of knowledge development, the skills of the participants and the control of the key variances. Seventh, information technology forums can provide the virtual shared space required for knowledge development, but care must be taken to ensure the technology is structured and developed to meet the needs of knowledge development. Many of the ideas and conclusions discussed above will be used in this thesis.

III. SOCIOTECHNICAL SYSTEMS

A. OVERVIEW

Sociotechnical systems design is a methodology that combines theory, principles and practical methods to achieve organizational improvement. The theory enables members of an organization to conceptualize and develop an organizational purpose. The principles and practical methods enable the theoretical ideas to be applied, achieving improvement in actual organizational settings. Classical sociotechnical design methods have developed from applications in routine, industrial work settings. New sociotechnical systems design methods involving deliberations have developed from applications in non-routine, knowledge work settings. The original tenets and principles developed for sociotechnical systems are the same and remain valid for all types of work settings. The sociotechnical approach used differs according to the type of work involved, allowing the analysis and design teams to accurately capture and understand the process and variances associated with the different types of work.

B. SOCIOTECHNICAL SYSTEMS DESIGN

1. The Basic Tenets of Sociotechnical Design

Sociotechnical systems design follows three basic tenets; holistic systems thinking, focus on throughput and joint optimization of technical and social subsystems (Trist, 1981). These basic tenets are employed to aid organizational members in

understanding their environment and establishing an organizational purpose. Practical methods, tools and steps are used to provide adaptive, productive and custom solutions for each organization, based on its system needs. The holistic systems thinking view presents the whole organization as an open system with input, output and feedback identifying the root causes of problems and improving the entire system. The throughput focus, also called output or product focus, helps organizational members understand their contribution to the system. Joint optimization of the technical and social subsystems aims to provide the appropriate amount of analysis and design emphasis to these often conflicting and competing subsystems [Fig. 8].

Sociotechnical Systems Design

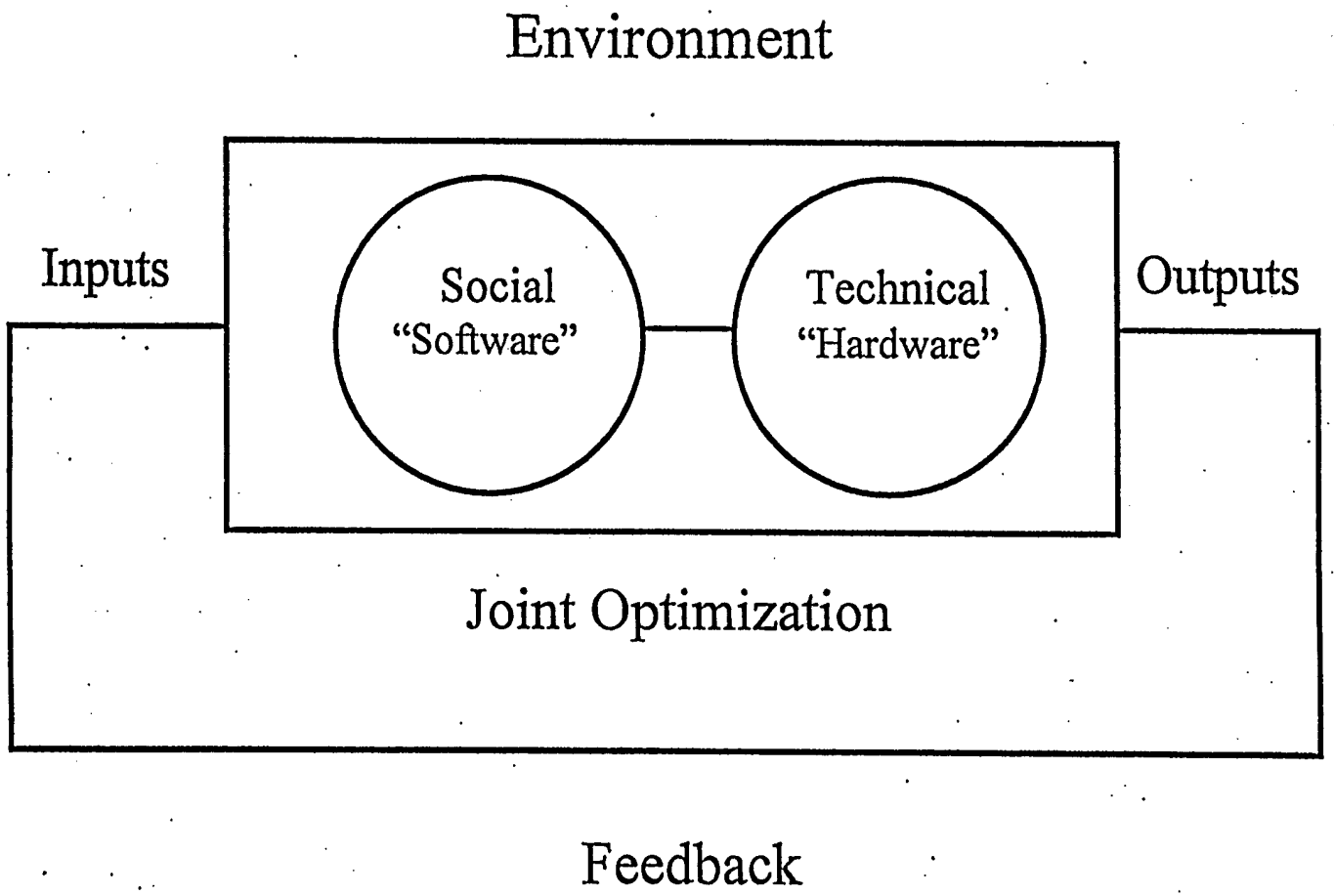

Figure 8. Holistic System and Joint Optimoization

From Taylor (1991)

2. Sociotechnical Design Procedures

Classic sociotechnical systems design has evolved from applications in industrial, routine, linear and sequential work environments. Taylor (1993) defines seven major steps in classical sociotechnical procedures: preparation, scan, analysis, joint optimization, system design, implementation and reiteration. These steps occur in four major phases: discovery, understanding, system design and implementation.

a. Discovery Phase

The first phase of sociotechnical system design is called discovery or preparation. In this phase, workers discover of new organizational ideas, methods and tools. The workers learn about the methodology of holistic systems thinking, throughput focus and joint optimization. The organization often sends people to workshops, retreats and training in this phase, to educate them, open their minds and cultivate a learning culture. The discovery phase also prepares members for an open and honest evaluation of organizational purpose and need by exposing them to modern business theory and practices. A steering committee made up of members of the organization's senior management is usually established to give guidance and act as an approving body for analysis and design teams.

b. Understanding Phase

The second phase of sociotechnical design is understanding. In this phase, the current work system is defined in sociotechnical terms using the newly learned methods and tools. This phase includes a broad look at the organization as an open system and a scan of its environment to specify the general system boundaries and understand the system's purpose. The system boundaries are used to define social and technical subsystems. This initial scan forms the basis for building a shared vision of mission and goals central to the organization. The scan is normally conducted by the steering committee. Following the scan, an analysis team is assembled from workers at varying levels of the organization, who use analytical methods to conduct an in-depth analysis of the technical and the social subsystems. Once the subsystems are analyzed and data are collected either the analysis team converts to a design team or a new design team is formed.

c. System Design Phase

The third phase of sociotechnical systems design uses the data and analysis from earlier steps to combine, match and jointly optimize the social and technical subsystems to fit the environment. The design team initially develops an ideal joint optimization of the subsystems, which is then converted into a provisional design using feedback and environmental constraints. The provisional design is then tested in

theory and actual operation to ensure it's output is consistent with the original organizational purpose.

d. Implementation Phase

The fourth phase of sociotechnical systems design involves approval of the new design by the steering committee, implementation of the new design and reiterative process improvement through continual review and feedback.

C. SOCIOTECHNICAL SYSTEMS AND ROUTINE WORK

Sociotechnical design applications in routine work environments, which include industrial production and linear transactional processes, are considered classic applications. These classic design applications have experienced both success and problems.

1. Classical Sociotechnical Systems Design Success

Classic sociotechnical design, following the basis tenents and procedures of Sociotechnical Systems, have been developed and applied since the 1950s. These classic designs have successfully increased the productivity, quality and capability of industrial production facilities engaged in routine work like General Motors. (Taylor, 1993, pp. 32) Routine work requires few skills and allows little room for discretion or thought while conducting the work tasks. This enables workers to master tasks quickly and for many workers to share similar skills. Industrial tasks have well-defined linear processes that

cannot be broken and have specific time limits for completion, adding a temporal relationship. The success of these industrial applications was based in part by the ability to understand and identify clearly the variances involved in the unit operations. Input variances to industrial processes were identified as fluctuations in the quality or quantity of raw material or services. Throughput variances were identified as production tolerances, material or process defects and the ability to measure the tolerances or defects. Once the variances were identified on a variance matrix, control of the variance could be distributed to the workers who were closest to their origin. Workers were now able to control the variances that were key to producing the desired product. This led to increased quality and quantity of throughput.

2. Classical Sociotechnical Systems Design Problems

The tenets of classical sociotechnical design call for joint optimization of the technical and social subsystems, but greater emphasis and energy is normally placed on the analysis and design of the technical subsystem. This greater emphasis is due in part to the higher status and influence technical engineers usually have over social engineers when making decisions about system design. The greater technical emphasis is also due to the technically based metrics used for routine work tasks. The technically based metrics provide more tangible and reliable information about technical problems than they do about social organizational problems. Due to both the status of technical engineers and the technical base of metrics, the technical subsystem is often over-

optimized. This techno-centric approach can lead to automation or computerization of operations, which increase the technical subsystem capability but reduce the whole system capability and flexibility.

The success of traditional sociotechnical systems designs in industrial routine work environments has relied on analysis of technical unit operations and social roles. This approach has produced a common or standard outcome of cross-training workers with overlapping skills in autonomous work groups. Yet, the principles of Sociotechnical Systems try to avoid standard outputs. The classic approach encountered further problems when it was applied in a non-routine work environment, due to the lack of non-routine metrics and standards to measure variances, as well as the lack of understanding of what non-routine variances looked like. The traditional variance matrix became complicated due to reliance on routine variances, non-linear work flow and undefined process beginnings. A new understanding of non-routine work flow, variances and transformation process was required to adapt sociotechnical design effectively to knowledge work.

D. SOCIOTECHNICAL SYSTEMS AND NON-ROUTINE WORK

Knowledge work has emerged, in the First world countries of Western Europe, North America, and Japan since the middle of the Twentieth century. Knowledge work involves non-routine and non-linear tasks with subjective value. (Davenport, 1998) Knowledge workers are highly educated professionals, managers and white-collar

workers who develop and create knowledge. Knowledge development is the transformation process for knowledge work. There are many barriers to developing knowledge these barriers affect the performance of knowledge workers. Pava (1986) developed a new sociotechnical design approach for applications involving knowledge work based on the concept of deliberation. The deliberation approach includes the classical design tenets and principles while redefining the technical and social analysis phases. Purser (1992) further develop the deliberation approach by establishing the variances that affect non-routine work deliberations. These deliberation variances cause barriers in the knowledge development process, which hinder knowledge development and organizational learning. Nanoka and Takeuchi (1995) and Davenport and Prusak (1998) have offered new insights to the variances and barriers that influence knowledge development.

1. Knowledge Work

A new kind of work has emerged, since the middle of the 20th century, involving contextual or mental tasks rather than transactional or physical ones. This new work is based on knowledge and involves the transformation of data to information and information to knowledge. Data, or discrete, objective facts, are the raw material that is transformed into information by giving it structure, meaning and form. Information is the raw material that is transformed into knowledge by further applying experience, skills and insights. Knowledge work is a complex, unstructured transformation process that

requires a higher degree of discretion, decision making, education and skill than the traditional production process [Fig 9].

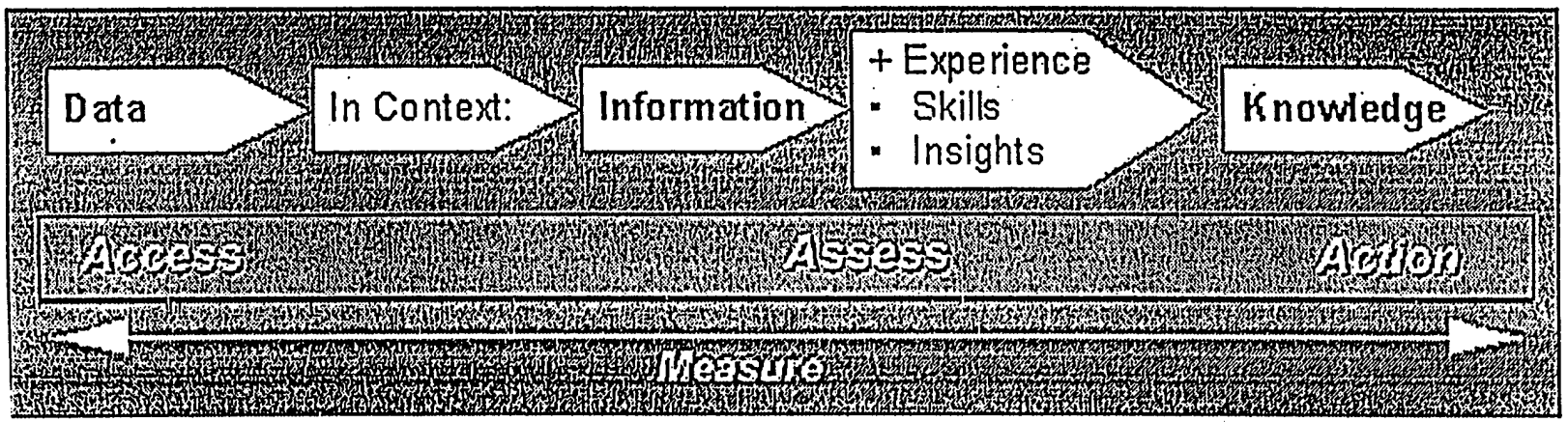

Figure 9. Knowledge Work

The input is ambiguous and there is no recognizable beginning. Davenport and Prusak (1998) provide three examples of knowledge work. The first is a Swiss pharmaceutical firm that develops new drug applications. The work of the researchers is mostly contextual as they search for information, make hypotheses and test those hypotheses. The second example is a heart surgery team in New England. The work of this team involves observing one another's operating procedures, exchanging ideas about the most effective techniques and collaborating to develop new techniques. The third example is the customer support center at Hewlett-Packard. The counselors at the support center must talk customers through solutions that involve interactions with constantly changing hardware, software and communication products. The counselors use a management tool called "case-base reasoning" to capture obscure and abstract knowledge and to assist them with conceptualizing the contextually based problems.

a. Non-routine and Non-linear Knowledge Work

Knowledge work includes routine, non-routine, linear and non-linear tasks [Fig. 10].

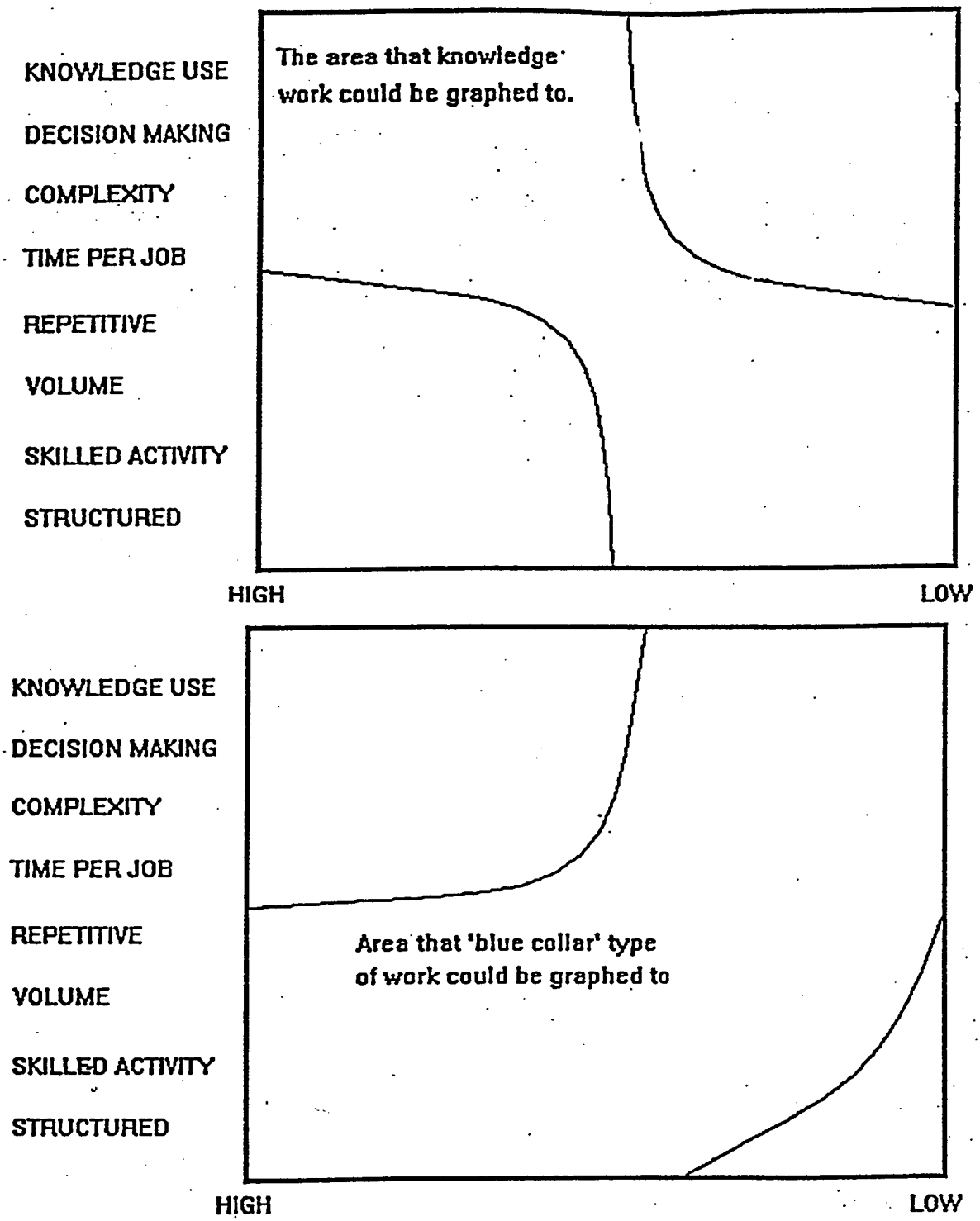

Figure 10. Expected Graph Area of Knowledge and Blue Collar Work

Non-routine tasks have a low action-to-outcome relationship. This means that the outcome, or effect, of the tasks cannot be directly predicted by inputs, actions taken or events caused during the conversion process. Non-routine tasks have erratic inputs, poorly structured problems and novel or unexpected outputs. Non-linear tasks are those that simultaneously add value from multiple workers with little or no temporal sequence. The effects of each task or change can often be transmitted to earlier ones, causing the links between tasks to be numerous and often saturating the entire transformation process. The pharmaceutical industry provides an example of non-routine and non-linear knowledge work, as researchers in this industry must combine the specialized communities of knowing, such as, molecular biology, physiology, biochemistry, synthetic chemistry pharmacology and molecular kinetics, to develop knowledge. The development of knowledge in this environment is more chaotic, following no predetermined sequential or temporal process. (Boland and Tenkasi, 1995)

b. Subjective Value of Knowledge

Knowledge work has a contextual instead of a transactional base. The value of knowledge is often ambiguous, subjective, difficult to define and without clear metrics. "It is a fluid mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information..." (Crawford, 1991). Knowledge has value based on its need, the context in which it is developed and its application. There is no average, norm

or standard against which to measure knowledge input or output. Most metrics and accounting systems are still based on the concept that 80 percent of production costs are manual or industrial labor. Traditional financial measures, such as return on investment (ROI), do not measure intangible attributes like flexibility, acceptance of work, or the impact on an organization's competitive position. Organizations utterly lack the metrics to measure intellectual resources. Artificial indicators are often evaluated to establish output knowledge value, because they are easier to quantify than the actual value of the knowledge work. Improving the performance of knowledge workers engaged in more non-routine tasks requires new methods and ideas. Intangibles are better conceptualized in markets or "knowledge exchanges" with key indicators to measure performance. (Edvinsson, 1997) Group techniques by which knowledge workers use independent value judgments to establish output expectations can help the workers achieve consensus on the value of the knowledge work outputs. Group techniques are not absolutely accurate, but they are better indicators than the traditional models used to increase industrial productivity.

2. Knowledge Workers

Drucker (1994) first coined the term "knowledge worker" to describe people who work with their minds as well as their hands. The rise of the knowledge worker represents a profound change in society. Traditional sociotechnical social design often yields the concept of autonomous work groups. The autonomous work group design is

less appropriate for knowledge workers because of their specialization and years of formal education devoted to a specific field of expertise. Knowledge specialization is less supportive of cross training and the creation of flexible team members, because the skills and roles are not easily rotated. Knowledge workers are best organized in collaborative teams that seek to combine people with the appropriate specialized skills to handle problems. The team members do not shift roles; rather, they bring their specialized skills in and share them with the group for collaboration. Knowledge workers bring to the organization the tools, skills, abilities and insights they have learned or discovered during the education process. Their productivity depends on their ability to access information, use the tools they have and continue to learn to use new tools. It is harder for organizations to break down the intangible skills and practices of knowledge workers than it was for factories to do the same with industrial workers.

a. Educated Professionals

Knowledge workers are highly educated professionals, managers, informational and white-collar workers who own the means and tools of production. Knowledge workers work in professional occupations and in occupations requiring higher educational degrees or specialized training. They engage in decisions and choices based on personal discretion and they are often responsible for the subjective quality or value of their output. A high degree of autonomy is required and granted to these professionals. Knowledge workers are often formally educated in colleges or universities, and their

knowledge is highly specialized due to the time they have invested in one area of formal education. Unfortunately the formal education of college graduates is out of date fewer than ten years after leaving school. Knowledge workers must therefor engage in continual lifelong learning to remain competent. The specialized skills of educated professionals are not highly transferable, and shared skills are less likely to bring cohesion to the work groups.

b. Knowledge Developers

Knowledge workers are conceptual and symbolic analysts who use their hands, and their analytical and theoretical knowledge to transform data and information into distillations of that information. They have learned how to learn, and they have a unique ability to acquire and apply new ideas. Knowledge workers do not contract to deliver a discrete product the way crafts people or industrial worker, do; rather, they offer the ability to apply discretionary thought and action. Knowledge workers begin their work by searching, browsing and accessing the available explicit, relevant knowledge assets. The input is selective data and information, and the output is mainly intangible and contextual knowledge. This unclear process requires a high degree of individual discretion. Influences on the development of knowledge include individual and organizational sharing, planning, cooperation, member involvement, frames of reference, common language, values, information access and retention, time limitation and clarity of purpose.

3. Knowledge Development

Pava (1986) defines knowledge development as a transformation process of knowledge work in which organizational learning is accomplished through non-routine tasks. Purser (1990) divided this transformation process into specific areas of availability, utilization and conceptualization of knowledge. Crawford (1991) defines similar areas and adds transmission through education and training. He views knowledge development as a market, with buyers, sellers and brokers. Buyers search for insights, judgment and understanding. Sellers have knowledge and either give it away or hoard it. Brokers are gatekeepers and boundary spanners that make connections by using meta-knowledge, knowledge maps or logic trails.

Nanoka and Takeuchi (1995) describe knowledge development as the interaction between tacit and explicit knowledge. He saw the process as a spiral of socialization, externalization, combination and internalization. Davenport (1998) also defines knowledge development areas similar to those noted by Pava (1986), adding knowledge codification. These ideas of knowledge development can be organized together according to common themes of (1) availability and access, (2) communication, sharing, codification and coordination and (3) processing, creating and developing [Fig 11].

Development Process	Barriers or Enablers	Variances
Purser and Pasmore		
Availability of Information	Acquisition	3 root and 17 derivative
Utilization of Information	Sharing and Planning	See Fig.2
Conception Knowledge	Common Frame of Reference	
	Retention and Handling	
Crawford		
Acquisition	Common Language	
Rendering		
Development		
Transmission		
Davenport		
Generation	Incomplete Information	Knowledge Monopolies
Codification	Asymmetry of Knowledge	Knowledge Scarcity
Coordination	Localness of Knowledge	Hoarding Knowledge
Transfer		
Lucas		
Access to Information		
Communication		
Processing		
Nanoka		
Sharing Tacit Knowledge	Socialization	Intention (Vision)
Creating Concepts	Externalization	Autonomy (Min Spec)
Justifying Concepts	Combination	Creative Chaos (Focus)
Building an Archetype	Internalization	Redundancy (Sharing)
Cross-Leveling of Knowledge	See Fig 5	Requisite Variety (Match the environment)

Figure 11. Variances and Barriers in Knowledge Development

Understanding how knowledge is developed is essential to identifying the barriers that impede its development. Organizations with a casual or unconscious approach to knowledge development lack the planning and support to prevent barriers from impeding development. Unmanaged knowledge development can become inefficient, relying on hit-or-miss, chance conversations. Unmanaged development can also lead to slow, unreliable, disorganized and localized searching.

4. Knowledge Development Barriers

Purser and Pasmore (1992) attribute poor knowledge development to planning and communication barriers in the knowledge development process. These barriers are caused by variations that influence the deliberation process. The authors further define these barriers as sharing and planning, frame of reference, retention and handling procedures, and acquisition. Hull's 1993 study of government acquisition reinforced these barriers by showing how lack of deliberation planning, improper forums, lack of employee involvement and time pressures caused poor deliberations in his case study. Crawford (1991) found that the barrier of dissimilar language also reduced communication and caused poor deliberations.

5. Sociotechnical Systems Deliberation Approach

The deliberations approach, developed by Pava (1986), provides a clearer picture of the knowledge transformation process than the unit operations concept discussed by Taylor (1986). Deliberation is a sense-making process in which the organization

develops an understanding of how to deal with issues, problems or discrepancies. A deliberation is an ongoing exchange between people. It starts when a problem or issue is identified and ends when a resolution is achieved. The process of deliberation includes anything that enables a change in the state of knowledge. Deliberations are the context and subtext of decisions that resolve topics and constitute the actual gist of information work. The deliberation concept does not try to define the tasks and operations to be performed; rather, it defines the issues or problems, identifies who is best qualified to resolve the issues and establishes how the organization can best support those workers in their quest for the resolution. This approach focuses on the development process, the involved members of the organization and how those members contribute to the exchange of information. Deliberations in knowledge work occur, whether they are planned or not, because non-routine tasks cause uncertainty that requires resolution. The proper design, planning and management of deliberations can reduce the variances that obstruct organizational learning and knowledge development.

a. Technical Analysis in Non-routine Work

The technical analysis phase of sociotechnical design involves examination of the tools and procedures in the technical subsystem of work. The technical analysis of non-routine work centers upon a deliberation matrix, as opposed to the development of a variance matrix in routine work. Current deliberations are listed and prioritized as major or minor, according to their contribution to the organizational

mission. The forums to be used are listed and categorized as structured, semi-structured and unstructured. Forums provide the architecture for deliberations. They are the places, rules and norms for the information exchange, where organizational members deliberate topics. Forums include individual reflection, discrete relations, personal encounters, ad hoc discussions, links to people and objects, communicative behavior, acquisition, sharing, debate, clarification and interpretation of information, exchanges and informal or formal meetings. The component activities of the knowledge work are listed and analyzed, such as typing, filing, sorting, mail, dictating, reading, reflecting, composing, scheduling, meeting, traveling, discussing and phoning. The component activities are similar to unit operations in that they are complete processes, but they are dissimilar in that they have no temporal or sequential relationship. The variances or gaps that cause barriers in the deliberations are listed along with the deliberations in which they occur. A deliberation-activity matrix is composed of deliberations, related activities, forums and variances. Finally, the ideal participants in each deliberation are listed along with the information they contribute and extract from the deliberation. (Pava, 1986) In mixed routine/non-routine work environments, the traditional variance matrix, listing unit operations and variances, is added to the deliberation-activity matrix.

b. Social Analysis in Non-routine Work

For each deliberation, a map of the role network is developed. The role network map is formed from the list of ideal participants created in the technical analysis.

The typical values or positions taken by the participants is described to identify divergent or opposite values that occur in deliberations. These divergent values require participants to achieve resolution through trade-offs in their positions. Trade-offs occur when participants get together in discretionary coalitions to give and take on their position. Discretionary coalitions are the alliances, combinations, collaborations and coordination activities of organizational members. Coalitions include any number of temporary or permanent interested parties, actors and stakeholders. Coalition members should be able to organize quickly and efficiently to develop and use their knowledge base, sharing insights, mental models and organization memory to deliberate issues. The role network map identifies the typical divergent positions of participants and the discretionary coalitions they form to resolve the divergence, enabling the design team to decide what discretionary coalitions to organize for major deliberations. Discretionary coalitions become the social format in non-routine work, just as autonomous work groups were the format in routine work. The role network map is used to ensure the best forum mix is available to support discretionary coalitions in effectively deliberating tradeoffs. (Pava, 1986)

E. SUMMARY

Sociotechnical systems are based on the three tenets of systems thinking, joint optimization of social and technical subsystems and throughput focus. These tenets endure as a lasting and viable groundwork for applications in both routine and non-

routine work. The design phases and procedures of routine and non-routine work follow similar steps and differ only in the approaches taken during the analysis and design steps. The routine work approach is based on analysis of unit operations and variances in the inputs or process, while the non-routine approach is based on activities and variances in the deliberations. Understanding the development of knowledge and its barrier enables deliberation designers to combine the optimum forums with the right discretionary coalitions to deliberate topics effectively and overcome the variances inherent in an organization.

IV. DELIBERATION PLANNING

Optimum deliberation planning occurs when topics are adequately defined, the right participants are combined in discretionary coalitions and the best forums are made available. The best forums enable control of the key variances by participants and complement the phase of knowledge development in which the deliberation is occurring. Planners must choose the key variances carefully, be aware of the phase of knowledge development in which the deliberation will occur and understand how the strengths and weaknesses of specific forums will affect the deliberation.

A. CHOOSING VARIANCES

During the technical analysis of non-routine work, key variances are chosen that demonstrate the greatest impact on deliberations. Most sociotechnical applications to non-routine work start with the seventeen variances developed by Pasmore (1988) as a base for choosing the organizations key variances. The accurate choice of key variances is important because those variances influence the design of deliberations. Deliberations are designed by choosing discretionary coalitions and forums that maximize the control and minimize the effect of variances that cause poor knowledge development. Pasmore's 1988 variances are listed in surveys and interviews and ranked or weighted according to their impact on the system being analyzed. In addition to Pasmore's 1988 variances, Nanoka and Takeuchi (1995) and Davenport and Prusak (1998) have identified variances that offer additional perspective to the factors that affect knowledge development.

These additional variances should be combined to establish the base for choosing key variances during technical analysis of non-routine work. The key variances are then used to identify the barriers of knowledge development. Once the barriers to knowledge development are established, the correct forums and coalitions can be developed and combined to overcome these barriers and enhance the knowledge development process.

B. CHOOSING FORUMS

Organizations need to create physical and virtual work spaces or marketplaces for knowledge exchange. These work spaces are the forums for knowledge development in which individual perspectives are articulated and conflicts are resolved. (Tyre, 1997) Pava (1986) classifies forums as unstructured, semi-structured and structured. He emphasizes that as deliberations progress in knowledge development, the forums must change to meet new barriers to development. Organizational members engage in a series of evolving forums to deliberate topics.

Hull (1993) proposes that loosely structured or unstructured forums should be planned in the early stages of knowledge development, progressing to more structured forums in the latter stages. Nanoka and Takeuchi (1995) grouped deliberation variances and knowledge barriers into four phases of knowledge development. If the variances and barriers of each knowledge development phase are compared to the structure and strengths of the available forums, optimal forums can be planned to overcome the knowledge development barriers inherent in each phase [Fig. 12].

Knowledge Development	Optimal Forums
Socialization Acquisition Incomplete Information	Unstructured Chat Rooms Expert and Robust Search Engine Redundant Information
Externalization Sharing and Planning Asymmetry of Knowledge Localness of Knowledge	Semistructured Shared Knowledge Base Collaboration Software Deliberation Support System Small Groups Cross Departmental Training Knowledge Fairs
Combination Common Language Common Frame of Reference	Structured Meetings
Internalization Retention and Handling Modeling and Simulation	Unstructured Forums Reflection

Figure 12. Optimal Forums for Knowledge Development

Boland and Tenkasi (1995) identified five classes of electronic forums that would enhance the perspective making and taking of knowledge development.

1. Forums in the Socialization Phase

During the socialization phase, tacit knowledge is converted to tacit knowledge. Participants are searching for knowledge and defining the topic or problem. The root variances inherent to this stage are lack of knowledge and lack of knowledge sharing. The common barriers to knowledge development are acquisition, access and incomplete information. The optimal forums that enhance knowledge development during this stage are unstructured, with loose connections and informal procedures. Unstructured forums include individual reflection, e-mail, phone conversations, talk or chat rooms, coffee room sessions, ad-hoc discussions, wipe boards, note pads, napkin sketches, memos and access to a networked or shared knowledge base with a robust or expert search engine. Boland and Tenkasi (1995) identify task narrative forums, which help to narrate our experiences and share our experiences with others. One example of socialization is the learning process of machine repair technicians. The knowledge of repair technicians does not come from what is taught in the classroom, but rather from informal story swapping among technicians and users about their experiences in particular work environments. (Tyre and Hippel, 1997) The task narratives are multimedia that enable the benefits of learning by experience to extend beyond normal time and space constraints. This enables the technicians to express their perspective and open themselves to the perspectives of

others. Intelligent agent and expert system forums help individuals assemble contextual materials, build links and representations and help members think about thinking. The goal in this stage is to enhance knowledge seeking and searching behavior by providing maximum access to all knowledge sources while providing some direction about the topic to be resolved. Time for searching and reflection is critical in this stage and must not be neglected or cut short. Recognize the importance of planning time for unstructured forums in this early stage of knowledge development is also important. This time ensures adequate reflection, understanding, topic definition and relationship building.

2. Forums in the Externalization Phase

During the externalization phase, tacit knowledge is converted into explicit knowledge. Participants are engaged in transferring knowledge, articulating ideas, sharing mental models, creating concepts and planning the progression of development. The root variances inherent to this stage are lack of knowledge sharing and lack of utilization of knowledge. The common barriers to knowledge development are lack of a common frame of reference or language, lack of development planning, justification of concepts and local and asymmetric knowledge. The optimal forums that enhance knowledge development during this stage are semi-structured and informal, with moderated rules and procedures that guide discretionary coalitions through deliberations. Semi-structured forums include conventions, conferences, informal reviews, seminars, access to a shared knowledge base, modeling and simulation software, collaborative

software, small informal group meetings and talk rooms or coffee-room sessions that have established definitive procedures and guidelines. Boland and Tenkasi's (1995) knowledge representation forums help link and embed documents for more rich representation of knowledge. These forums are openly reflexive. In them communities talk explicitly about their knowledge. The goal of this phase is to enhance knowledge sharing by establishing cooperation, common language, rich media discussions, clear goals and identification of divergent values of participants. This ensures the correct people are present to stimulate the generation of ideas and alternatives. Clarifying and codifying the development process is also important during this stage. Time should now be shifted from searching to planning and sharing. This sets the groundwork for the combination phase.

3. Forums in the Combination Phase

During the combination phase, explicit knowledge is converted into explicit knowledge. Participants are engaged in exchanging and combining documents, media and text; developing new knowledge; building archetypes; and coordinating ideas and concepts to be used throughout the rest of the knowledge development process. The root variances are lack of utilization of knowledge, under-structured forums and the presence of the wrong parties during deliberations. The common barrier to knowledge development is the lack of a common language or frame of reference. The optimal forums that enhance knowledge development during this phase are structured and

formalized, with explicitly defined procedures and methods. Structured forums include small, formal, in-person or electronically distributed meetings and collaborative software that can enable the sharing of knowledge through multimedia. The goal of this phase is to enhance decision making by determining decision protocol, screening criteria for evaluating technical alternatives and negotiating optimal trade-offs. This is the most critical time for knowledge development, because the most decisions are made and the right participants and resources must be available to ensure that decisions are effective. These forums must be highly focused on objectives, ensuring that only participants who have the ability to resolve the topic are present.

4. Forums in the Internalization Phase

During the internalization phase, explicit knowledge is converted to tacit knowledge. Participants engage in internalizing tacit knowledge by adding it to their individual knowledge base and to the shared organizational knowledge base. Participants also prepare for the spiral into the next socialization phase, in which they will use this newly established tacit knowledge. The variances encountered are lack of technical documentation, diffused responsibilities and time pressure. The common barriers are retention capacity, handling procedures and time. The optimal forums are unstructured and informal allowing participants to search through the development trail and archive important, knowledge. The unstructured forums include reflection, e-mail archives, groupware journals, access to a shared knowledge base, documentation and manuals.

Boland and Tenkasi's (1995) interpretive reading forums provide a space for reflecting upon the assumptions and readings of other forums. In these forums, participants reread material, consider perspectives and interpret ideas for their own perspective making. The goal of this phase is to build the knowledge base, codify learning experiences and enhance the organization and archiving of knowledge that has been developed. Participants use this phase to redevelop their mental models and skills, and update knowledge interdependencies and networks. The forums of this phase are most important to the long-term success of knowledge development. Time, again, has a great effect on the quality of deliberation occurring in the forums of the internalization phase.

C. INFORMATION TECHNOLOGY FORUMS

Information technology forums can add to the infrastructure of knowledge exchange. Boland and Tenkasi (1995) have identified five classes of information technology forums that enhance deliberations: task narrative, knowledge representation, interpretive reading, theory building and expert systems. Deciding which forums are best for the deliberation depends on the skills of the participants, the phase of knowledge development and the key variances that need to be controlled. Pasmore (1988), Nanoka and Takeuchi (1995) and Purser (1992) have conducted extensive research in determining the variances that exist in knowledge development. Identifying the key variances that exist during each phase of knowledge development provides additional detail on which forums would best overcome knowledge barriers. The following section looks at

electronic communication forums and associates their applicability to the deliberation process based on how they support participant's skills and their strengths in overcoming the variances that cause barriers to knowledge development.

1. Stuctured Electronic Mail (E-Mail)

Structured electronic mail (e-mail) allows members of an organization to communicate and exchange explicit knowledge. E-mail can also be the conduit to conduct virtual meetings, in which a group of people sit down in front of personal computers and exchange multimedia information such as text, data, vocal messages, graphs, pictures and videos. (Nanoka and Takeuchi, 1995, pp. 244) The e-mail environment distributes messages, documents and files among user mailboxes, facsimile machines and voice mail. This enables communication that can cross traditional boundaries of time, space and bureaucracy. E-mail creates permanent searchable records for documentation and archiving. It can also enhance relationship building by reducing the effort required to communicate.

Many e-mail applications are being integrated with other software applications, dissolving the distinction between e-mail and groupware. The strengths of e-mail are its ability to enhance communication and exchange of explicit knowledge as well as documentation of knowledge generated during the development process. E-mail can be a task narrative forum. It can also support expert systems, knowledge representation and theory building. An example of structured e-mail is the Information Lens system.

Information Lens allows users to define semi-structured messages; that is, each message has both a structured and unstructured part. The structured part is the header or date, subject and so forth; the unstructured part handles the rest of the message. (Hamalainen, et al., 1992) The semi-structured nature of e-mail makes it an excellent forum for use in all phases of knowledge development.

E-mail would be especially useful in the socialization and internalization phases of knowledge development, when semi-structured forums are required. It would also be most useful in an organization with over-structured forums, asymmetric knowledge, functional boundaries, lack of technical documentation, language barriers and lack of cooperation.

2. Electronic Talk or Chat Rooms

Electronic talk or chat rooms are virtual spaces that use electronic models, messages and simulations to help participants brainstorm. Informal chat rooms can be areas for random conversations surrounding a topic. On the more formal side, the chat rooms are similar to electronic meetings. Electronic chat rooms can vary their formality making them an excellent vehicle to build upon during the development of deliberations. Chat rooms can begin in the socialization phase as informal and then add formality as the development of knowledge moves into the externalization and combination phases. Chat rooms can be task-narrative, knowledge-representation and theory-building forums. Lotus Teamroom is an example of an electronic chat room that helps groups create shared

goals. This software tool provides a shared virtual space for unstructured discussion and collaboration. The addition of a facilitator moves the tool into the semi-structured arena, and the use of additional protocols establishes the formal structure. (Davenport and Prusak, 1998)

3. Electronic Collaboration or Groupware

Electronic collaboration has been called computer-supported cooperative work, groupware, coordination technology and decision conferences. Groupware is the most common term found that covers these applications. Groupware is electronically distributed meetings, video teleconferencing and collaboration software that can increase the quantity of interactions but not necessarily the quality. Groupware has the capacity to create a shared work space with structure and procedures to communicate, collaborate, plan, brainstorm and make decisions. This medium can become an effective knowledge market, providing a common language for knowledge exchange. The formality of groupware can be controlled by the structure and rules invoked. (Hargrove, 1998) In the socialization phase, unstructured groupware would be most useful. Unstructured groupware could take the form of informal electronic meetings with flexible time constraints, no agenda and minimal defined procedures. As knowledge development progressed into the externalization phase, groupware could be useful for planning, by deconflicting schedules, meetings and appointments. Semi-structured groupware with some formality and a few defined procedures could be employed to overcome

communication and language barriers. In the combination phase, groupware could add the structured and shared space participants need to provide focus. The use of facilitators, highly defined procedures, objectives, roles, tools and protocols with groupware would overcome many of the common variances and barriers inherent to this phase. Finally, in the internalization phase, groupware could retrace the development process, tracking, storing and documenting multimedia messages, thereby enhancing the reflection and archiving of knowledge. Hewlett Packard (HP) employs Lotus Notes for discussion-oriented applications. The company initially adopted an intranet-based system but it has since moved to an internet-based application. The company also uses groupware for knowledge management. The HP system handles hundreds of thousands of documents, including white papers, presentations, technical specifications and hyperlinks to the World Wide Web. The system enables anyone at HP to create and include a document in the company's knowledge base. The system also tracks and documents all interactions (Davenport and Prusak, 1998). Groupware has the capacity to support all phases of knowledge development by facilitating all five classes of forums, depending on how it is structured and administrated.

D. SUMMARY

Effective deliberations come from adequately defining topics, and from choosing the right key variances and the best mix of forums. The seventeen variances developed by Pasmore should be combined with those developed by Nanoka and Takeuchi (1995)

and Davenport and Prusak (1998) to form the base of variances from which to choose key variances. Forums should be chosen to match the specific requirements of the knowledge development phase and to allow the discretionary coalitions to control the key variances. Generally unstructured forums are best employed at the beginning and ending of the knowledge development process, and more structured forums are used in between. Information technology forums can greatly enhance the deliberation structure, acting as the medium or pipeline for knowledge development. Information technology forums should be applied only to meet the requirements of the knowledge development phase and to ensure control of the key variances by the discretionary coalitions. Groupware is one example of information technology that could enhance all phases of knowledge development by redefining the structure and procedures of the forum as the phases of knowledge development progress.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SYNOPSIS

Sociotechnical systems designs recently have been adapted for application in non-routine, knowledge work environments. This application uses Pava's 1986 concept of deliberating topics in forums by discretionary coalitions. The technical analysis of deliberations consists of establishing topics for deliberation, deliberation activities, variances in the deliberation process and forums. The social analysis establishes the discretionary coalitions and the role networks that control variances. Purser (1990) has conducted extensive research to establish a list of root and derivative variances from which to choose key variances. The work of Nanoka and Takeuchi (1995) and Davenport and Prusak (1998) has provided additional perspective on the variances that affect deliberations in the development of knowledge. The combined variances of Purser, (1992), Nanoka and Takeuchi (1995) and Davenport and Prusak (1998) make up a comprehensive variance base from which key variances may be chosen.

Understanding the development of knowledge is essential to identifying the barriers to development and the variations that cause poor deliberations. The four-phase knowledge development spiral established by Nanoka and Takeuchi (1995) provides the clearest and most comprehensive analysis of the process. Using the knowledge development spiral, and the variances common to specific stages of development, an understanding of the optimal forums and coalitions can be developed. Specific

information technology forums can be structurally analyzed for their strengths and weaknesses throughout the four phases of knowledge development. The best mix of forums can then be developed and applied based on meeting the need, controlling the variances and enhancing the skills of discretionary coalitions throughout the deliberation process.

B. RECOMMENDATIONS

During the technical analysis of non-routine, knowledge work environments, the root and derivative variances of Purser (1992), Nanoka and Takeuchi (1995) and Davenport and Prusak (1998) should be combined to form a variance base from which to choose key variances.

While conducting a sociotechnical analysis of a knowledge work environment, an organization should be aware of the knowledge development process and the barriers that exist to the development of knowledge. Once an organization understands the key variances and the barriers to the development of knowledge, it can more effectively design forums and discretionary coalitions.

Information technology forums such as e-mail, chat rooms and groupware have specific strengths and weaknesses. These forums should be designed and applied to complement the control of the key variance, the skills of participants and the phase of knowledge development in which the deliberation is taking place.

C. ANSWERS TO RESEARCH QUESTIONS

1. Primary Research Question

How can sociotechnical systems design enhance the ability an organization engaged in knowledge work has to establish key variances and the best mix of forums for the development of knowledge?

This study has clearly indicated that an organization engaged in knowledge work can use the sociotechnical systems deliberation approach to gain a clear understanding of knowledge development, knowledge development barriers and the variances that contribute to poor deliberations. A well-defined and complete body of root and derivative variances also exists from which an organization can identify its key variances. Once an organization has an understanding of the knowledge development process and the key variances, it can then design discretionary coalitions and forums to control key variances, enhance the participant's skills and ensure the development of knowledge.

2. Secondary Research Questions

a. What is the new paradigm of knowledge work?

Knowledge work involves the transformation of data to information and information to knowledge. It includes routine, non-routine, linear and non-linear tasks with erratic inputs, poorly structured problems and novel or unexpected outputs. Knowledge work has a contextual base rather than a transactional base. Understanding

knowledge work requires an understanding of the knowledge development process, which is best described by Nanoka and Takeuchi's (1995) four-phase knowledge development spiral.

b. What is the sociotechnical systems deliberation approach?

The sociotechnical systems deliberation approach, developed by Pava (1983), is a sense-making process in which the organization develops an understanding with how to deal with issues, problems or discrepancies. A deliberation is an ongoing exchange between people that starts when a problem or issue is identified and ends when a resolution is achieved. The process of deliberation includes anything that enables a change in the state of knowledge. Deliberations are the context and subtext of decisions that resolve topics and constitute the actual gist of information work. The deliberation concept does not try to define the tasks and operations to be performed; rather, it defines the issues or problems, identifies who is best qualified to resolve the issues and establishes how the organization can best support those people in their quest for the resolution. This approach focuses on the development process, the involved members of the organization and how those members contribute to the exchange of information. Deliberations in knowledge work occur, whether they are planned or not, because non-routine tasks cause uncertainty that requires resolution. The proper design, planning and management of deliberations can reduce the variances that obstruct organizational learning and knowledge development.

c. *What are the appropriate root variances from which to choose key variances?*

Most sociotechnical applications to non-routine work start with the seventeen variances developed by Pasmore (1988) as a base for choosing organizational key variances. The accurate choice of key variances is important because they influence the design of deliberations. Deliberations are designed by choosing discretionary coalitions and forums that maximize the control and minimize the effect of variances that cause poor knowledge development. Pasmore's (1988) seventeen variances are listed in surveys and interviews and ranked or weighted according to their impact on the system being analyzed. In addition to these seventeen variances, Nanoka and Takeuchi (1995) and Davenport (1998) have identified variances that offer additional perspective to the factors that affect knowledge development. These variances should be combined to establish the base for choosing key variances during technical analysis of non-routine work.

d. *How should forums be evaluated and designed to enhance the development of knowledge?*

Organizations need to create physical and virtual work spaces or marketplaces for knowledge exchange. These work spaces are the forums for knowledge development. Pava (1986) classifies forums as unstructured, semi-structured and structured. He emphasizes that as deliberations progress in knowledge development, the forums must change to meet new barriers to development. Hull (1993) proposes that

loosely structured or unstructured forums should be planned in the early stages of knowledge development, progressing to more structured forums in the latter stages. Nanoka and Takeuchi (1995) group deliberation variances and barriers into four phases of knowledge development. By comparing the variances and barriers of each knowledge development phase to the structure and strengths of the available forums, optimal forums can be planned to overcome the knowledge development barriers inherent in each phase.

e. What is the best application for information technology forums such as e-mail, chat rooms or groupware in a knowledge work environment?

Information technology forums should be applied only to meet the requirements of the knowledge development phase and to ensure control of the key variances by the discretionary coalitions. Groupware is one example of information technology that could enhance all phases of knowledge development by redefining the structure and procedures of the forum as the phases of knowledge development progress.

D. AREAS FOR FURTHER RESEARCH

1. Validating the combined variances that provide a variance base for choosing key variances of deliberations.

2. Restructuring the design of information technology forums during deliberations in non-routine work according to changes in the phase of knowledge development.

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