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Source: *Organization Science*, Vol. 5, No. 1 (Feb., 1994), pp. 14-37

Published by: [INFORMS](#)

Stable URL: <http://www.jstor.org/stable/2635068>

Accessed: 13/01/2011 06:07

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# A Dynamic Theory of Organizational Knowledge Creation

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I recommend this paper to *Organization Science* readers because I believe that it has the potential to stimulate the next wave of research on organization learning. It provides a conceptual framework for research on the differences and similarities of learning by individuals, groups, and organizations.

*Arie Y. Lewin*

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## Abstract

This paper proposes a paradigm for managing the dynamic aspects of organizational knowledge creating processes. Its central theme is that organizational knowledge is created through a continuous dialogue between tacit and explicit knowledge. The nature of this dialogue is examined and four patterns of interaction involving tacit and explicit knowledge are identified. It is argued that while new knowledge is developed by individuals, organizations play a critical role in articulating and amplifying that knowledge. A theoretical framework is developed which provides an analytical perspective on the constituent dimensions of knowledge creation. This framework is then applied in two operational models for facilitating the dynamic creation of appropriate organizational knowledge.

*(Self-Designing Organization; Teams; Knowledge Conversion; Organizational Innovation; Management Models)*

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## 1. Introduction

It is widely observed that the society we live in has been gradually turning into a “knowledge society” (Drucker 1968; Bell 1973; Toffler 1990). The ever increasing importance of knowledge in contemporary society calls for a shift in our thinking concerning innovation in large business organizations—be it technical innovation, product innovation, or strategic or organizational innovation.<sup>1</sup> It raises questions about how organizations process knowledge and, more importantly, how they create new knowledge. Such a shift in general orientation will involve, among other things, a reconceptualization of the organizational knowledge creation processes.

The theory of organization has long been dominated by a paradigm that conceptualizes the organization as a system that ‘processes’ information or ‘solves’ problems. Central to this paradigm is the assumption that a fundamental task for the organization is how efficiently it can deal with information and decisions in an uncertain environment. This paradigm suggests that the solution lies in the ‘input-process-output’ sequence of hierarchical information processing. Yet a critical problem with this paradigm follows from its passive and static view of the organization. Information processing is viewed as a problem-solving activity which centers on what is given to the organization—without due consideration of what is created by it.

Any organization that dynamically deals with a changing environment ought not only to process information efficiently but also create information and knowledge. Analyzing the organization in terms of its design and capability to process information imposed by the environment no doubt constitutes an important approach to interpreting certain aspects of organizational activities. However, it can be argued that the organization’s interaction with its environment, together with the means by which it creates and distributes information and knowledge, are more important when it comes to building an active and dynamic understanding of the organization. For example, innovation, which is a key form of organizational knowledge creation, cannot be explained sufficiently in terms of information processing or problem solving. Innovation can be better understood as a process in which the organization creates and defines problems and then actively develops new knowledge to solve them. Also, innovation produced by one part of the organization in

turn creates a stream of related information and knowledge, which might then trigger changes in the organization's wider knowledge systems. Such a sequence of innovation suggests that the organization should be studied from the viewpoint of how it creates information and knowledge, rather than with regard to how it processes these entities.

The goal of this paper is to develop the essential elements of a theory of organizational knowledge creation. In the sections which follow, the basic concepts and models of the theory of organizational knowledge creation are presented. Based on this foundation, the dynamics of the organizational knowledge creation process are examined and practical models are advanced for managing the process more effectively.

## 2. Basic Concepts and Models of Organizational Knowledge Creation

The following subsections explore some basic constructs of the theory of organizational knowledge creation. They begin by discussing the nature of information and knowledge and then draw a distinction between "tacit" and "explicit" knowledge. This distinction represents what could be described as the epistemological dimension to organizational knowledge creation. It embraces a continual dialogue between explicit and tacit knowledge which drives the creation of new ideas and concepts.

Although ideas are formed in the minds of individuals, interaction between individuals typically plays a critical role in developing these ideas. That is to say, "communities of interaction" contribute to the amplification and development of new knowledge. While these communities might span departmental or indeed organizational boundaries, the point to note is that they define a further dimension to organizational knowledge creation, which is associated with the extent of social interaction between individuals that share and develop knowledge. This is referred to as the "ontological" dimension of knowledge creation.

Following a consideration of the two dimensions of knowledge creation, some attention is given to the role of individuals and, more specifically, to their "commitment" to the knowledge creating process. This covers aspects of their "intention," the role of autonomy, and the effects of fluctuations or discontinuities in the organization and its environment.

Next, a "spiral" model of knowledge creation is proposed which shows the relationship between the

epistemological and ontological dimensions of knowledge creation. This spiral illustrates the creation of a new concept in terms of a continual dialogue between tacit and explicit knowledge. As the concept resonates around an expanding community of individuals, it is developed and clarified. Gradually, concepts which are thought to be of value obtain a wider currency and become crystalized. This description of the spiral model is followed by some observations about how to support the practical management of organizational knowledge creation.

### 2.1. Knowledge and Information

Knowledge is a multifaceted concept with multilayered meanings. The history of philosophy since the classical Greek period can be regarded as a never-ending search for the meaning of knowledge.<sup>2</sup> This paper follows traditional epistemology and adopts a definition of knowledge as "justified true belief." It should be noted, however, that while the arguments of traditional epistemology focus on "truthfulness" as the essential attribute of knowledge, for present purposes it is important to consider knowledge as a personal "belief," and emphasize the importance of the "justification" of knowledge. This difference introduces another critical distinction between the view of knowledge of traditional epistemology and that of the theory of knowledge creation. While the former naturally emphasizes the absolute, static, and nonhuman nature of knowledge, typically expressed in propositional forms in formal logic, the latter sees knowledge as a dynamic human process of justifying personal beliefs as part of an aspiration for the "truth."

Although the terms "information" and "knowledge" are often used interchangeably, there is a clear distinction between information and knowledge. According to Machlup (1983), information is a flow of messages or meanings which might add to, restructure or change knowledge. Dretske (1981) offers some useful definitions. In his words:

Information is that commodity capable of yielding knowledge, and what information a signal carries is what we can learn from it (Dretske 1981, p. 44). Knowledge is identified with information-produced (or sustained) belief, but the information a person receives is relative to what he or she already knows about the possibilities at the source (ibid, p. 86).

In short, information is a flow of messages, while knowledge is created and organized by the very flow of information, anchored on the commitment and beliefs of its holder. This understanding emphasizes an essential aspect of knowledge that relates to human action.

The importance of knowledge related to action has been recognized in the area of artificial intelligence. For example, Gruber (1989) addresses the subject of an expert's "strategic knowledge" as that which directly guides his action, and attempts to develop the tools to acquire it. Since the 1980s, the development of cognitive science has been based on a serious reflection on behaviorist psychology's neglect of such traditional questions as, 'Why do human beings act in a certain way?', which was a central issue for so-called "folk psychology" (Stich 1986). Searle's discussion on the "speech act" also points out a close relationship between language and human action in terms of the "intention" and "commitment" of speakers (Searle 1969). In sum, as a fundamental basis for the theory of organizational creation of knowledge, it can be argued that attention should be focused on the active, subjective nature of knowledge represented by such terms as "belief" and "commitment" that are deeply rooted in the value systems of individuals.

The analysis of knowledge and information does not stop at this point. Information is a necessary medium or material for initiating and formalizing knowledge and can be viewed from "syntactic" and "semantic" perspectives. The syntactic aspect of information is illustrated by Shannon's analysis of the volume of information which is measured without regard to its meaning or value. A telephone bill, for example, is not calculated on the basis of the content of a conversation but according to the duration of time and the distance involved. Shannon said that the semantic aspects of communication, which center on the meaning of information, are irrelevant to the engineering problem (Shannon and Weaver 1949). A genuine theory of information would be a theory about the content of our messages, not a theory about the form in which this content is embodied (Dretske 1981).

In terms of creating knowledge, the semantic aspect of information is more relevant as it focuses on conveyed meaning. The syntactic aspect does not capture the importance of information in the knowledge creation process. Therefore, any preoccupation with the formal definition will tend to lead to a disproportionate emphasis on the role of information processing, which is insensitive to the creation of organizational knowledge out of the chaotic, equivocal state of information. Information, seen from the semantic standpoint, literally means that it contains new meaning. As Bateson (1979, p. 5) put it, "information consists of differences that make a difference." This insight provides a new point of view for interpreting events that make previously invisible connections or ideas obvious or shed

light on unexpected connections (Miyazaki and Ueno 1985). For the purposes of building a theory of knowledge creation, it is important to concentrate on the semantic aspects of information.

## 2.2. Two Dimensions of Knowledge Creation

Although a great deal has been written about the importance of knowledge in management, relatively little attention has been paid to how knowledge is created and how the knowledge creation process can be managed. One dimension of this knowledge creation process can be drawn from a distinction between two types of knowledge—"tacit knowledge" and *explicit knowledge*." As Michael Polanyi (1966, p. 4) put it, "We can know more than we can tell".<sup>3</sup> Knowledge that can be expressed in words and numbers only represents the tip of the iceberg of the entire body of possible knowledge. Polanyi classified human knowledge into two categories. "Explicit" or codified knowledge refers to knowledge that is transmittable in formal, systematic language. On the other hand, "tacit" knowledge has a personal quality, which makes it hard to formalize and communicate. Tacit knowledge is deeply rooted in action, commitment, and involvement in a specific context. In Polanyi's words, it "indwells" in a comprehensive cognizance of the human mind and body.

While Polanyi articulates the contents of tacit knowledge in a philosophical context, it is also possible to expand his idea in a more practical direction. Tacit knowledge involves both cognitive and technical elements. The cognitive elements center on what Johnson-Laird (1983) called "mental models" in which human beings form working models of the world by creating and manipulating analogies in their minds. These working models include schemata, paradigms, beliefs, and viewpoints that provide "perspectives" that help individuals to perceive and define their world. By contrast, the technical element of tacit knowledge covers concrete know-how, crafts, and skills that apply to specific contexts. It is important to note here that the cognitive element of tacit knowledge refers to an individual's images of reality and visions for the future, that is to say, what is and what ought to be. As will be discussed later, the articulation of tacit perspectives—in a kind of "mobilization" process—is a key factor in the creation of new knowledge.

Tacit knowledge is a continuous activity of knowing and embodies what Bateson (1973) has referred to as an "analogue" quality. In this context, communication between individuals may be seen as an analogue pro-

cess that aims to share tacit knowledge to build mutual understanding. This understanding involves a kind of “parallel processing” of the complexities of current issues, as the different dimensions of a problem are processed simultaneously. By contrast, explicit knowledge is discrete or “digital.” It is captured in records of the past such as libraries, archives, and databases and is assessed on a sequential basis.

*The Ontological Dimension: The Level of Social Interaction.* At a fundamental level, knowledge is created by individuals. An organization cannot create knowledge without individuals. The organization supports creative individuals or provides a context for such individuals to create knowledge. Organizational knowledge creation, therefore, should be understood in terms of a process that “organizationally” amplifies the knowledge created by individuals, and crystallizes it as a part of the knowledge network of organization.

In this line, it is possible to distinguish several levels of social interaction at which the knowledge created by an individual is transformed and legitimized. In the first instance, an informal community of social interaction provides an immediate forum for nurturing the emergent property of knowledge at each level and developing new ideas. Since this informal community might span organizational boundaries—for example, to include suppliers or customers—it is important that the organization is able to integrate appropriate aspects of emerging knowledge into its strategic development. Thus, the potential contribution of informal groups to organizational knowledge creation should be related to more formal notions of a hierarchical structure. If this is done effectively, new knowledge associated with more advantageous organizational processes or technologies will be able to gain a broader currency within the organization.

In addition to the creation of knowledge within an organization, it is also possible that there will be formal provisions to build knowledge at an interorganizational level. This might occur if informal communities of interaction, that span the link between customers, suppliers, distributors, and even competitors, are put on a more formal basis, for example, through the formation of alliances or outsourcing.

### **2.3. Commitment on the Part of the Knowledge Subject: Intention, Autonomy, and Fluctuation**

The prime movers in the process of organizational knowledge creation are the individual members of an organization. Individuals are continuously committed to recreating the world in accordance with their own

perspectives. As Polanyi noted, “commitment” underlies human knowledge creating activities. Thus, commitment is one of the most important components for promoting the formation of new knowledge within an organization. There are three basic factors that induce individual commitment in an organizational setting: “intention,” and “autonomy,” and a certain level of environmental “fluctuation.”

*Intention.* Intention is concerned with how individuals form their approach to the world and try to make sense of their environment. It is not simply a state of mind, but rather what might be called an action-oriented concept. Edmund Husserl (1968) called this attitude on the part of the subject “intentionality.” He denied the existence of “consciousness” per se, which was generally assumed by psychologists in 19th century, and argued that consciousness arises when a subject pays attention to an object. In other words, any consciousness is a ‘consciousness of something.’ It arises, endures, and disappears with a subject’s commitment to an object.

Eigen (1971) argued, in his evolutionary theory, that evolution involves the process of acquiring environmental information for better adaptation. Eigen insisted that the degree of meaningfulness of information, or a value parameter, needs to be introduced to explain this system. Human beings, as organic systems, derive meaning from the environment which is based on their ultimate pursuit of survival (Shimizu 1978). Man cannot grasp the meaning of information about his environment without some frame of value judgment.

The meaning of information differs according to what a particular system aims to do (manifest purpose or problem consciousness) and the broader environment in which that system exists (context). It is more concerned with the system’s future aspirations than its current state. Weick (1979) explains this “self-fulfilling prophecy” of a system as the “enactment” of the environment, which may be a projection of its strong will for self-actualization. While mechanistic information-processing models treat the mind as a fixed capacity device for converting meaningless information into conscious perception, in reality cognition is the activity of knowing and understanding as it occurs in the context of purposeful activity (Neisser 1976). Intention becomes apparent against this background. Without intention, it would be impossible to judge the value of the information or knowledge perceived or created. “The intentionality of the mind not only creates the possibility of meaning, but also limits its form” (Searle 1983, p. 166).

*Autonomy.* The principle of autonomy can be applied at the individual, group, and organizational levels—either separately or all together. However, the individual is a convenient starting point for analysis. Individuals within the organization may have different intentions. Every individual has his or her own personality. By allowing people to act autonomously, the organization may increase the possibility of introducing unexpected opportunities of the type that are sometimes associated with the so-called “garbage can” metaphor (Cohen et al. 1972). From the standpoint of creating knowledge, such an organization is more likely to maintain greater flexibility in acquiring, relating, and interpreting information. In a system where the autonomy of individuals is assured, or where only “minimum critical specification” (Morgan 1986) is intended, it is possible to establish a basis for self-organization.

Individual autonomy widens the possibility that individuals will motivate themselves to form new knowledge. Self-motivation based on deep emotions, for example, in the poet’s creation of new expressions, serves as a driving force for the creation of metaphors. A sense of purpose and autonomy becomes important as an organizational context. Purpose serves as the basis of conceptualization. Autonomy gives individuals freedom to absorb knowledge.

*Fluctuation.* Even though intention is internal to the individual, knowledge creation at the individual level involves continuous interaction with the external world. In this connection, chaos or discontinuity can generate new patterns of interaction between individuals and their environment. Individuals recreate their own systems of knowledge to take account of ambiguity, redundancy, noise, or randomness generated from the organization and its environment. These fluctuations differ from complete disorder and are characterized by “order without recursiveness”—which represents an order where the pattern is hard to predict in the beginning (Gleick 1987).

Winograd and Flores (1986) emphasize the role of periodic “breakdowns” in human perception. Breakdown refers to the interruption of an individual’s habitual, comfortable ‘state-of-being.’ When breakdowns occur, individuals question the value of habits and routine tools, which might lead to a realignment of commitments. Environmental fluctuation often triggers this breakdown. When people face such a breakdown or contradiction, they have an opportunity to reconsider their fundamental thinking and perspectives. In other words, they begin to question the validity of basic attitudes toward the world. This process necessarily

involves deep personal commitment by the individual and is similar in context to Piaget’s (1974) observations about the importance of the role of contradiction in the interaction between the subject and its environment in such a way that the subject forms perceptions through behavior.

#### **2.4. Knowledge Conversion and the Spiral of Knowledge**

It is now possible to bring together the epistemological and ontological dimensions of knowledge creation to form a “spiral” model for the processes involved. This involves identifying four different patterns of interaction between tacit and explicit knowledge. These patterns represent ways in which existing knowledge can be “converted” into new knowledge. Social interaction between individuals then provides an ontological dimension to the expansion of knowledge.

The idea of “knowledge conversion” may be traced from Anderson’s ACT model (Anderson 1983) developed in cognitive psychology. In the ACT model, knowledge is divided into “declarative knowledge” (actual knowledge) that is expressed in the form of propositions and “procedural knowledge” (methodological knowledge) which is used in such activities as remembering how to ride a bicycle or play the piano. In the context of the present discussion, the former might approximate to explicit knowledge and the latter to tacit knowledge. Anderson’s model hypothesizes that declarative knowledge has to be transformed into procedural knowledge in order for cognitive skills to develop. This hypothesis is consistent with Ryle’s classification (1949) of knowledge into categories of knowing that something “exists” and knowing “how” it operates. Anderson’s categorization can be regarded as a more sophisticated version of Ryle’s classification. One limitation of the ACT model is the hypothesis that transformation of knowledge is unidirectional and only involves transformations from declarative to procedural knowledge, while it can be argued that transformation is bidirectional. This may be because the ACT model is more concerned with maturation than with the creation of knowledge.

*Four Modes of Knowledge Conversion.* The assumption that knowledge is created through conversion between tacit and explicit knowledge allows us to postulate four different “modes” of knowledge conversion: (1) from tacit knowledge to tacit knowledge, (2) from explicit knowledge to explicit knowledge, (3) from tacit knowledge to explicit knowledge, and (4) from explicit knowledge to tacit knowledge.

First, there is a mode of knowledge conversion that enables us to convert tacit knowledge through interaction between individuals. One important point to note here is that an individual can acquire tacit knowledge without language. Apprentices work with their mentors and learn craftsmanship not through language but by observation, imitation, and practice. In a business setting, on-the-job training (OJT) uses the same principle. The key to acquiring tacit knowledge is experience. Without some form of shared experience, it is extremely difficult for people to share each others' thinking processes. The mere transfer of information will often make little sense if it is abstracted from embedded emotions and nuanced contexts that are associated with shared experiences. This process of creating tacit knowledge through shared experience will be called "socialization."

The second mode of knowledge conversion involves the use of social processes to combine different bodies of explicit knowledge held by individuals. Individuals exchange and combine knowledge through such exchange mechanisms as meetings and telephone conversations. The reconfiguring of existing information through the sorting, adding, recategorizing, and recontextualizing of explicit knowledge can lead to new knowledge. Modern computer systems provide a graphic example. This process of creating explicit knowledge from explicit knowledge is referred to as "combination."

The third and fourth modes of knowledge conversion relate to patterns of conversion involving both tacit and explicit knowledge. These conversion modes capture the idea that tacit and explicit knowledge are complementary and can expand over time through a process of mutual interaction. This interaction involves two different operations. One is the conversion of tacit knowledge into explicit knowledge, which will be called "externalization." The other is the conversion of explicit knowledge into tacit knowledge, which bears some similarity to the traditional notion of "learning" and will be referred to here as "internalization." As will be discussed later, "metaphor" plays an important role in the externalization process, and "action" is deeply related to the internalization process. Figure 1 illustrates the four modes of knowledge conversion.

Three of the four types of knowledge conversion—socialization, combination, and internalization, have partial analogs with aspects of organizational theory. For example, socialization is connected with theories of organizational culture, while combination is rooted in information processing and internalization has associations with organizational learning. By contrast, the

Figure 1 Modes of the Knowledge Creation

		Tacit knowledge	To	Explicit knowledge
Tacit knowledge	From	Socialization		Externalization
Explicit knowledge		Internalization		Combination

concept of externalization is not well developed. The limited analysis that does exist is from the point of view of information creation (see Nonaka 1987).

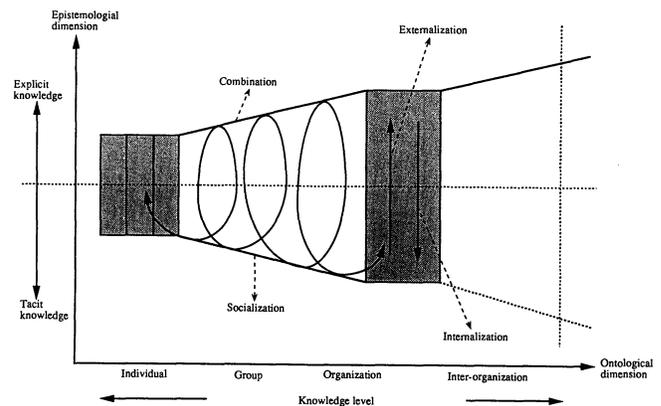
Theories of organizational learning do not address the critical notion of externalization, and have paid little attention to the importance of socialization even though there has been an accumulation of research on "modeling" behavior in learning psychology. Another difficulty relates to the concepts of "double-loop learning" (Argyris and Schön 1978) or "unlearning" (Hedberg 1981), which arises from a strong orientation toward organization development (OD). Since the first integrated theory of organizational learning presented by Argyris and Schön, it has been widely assumed, implicitly or explicitly, that double-loop learning, i.e., the questioning and reconstruction of existing perspectives, interpretation frameworks, or decision premises, can be very difficult for organizations to implement by themselves. In order to overcome this difficulty, they argue that some kind of artificial intervention such as the use of organizational development programs is required. The limitation of this argument is that it assumes implicitly that someone inside or outside an organization knows "objectively" the right time and method for putting double-loop learning into practice. A mechanistic view of the organization lies behind this assumption. Seen from the vantage point of organizational knowledge creation, on the contrary, double-loop learning is not a special, difficult task but a daily activity for the organization. Organizations continuously create new knowledge by reconstructing existing perspectives, frameworks, or premises on a day-to-day basis. In other words, double-loop learning ability is "built into" the knowledge creating model, thereby circumventing the need to make unrealistic assumptions about the existence of a "right" answer.

*Modal Shift and Spiral of Knowledge.* While each of the four modes of knowledge conversion can create new knowledge independently, the central theme of the model of organizational knowledge creation proposed here hinges on a dynamic interaction between the different modes of knowledge conversion. That is to say, knowledge creation centers on the building of both tacit and explicit knowledge and, more importantly, on the interchange between these two aspects of knowledge through internalization and externalization.

A failure to build a dialogue between tacit and explicit knowledge can cause problems. For example, both pure combination and socialization have demerits. A lack of commitment and neglect of the personal meaning of knowledge might mean that pure combination becomes a superficial interpretation of existing knowledge, which has little to do with here-and-now reality. It may also fail to crystallize or embody knowledge in a form that is concrete enough to facilitate further knowledge creation in a wider social context. The “sharability” of knowledge created by pure socialization may be limited and, as a result, difficult to apply in fields beyond the specific context in which it was created.

Organizational knowledge creation, as distinct from individual knowledge creation, takes place when all four modes of knowledge creation are “organizationally” managed to form a continual cycle. This cycle is shaped by a series of shifts between different modes of knowledge conversion. There are various “triggers” that induce these shifts between different modes of knowledge conversion. First, the socialization mode usually starts with the building of a “team” or “field” of interaction. This field facilitates the sharing of members’ experiences and perspectives. Second, the externalization mode is triggered by successive rounds of meaningful “dialogue.” In this dialogue, the sophisticated use of “metaphors” can be used to enable team members to articulate their own perspectives, and thereby reveal hidden tacit knowledge that is otherwise hard to communicate. Concepts formed by teams can be combined with existing data and external knowledge in a search of more concrete and sharable specifications. This combination mode is facilitated by such triggers as “coordination” between team members and other sections of the organization and the “documentation” of existing knowledge. Through an iterative process of trial and error, concepts are articulated and developed until they emerge in a concrete form. This “experimentation” can trigger internalization through a process of “learning by doing.” Participants in a “field” of action share explicit knowledge that is gradu-

**Figure 2** Spiral of Organizational Knowledge Creation



ally translated, through interaction and a process of trial-and-error, into different aspects of tacit knowledge.

While tacit knowledge held by individuals may lie at the heart of the knowledge creating process, realizing the practical benefits of that knowledge centers on its externalization and amplification through dynamic interactions between all four modes of knowledge conversion. Tacit knowledge is thus mobilized through a dynamic “entangling” of the different modes of knowledge conversion in a process which will be referred to as a “spiral” model of knowledge creation, illustrated in Figure 2. The interactions between tacit knowledge and explicit knowledge will tend to become larger in scale and faster in speed as more actors in and around the organization become involved. Thus, organizational knowledge creation can be viewed as an upward spiral process, starting at the individual level moving up to the collective (group) level, and then to the organizational level, sometimes reaching out to the interorganizational level.

### 2.5. From Metaphor to Model: Methodology of Knowledge Creation

Before concluding this presentation of the basic constructs of the theory, it is helpful to consider some general principles for facilitating the management of knowledge conversion. One effective method of converting tacit knowledge into explicit knowledge is the use of metaphor. As Nisbet (1969, p. 5) noted, “(m)uch of what Michael Polanyi has called ‘tacit knowledge’ is expressible—in so far as it is expressible at all—in metaphor.” “The essence of metaphor is understanding and experiencing one kind of thing in terms of another (Lakoff and Johnson 1980, p. 5).” Even though

the metaphor is not in itself a thinking process, it enables us to experience a new behavior by making inferences from the model of another behavior. The use of metaphor is broader than the traditional, lexical definition of the term (meta = change; phor = move). According to Lakoff and Johnson: "metaphor is pervasive in everyday life, not just in language but in thought and action. Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature" (Lakoff and Johnson 1980, p. 3).

As a method of perception, metaphor depends on imagination and intuitive learning through symbols, rather than on the analysis or synthesis of common attributes shared by associated things. Rosch (1973) suggested that man describes the world, not in the formal attributes of concepts, but in terms of prototypes. For example, the robin could be seen as a better prototype than the turkey for a small bird. Prototypes provide a mechanism for recognizing the maximum level of information with a minimum of energy.

Metaphor is not merely the first step in transforming tacit knowledge into explicit knowledge; it constitutes an important method of creating a network of concepts which can help to generate knowledge about the future by using existing knowledge. Metaphor may be defined as being 'two contradicting concepts incorporated in one word.' It is a creative, cognitive process which relates concepts that are far apart in an individual's memory. While perception through prototype is in many cases limited to concrete, mundane concepts, metaphor plays an important role in associating abstract, imaginary concepts. When two concepts are presented in a metaphor, it is possible not only to think of their similarity, but also to make comparisons that discern the degree of imbalance, contradiction or inconsistency involved in their association. The latter process becomes the basis for creating new meaning.<sup>4</sup> According to Bateson (1973) metaphors cut across different contexts and thus allow imaginative perceptions to combine with literal levels of cognitive activities. This experience, he further argues, will promote the type of "presupposition-negation" learning that is closely related with the formation of new paradigms.

Contradictions incorporated in metaphor may be harmonized through the use of analogies. Analogy reduces ambiguity by highlighting the commonness of two different things. Metaphor and analogy are often confused. The association of meanings by metaphor is mostly driven by intuition, and involves images. On the other hand, the association of meanings through analogy is more structural/functional and is carried out

through rational thinking. As such, metaphors provide much room for free association (discontinuity). Analogy allows the functional operation of new concepts or systems to be explored by reference to things that are already understood. In this sense, an analogy—that enables us to know the future through the present—assumes an intermediate role in bridging the gap between image and logic.

It follows from the preceding discussion that tacit knowledge may be transformed into explicit knowledge by (1) recognizing contradictions through metaphor, and (2) resolving them through analogy. Explicit knowledge represents a model within which contradictions are resolved and concepts become transferable through consistent and systematic logic. In the business organization, a typical model is the prototype that represents the product concept. The prototype's specification is then explicit knowledge. It has been pointed out that metaphor, analogy, and model are all part of the process of scientific discovery.<sup>5</sup> Whether the metaphor-analogy-model sequence is indispensable in all such processes will depend upon the nature of the question under study; yet in creating new concepts, the model is usually generated from a metaphor.

### 3. The Process of Organizational Knowledge Creation

The theoretical constructs and models described in §2 may now be related to organizational knowledge creation in a corporate organizational setting. This will be approached by assessing the processes that enable individual knowledge to be enlarged, amplified, and justified within an organization.

#### 3.1. The Enlargement of an Individual's Knowledge

The prime mover in the process of organizational knowledge creation is the individual. Individuals accumulate tacit knowledge through direct "hands-on" experience. The quality of that tacit knowledge is influenced by two important factors. One factor is the "variety" of an individual's experience. If this experience is limited to routine operations, the amount of tacit knowledge obtained from monotonous and repetitive tasks will tend to decrease over time. Routine tasks mitigate against creative thinking and the formation of new knowledge. However, increasing the variety of experience is not sufficient by itself to raise the quality of tacit knowledge. If the individual finds various experiences to be completely unrelated, there will be little chance that they can be integrated to create a new perspective. What matters is "high quality" expe-

rience which might, on occasion, involve the complete redefinition of the nature of a “job.”

A second factor that determines the quality of tacit knowledge is “knowledge of experience.” The essence of “knowledge of experience” is an embodiment of knowledge through a deep personal commitment into bodily experience. Varela et al. (1991) have pointed out that the embodied nature of human knowledge has long been neglected in Western epistemological traditions that have followed from Descartes. They define embodiment as: “a reflection in which body and mind have been brought together” (1991, p. 27). Yuasa (1987) describes this “oneness of body-mind” as the free state of minimal distance between movement of the mind and of the body, as for example in the dynamic performance of a master actor on a stage (1987, p. 28). As Merleau-Ponty (1964) pointed out, bodily experience plays a critical role in the process of crystallization. Commitment to bodily experience means an intentional self-involvement in the object and situation which transcends the subject-object distinction, thereby providing access to “pure experience” (Nishida 1960). This notion is prevalent in oriental culture. As Yuasa mentions:

One revealing characteristic of the philosophical uniqueness of Eastern thought is presupposed in the philosophical foundation of the Eastern theories. To put it simply, true knowledge cannot be obtained simply by means of theoretical thinking, but only through “bodily recognition or realization” (*tainin* or *taikoku*), that is, through the utilization of one’s total mind and body. Simply stated, this is to “learn with the body” not the brain. Cultivation is a practice that attempts, so to speak, to achieve true knowledge by means of one’s total mind and body (1987, pp. 25–26).

A good case in point is “on-the-spot-ism” in Japanese management. In developing the products and identifying the markets, Japanese firms encourage the use of judgement and knowledge formed through interaction with customers—and by personal bodily experience rather than by “objective,” scientific conceptualization. Social interaction between individuals, groups and organizations are fundamental to organizational knowledge creation in Japan. Nevertheless, since this approach uses hands-on experience and action, it sometimes falls in the category of “experientism” which neglects the importance of reflection and logical thinking. It tends to overemphasize action and efficiency at the expense of a search for higher level concepts which have universal application.

While the concepts of “high-quality experience” and “knowledge of experience” may be used to raise the

quality of tacit knowledge, they have to be counterbalanced by a further approach to knowledge creation that raises the quality of explicit knowledge. Such an approach may be called a “knowledge of rationality,” which describes a rational ability to reflect on experience. Knowledge of rationality is an explicit-knowledge-oriented approach that is dominant in Western culture. It centers on the “combination” mode of knowledge conversion, and is effective in creating digital, discrete declarative knowledge. Knowledge of rationality tends to ignore the importance of commitment, and instead centers a reinterpretation of existing explicit knowledge.

In order to raise the total quality of an individual’s knowledge, the enhancement of tacit knowledge has to be subjected to a continual interplay with the evolution of relevant aspects of explicit knowledge. In this connection, Schön (1983) pointed out the importance of “reflection in action,” i.e., reflecting while experiencing. Individual knowledge is enlarged through this interaction between experience and rationality, and crystallized into a unique perspective original to an individual. These original perspectives are based on individual belief and value systems, and will be a source of varied interpretations of shared experience with others in the next stage of conceptualization.

### 3.2. Sharing Tacit Knowledge and Conceptualization

As we saw in the previous section, the process of organizational knowledge creation is initiated by the enlargement of an individual’s knowledge within an organization. The interaction between knowledge of experience and rationality enables individuals to build their own perspectives on the world. Yet these perspectives remain personal unless they are articulated and amplified through social interaction. One way to implement the management of organizational knowledge creation is to create a “field” or “self-organizing team” in which individual members collaborate to create a new concept.

In this connection, it is helpful to draw on the concept of an organization’s “mental outlook” as articulated in Sandelands and Stablein’s (1987) pioneering work on “organizational mind.” While making caveats about the dangers of reification and anthropomorphism, these authors use the analogy of “mind” to identify the process by which organizations form ideas. Mind is distinct from the brain in the same way that computer software is distinct from hardware. Against this background, intelligence may be seen as the ability to maintain a working similarity between mind and nature.

The development of ideas associated with organizational mind requires some form of physical substrate (i.e. hardware) which Sandelands and Stablein (1987) argue might be derived from “patterns of behavior traced by people and machines” (p. 139). Organizational behaviors can convey ideas and, like the firing of neurons in the brain, may trigger other behaviors and so form a trace of activation.

In the brain, whether or not one neuron influences another depends on a complex set of factors having primarily to do with physical proximity, availability of pathways, intensity of the electrochemical signal, and whether or not the target neuron is inhibited by other neurons. Similarly, whether one behavior influences another in social organizations depends on a complex of factors primarily concerned with physical access, lines of communication, power, and competition from other behaviors. At an abstract formal level, at least, the politics of the social organization and the physiology of the brain share much in common (Sandelands and Stablein 1987, p. 140).

It is human activity that creates organizational mind as individuals interact and trigger behavior patterns in others. Managing a self-organizing team involves building an appropriate degree of flexibility into the system which can accommodate a diversity of imaginative thinking in the pursuit of new problems and solutions.

*Constructing a Field: Building a Self-organizing Team.* To bring personal knowledge into a social context within which it can be amplified, it is necessary to have a “field” that provides a place in which individual perspectives are articulated, and conflicts are resolved in the formation of higher-level concepts. Berger and Luchman (1966) say that reality in everyday life is socially constructed. Individual behavior ought to be relativized through an interactive process to construct “social reality.”

In the business organization, the field for interaction is often provided in the form of an autonomous, self-organizing “team” made of several members coming from a variety of functional departments. It is a critical matter for an organization to decide when and how to establish such a “field” of interaction in which individuals can meet and interact. It defines “true” members of knowledge creation and thus clarifies the domain in which perspectives are interacted.

The team needs to be established with regard to the principles of self-organization. In Lewin’s (1951) development of the field theory in social psychology, a group is defined as “a dynamic whole based on interdepen-

dence rather on similarity.” Some indication of the number of members and the composition of their background can be achieved using the principle of “requisite variety” (Ashby 1956). According to our observation of successful project teams in Japanese firms, the appropriate team size may be in the region between 10 and 30 individuals, with an upper limit arising because direct interaction between all the group members tends to decrease as group size increases. Within the team, there are usually 4 to 5 “core” members who have career histories that include multiple job functions. These core members form focal points in the team and could be seen as the organizational equivalent of the central element in a series of nested Russian dolls.<sup>6</sup> That is to say there is a radial pattern of interaction with other members, with closer links being associated with key individuals. Core members play a critical role in assuring appropriate “redundancy” of information within the cross-functional team. Other attributes of members such as formal position, age, gender, etc. might be determined with regard to Morgan’s (1986) four principles of “learning to learn, requisite variety, minimum critical specification, and redundancy of functions.”

The span of team activities need not be confined to the narrow boundary of the organization. Rather, it is a process that frequently makes extensive use of knowledge in environment, especially that of customers and suppliers. As Norman (1988) argues, the mental outlook of an organization is shaped by a complex pattern of factors within and outside the organization.<sup>7</sup> In some Japanese firms, for example, suppliers of parts and components are sometimes involved in the early stages of the product development. The relationship between manufacturers and suppliers is less hierarchical and arms length than in Western countries. Some other Japanese companies involve customers in the field of new product planning. In both cases, sharing tacit knowledge with suppliers or customers through coexperience and creative dialogue play a critical role in creating relevant knowledge.

The significance of links between individuals that span boundaries, both within and outside the organization, has been highlighted by Brown and Duguid’s (1991) revealing insight into the operation of “evolving communities of practice.” These communities reflect the way in which people actually work as opposed to the formal job descriptions or task-related procedures that are specified by the organization. Attempts to solve practical problems often generate links between individuals who can provide useful information. The exchange and development of information within these

evolving communities facilitate knowledge creation by linking the routine dimensions of day-to-day work to active learning and innovation. Collaboration to exchange ideas through shared narratives and “war stories” can provide an important platform on which to construct shared understanding out of conflicting and confused data.

By contrast with conceptions of groups as bounded entities within an organization, evolving communities of practice are “more fluid and interpenetrative than bounded, often crossing the restrictive boundaries of the organization to incorporate people from outside” (Brown and Duguid 1991, p. 49). Moreover, these communities can provide important contributions to visions for future development. Thus these communities represent a key dimension to socialization and its input to the overall knowledge creation process.

The self-organizing team triggers organizational knowledge creation through two processes. First, it facilitates the building of mutual trust among members, and accelerates creation of an implicit perspective shared by members as tacit knowledge. The key factor for this process is sharing experience among members. Second, the shared implicit perspective is conceptualized through continuous dialogue among members. This creative dialogue is realized only when redundancy of information exists within the team. The two processes appear simultaneously or alternatively in the actual process of knowledge creation within a team.

Before discussing these two processes further, it is necessary to mention another dimension of the knowledge creating process that can be associated with the self-organizing team. Schefflen (1982) proposed an idea of “interaction rhythms,” in which social interactions were viewed as being both simultaneous and sequential. The management of interaction rhythms among team members, i.e., that of divergence and convergence of various interaction rhythms, plays a critical role in accelerating the knowledge creation process. Within the team, rhythms of different speed are first generated and amplified up to certain point of time and level, and then are given momentum for convergence towards a concept. Therefore, the crucial role of the team leader concerns how to balance the rhythm of divergence and convergence in the process of dialogues and shared experience.

In sum, the cross-functional team in which experience sharing and continuous dialogue are facilitated by the management of interaction rhythms serves as the basic building block for structuring the organization knowledge creation process. The team is different from a mere group in that it induces self-organizing process

of the entire organization through which the knowledge at the group level is elevated to the organizational level.

*Sharing Experience.* In order for the self-organizing team to start the process of concept creation, it first needs to build mutual trust among members. As we shall see later, concept creation involves a difficult process of externalization, i.e., converting tacit knowledge (which by nature is hard to articulate) into an explicit concept. This challenging task involves repeated, time-consuming dialogue among members. Mutual trust is an indispensable base for facilitating this type of constructive “collaboration” (Schrage 1990). A key way to build mutual trust is to share one’s original experience—the fundamental source of tacit knowledge. Direct understanding of other individuals relies on shared experience that enables team members to “indwell” into others and to grasp their world from “inside.”

Shared experience also facilitates the creation of “common perspectives” which can be shared by team members as a part of their respective bodies of tacit knowledge. The dominant mode of knowledge conversion involved here is socialization. Various forms of tacit knowledge that are brought into the field by individual members are converted through coexperience among them to form a common base for understanding.

As was mentioned earlier, tacit knowledge is a distinctly personal concept. Varela et al. (1991) point out the limitation of the cognitivist view of human experience in comparison with the non-Western philosophical view, and suggest that cognitive experience is “embodied action” rather than a mere representation of a world that exists independent of our cognitive system. The mutual conversion of such embodied, tacit knowledge is accelerated by synchronizing both body and mind in the face of the same experience. Coexperience with others enables us to transcend the ordinary “I-Thou” distinction, and opens up the world of common understanding, which Schefflen (1982) called “Field Epistemology.” Condon (1976) shared this view that communication is a simultaneous and contextual phenomenon in which people feel a change occurring, share the same sense of change, and are moved to take action. In other words, communication is like a wave that passes through people’s bodies and culminates when everyone synchronizes himself with the wave. Thus, the sharing of mental and physical rhythm among participants of a field may serve as the driving force of socialization.

*Conceptualization.* Once mutual trust and a common implicit perspective have been formed through shared experience, the team needs to articulate the perspective through continuous dialogues. The dominant mode of knowledge conversion here is externalization. Theories of organizational learning have not given much attention to this process. Tacit “field-specific” perspectives are converted into explicit concepts that can be shared beyond the boundary of the team. Dialogue directly facilitates this process by activating externalization at individual levels.

Dialogue, in the form of face-to-face communication between persons, is a process in which one builds concepts in cooperation with others. It also provides the opportunity for one’s hypothesis or assumption to be tested. As Markova and Foppa (1990) argue, social intercourse is one of the most powerful media for verifying one’s own ideas. As such, dialogue has a congenetic quality, and thus the participants in the dialogue can engage in the mutual codevelopment of ideas. As Graumann (1990) points out, dialogue involves “perspective-setting, perspective-taking, and multiperspectivity of cognition.” According to the theory of language action suggested by Austin (1962) and Searle (1969), illocutionary speech does not only involve a description of things and facts but the taking of action itself. The expression “language is behavior,” therefore, implies that language is a socially creative activity and accordingly reveals the importance of the connection between language and reality created through dialogue.

For these purposes, dialectic is a good way of raising the quality of dialogue. Dialectic allows scope for the articulation and development of personal theories and beliefs. Through the use of contradiction and paradox, dialectic can serve to stimulate creative thinking in the organization. If the creative function of dialectic is to be exploited to the full, it is helpful to pay regard to certain preconditions or “field rules.” First, the dialogue should not be single-faceted and deterministic but temporary and multifaceted so that there is always room for revision or negation. Second, the participants in the dialogue should be able to express their own ideas freely and candidly. Third, negation for the sake of negation should be discouraged. Constructive criticism substantiated by reasoned arguments should be used to build a consensus. Fourth, there should be temporal continuity. Dialectic thinking is a repetitive, spiral process in which affirmation and negation are synthesized to form knowledge. Strict and noncontinuous separation of affirmation and negation will only result in logical contradictions and thus hamper the

creation of knowledge. Team leaders, therefore, should not discourage the dramatic and volatile dimensions of dialogue. If these conditions are met, dialogue will add much to the potential of the group in knowledge creation.

The process of creating a new perspective through interpersonal interaction is assisted by the existence of a degree of redundant information. Making and solving new problems are made possible when its members share information by obtaining extra, redundant information which enables them to enter another person’s area and give advice. Instances of “learning by intrusion” (Nonaka 1990) are particularly widespread in Japanese firms.<sup>8</sup> In the meantime, redundancy of information also functions to determine the degree to which created perspectives are diffused. It may sound paradoxical; yet the degree of information redundancy will limit the degree of diffusion. In this sense, information redundancy can serve to regulate the creation of perspectives.

It is now possible to turn to the question of how to conceptualize new perspectives created from shared tacit knowledge. According to Bateson (1979), concepts are created through deduction, induction, and abduction. Abduction has a particular importance in the conceptualization process. While deduction and induction are vertically-oriented reasoning processes, abduction is a lateral extension of the reasoning process which centers on the use of metaphors. Deduction and induction are generally used when a thought or image involves the revision of a preexisting concept or the assigning of a new meaning to a concept. When there is no adequate expression of an image it is necessary to use abductive methods to create completely new concepts. While analytical methods can be used to generate new concepts via inductive or deductive reasoning, they may not be sufficient to create more meaningful—or radical—concepts. At the early stages of information creation, it is very useful to pursue creative dialogues and to share images through the metaphorical process by merging perspectives, i.e., tacit knowledge.

### 3.3. Crystallization

The knowledge created in an interactive field by members of a self-organizing team has to be crystallized into some concrete “form” such as a product or a system. The central mode of knowledge conversion at this stage is internalization. Crystallization may then be seen as the process through which various departments within the organization test the reality and applicability of the concept created by the self-organizing team. These internalization processes are facilitated by en-

couraging experimentation. It should be noted that because the instrumental skill, a part of tacit knowledge, is exploited in this process, a new process of knowledge creation is triggered by crystallization. While this usually leads to refinement of the concept, sometimes the concept itself is abandoned and fundamentally recreated.

The process of crystallization is a social process which occurs at a collective level. It is realized through what Haken (1978) called "dynamic cooperative relations" or "synergetics" among various functions and organizational departments. This relationship tends to be achieved most effectively when redundancy of information creates scope for critical knowledge conversion processes to take place. In an organization where there is redundancy of information, the initiative for action can be taken by the experts who have more information and knowledge. This characteristic is what McCulloch (1965) called "the principle of redundancy of potential command." In this principle, all parts of a system carry the same degree of importance, and each part's impact upon the system is determined by the importance of information it contains in each specified context. In sum, each part has the potential of becoming the leader of the entire system when there exists redundancy of information.

The speed at which Japanese firms develop new products seems to be assisted by information redundancy. In the product development process of Japanese firms, different phases of the process are loosely linked, overlapping in part, and the creation and realization of information is carried out flexibly. The loosely linked phases, while simultaneously maintaining mutual independence, have redundant information that activates their interactive inquiry thereby facilitating cyclical generation and solution of problems (Imai et al. 1985). This "rugby-style" product development is equipped with the flexible capability of knowledge conversion. Clark and Fujimoto (1991) showed that Japanese firms take relatively less time for product development than American and European firms.

The specific characteristics of the product development in Japanese firms is its lateral breadth covering the whole organization. In other words it is overlapping and synthetic rather than analytic or linear. In this system, development staff can traverse overlapping phases and, to a certain extent, share each other's functions. This is far different from the usual product development process of U.S. firms, which have definite partitions between phases over which a baton is relayed. In the Japanese "rugby-style" product development (Takeuchi and Nonaka 1986), staff involved in

one phase also may be in the next phase. Thus, some development staff can be involved in all phases of development. Sometimes this process also involves those outside the organization such as suppliers and customers in order to mobilize and explicit environmental knowledge.

One problem with this developmental style is the potential risk of confusion if, for example, the design changes or other alterations take place. Participants might have to exert more effort to organize the process due to the lack of strict specifications at each phase and definite boundaries between them. However, these risks are counterbalanced by a tendency to create and realize concepts quickly and flexibly in an integral fashion. In this context, redundant information can play a major role in facilitating the process.

#### **3.4. The Justification and Quality of Knowledge**

While organizational knowledge creation is a continuous process with no ultimate end, an organization needs to converge this process at some point in order to accelerate the sharing of created knowledge beyond the boundary of the organization for further knowledge creation. As knowledge is conventionally defined as "justified true belief," this convergence needs to be based on the "justification" or truthfulness of concepts. Justification is the process of final convergence and screening, which determines the extent to which the knowledge created within the organization is truly worthwhile for the organization and society. In this sense, justification determines the "quality" of the created knowledge and involves criteria or "standards" for judging truthfulness.

What matters here are the evaluation "standards" for judging truthfulness. In the business organizations, the standards generally include cost, profit margin, and the degree to which a product can contribute to the firm's development. There are also value premises that transcend factual or pragmatic considerations. These might be opinions about such things as the extent to which the knowledge created is consistent with the organization's vision and perceptions relating to adventure, romanticism, and aesthetics. The inducements to initiate a convergence of knowledge may be multiple and qualitative rather than simple and quantitative standards such as efficiency, cost, and return on investment (ROI).

In knowledge-creating organizations, it is the role of top or middle management to determine the evaluation standard. Determining the turning point from dissipation to convergence in the creation process is a highly strategic task which is influenced by the "aspiration" of

the leaders of the organization. Justification standards have to be evaluated in terms of their consistency with higher-order value systems. The ability of leaders to maintain continuous self-reflection in a wider perspective is indispensable when it comes to increasing the quality of knowledge created.

### 3.5. Networking Knowledge

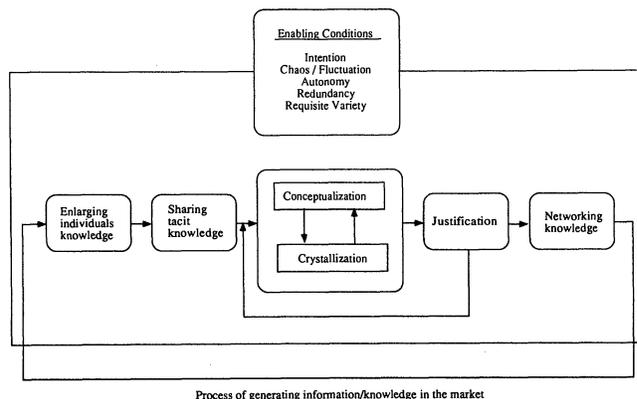
The realization of new concepts, described above, represents a visible emergence of the organization's knowledge network. During this stage of organizational knowledge creation, the concept that has been created, crystallized and justified in the organization is integrated into the organizational knowledge-base which comprises a whole network of organizational knowledge. The organizational knowledge base is then reorganized through a mutually-inducing process of interaction between the established organizational vision and the newly-created concept.

Speaking in sociological terms, this mutually-inducing relationship corresponds to the relationship between a grand concept and a middle-range concept. A middle-range concept is induced from an equivocal knowledge base as a grand concept and then is condensed into concrete form. The grand concept is not fully understood at the organizational level unless these middle-range concepts are verified on site. This verification also induces the creation or reconstruction of a grand concept, causing the interactive proliferation of grand concepts presented by top management, and middle-range concepts created by middle management. This interaction, mediated by the concrete form as condensed information, is another dynamic self-organizing activity of knowledge network that continuously creates new information and meaning.

It should be noted that the process of organizational knowledge creation is a never-ending, circular process that is not confined to the organization but includes many interfaces with the environment. At the same time, the environment is a continual source of stimulation to knowledge creation within the organization. For example, Hayek (1945) pointed out that the essential function of market competition is to discover and mobilize knowledge "on-the-spot," i.e., the implicit, context-specific knowledge held by market participants.

In the case of business organizations, one aspect of the relationship between knowledge creation and the environment is illustrated by reactions to the product by customers, competitors, and suppliers. For example, many dimensions of customer needs take the form of tacit knowledge that an individual customer or other market participants cannot articulate by themselves. A

Figure 3 Organizational Knowledge Creation Process



product works as a trigger to articulate the tacit knowledge. Customers and other market participants give meaning to the product by their bodily actions of purchasing, adapting, using, or not purchasing. This mobilization of tacit knowledge of customers and market will be reflected to the organization, and a new process of organizational knowledge creation is again initiated.

The total process of organizational knowledge creation is summarized in Figure 3. Even though the figure is illustrated as a sequential model, the actual process progresses forming multilayered loops. Respective stages can take place simultaneously, or sometimes jump forward or backward.

## 4. Managing the Process of Organizational Knowledge Creation: Creative Chaos, Redundancy, and Requisite Variety

This section draws on preceding arguments in order to develop a practical perspective on the management of organizational knowledge creation. Its main purpose is to complement the aspects of "individual commitment" to the knowledge creating process (i.e., intention, autonomy, and fluxuation, discussed in §2.2) with, what could be seen as, "organization-wide" enabling conditions that promote a more favorable climate for effective knowledge creation<sup>9</sup> (see Figure 3). An analysis of these enabling conditions—creative chaos, redundancy of information, and requisite variety—is developed below, prior to making specific proposals for two management models: "middle-up-down management" and a "hypertext" organization. The former model relates to

management style, while the latter centers on organizational design.

As was mentioned earlier, environmental fluctuation is one of the three factors that induce individual commitment. At an organizational level, environmental fluctuation can generate "creative chaos" which triggers the process of organizational knowledge creation. When the organization faces nonrecursiveness that cannot be dealt with by existing knowledge, it might try to create a new order of knowledge by making use of the fluctuation itself. According to the principle of "order out of noise" proposed by von Foerster (1984), the self-organizing system can increase its ability to survive by purposefully introducing its own noise. In the context of evolutionary theory, Jantsch (1980) argues:

In contrast to a widely held belief, planning in an evolutionary spirit therefore does not result in the reduction of uncertainty and complexity, but in their increase. Uncertainty increases because the spectrum of options is deliberately widened; imagination comes into play (1980, p. 267).

This represents a circular process in which chaos is perceived in its interaction with cosmos and then becomes a cosmos, which in turn produces another chaos.

Creative chaos is generated naturally when the organization faces a real "crisis" such as rapid decline of performance due to changes in technologies or market needs, or the realization of a significant competitive advantage on the part of a rival firm. It can also be generated intentionally when leaders of an organization try to evoke a "sense of crisis" among organizational members by proposing challenging goals. This creative chaos increases tension within the organization and focuses attention on forming and solving new problems. In the information processing paradigm, a problem is simply given and a solution is reached through a process of combining relevant information based on a preset algorithm. But this process ignores the importance of problem setting—defining the problem to be solved. In reality, problems do not present themselves as given but instead have to be constructed from the knowledge available at a certain point in time and context.

It should be noted, however, that this process takes place only when organizational members reflect on their actions. Without reflection, the introduction of fluctuation tends to produce "destructive" chaos. As Schön (1983) observed, "When someone reflects while in action, he becomes a researcher. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case"

(1983, p. 68). The knowledge-creating organization is required to institutionalize this reflection-in-action in its process as well as in its structure to make the chaos truly "creative."

A second principle for managing organizational knowledge creation is redundancy. In business organizations, this means the conscious overlapping of company information, business activities, and management responsibilities. To Western managers, the term "redundancy," with its connotations of unnecessary duplication and waste, may sound unappealing. Nevertheless, redundancy (Landau 1969 and Nonaka 1990) plays a key role, especially in the process of knowledge creation at the level of the organization. Redundant information can be instrumental in speeding up concept creation. A concept that was created by an individual or a group often needs to be shared by other individuals who may need the concept immediately. The redundancy of information refers to the existence of information more than the specific information required immediately by each individual. The sharing of extra information between individuals promotes the sharing of individual tacit knowledge. Since members share overlapping information, they can sense what others are trying to articulate. Especially in the concept development stage, it is critical to articulate images rooted in tacit knowledge. In this situation, individuals can enter each others' area of operation and can provide advice. This allows people to provide new information from new and different perspectives. In short, redundancy of information brings about "learning by intrusion" into an individual's sphere of perception.

Redundant information can be an instrumental factor in reducing the impact of managerial hierarchy. That is to say, redundant information provides a vehicle for problem generation and knowledge creation which follows procedures that are different from those specified by the "official" organizational structure. This concept of "nonhierarchy" has been described by Hedlund (1986) as "heterarchy." The important point to note is that redundancy of information makes the interchange between hierarchy and nonhierarchy more effective in problem solving and knowledge creation. It enables all members of the organization to participate in the process on the basis of consensus and equal preparation. In this sense, redundancy of information is an indispensable element in inducing the "synergetics" and to realize the "principle of redundancy of potential command."

Deep, mutual trust between the members of the organization—the creators of knowledge—can be pro-

moted through information redundancy and, in this way, the organization can control its knowledge creation. If an organization contains enough redundancy of information to deal with as many contingencies as possible, it can generate various combinations of information flexibly. This redundancy also facilitates interaction among organizational members and consequently makes it easier to transfer tacit knowledge among them. Redundancy can eliminate cheating among organizational members and facilitates establishment of mutual trust. Williamson (1975) argues convincingly that opportunism tends to appear less frequently in internally organized activities than in market transactions. Close interaction and trust based upon sharing of redundant information minimizes the possibility of cheating. Since "trust is a critical lubricant in social systems" (Arrow 1974), it would be impossible to form "synergetics" needed for knowledge creation without trust.

Sharing of extra information also helps individuals to recognize their location in the organization, which in turn increases the sense of control and direction of individual thought and behavior. This state is different from the one in which all members are scattered with no relationship to each other. Redundancy of information connects individuals and the organization through information, which converges rather than diffuses.

There are several ways to build redundancy into the organization. One is to adopt an overlapping approach and internal competition in product development. As was stressed in the section on crystallization, Japanese companies manage product development as an overlapping, "rugby-style" process where different functional divisions work together in a shared division of labor. Some of them also divide the product-development team into competing groups that develop different approaches to the same project and then argue over the advantages and disadvantages of their proposals. Internal rivalry encourages the team to look at a project from a variety of perspectives. Under the guidance of a team leader, the team eventually develops a common understanding of the "best" approach. In one sense, such internal competition is wasteful. But when responsibilities are shared, information proliferates, and the organization's ability to create and implement concepts is accelerated.

Another way to build redundancy into an organization is through strategic rotation, especially between different areas of technology and between functions such as R&D and marketing. Rotation helps members of an organization understand the business from a multiplicity of perspectives. This makes organizational

knowledge more fluid and easier to put into practice. Wide access to company information also helps build redundancy. When information differentials exist, members of an organization can no longer interact on equal terms, which hinders the search for different interpretations of new knowledge.

Since redundancy of information increases the amount of information to be processed, it is important to strike a balance between the creation and processing of information. One way of dealing with this issue is to determine the appropriate location of information and knowledge storage within an organization. Ashby (1956) has suggested the concept of "requisite variety" which refers to the constructing of information process channels that match the information load imposed by the environment. According to the principle of requisite variety, an organization can maximize efficiency by creating within itself the same degree of diversity as the diversity it must process. Following Ashby, requisite variety may be seen as the third principle of organizing knowledge creating activities.

Efficient knowledge creation requires quick inquiry and preprocessing of existing knowledge and information. Therefore, it is a practical requirement here that everyone is given access to necessary information with the minimum number of steps (Numangami et al. 1989). For this purpose, (1) organizational members should know who owns what information, and (2) they should be related to the least number of colleagues so that they are not loaded with information in the excess of each one's cognitive capacity.

#### **4.1. Middle-Up-Down Management: Leadership for Parallel Process**

In earlier work, a new model of management called "middle-up-down management" was proposed and contrasted with typical "top-down" management or "bottom-up" management (Nonaka 1988b). This middle-up-down management model is suitable for promoting the efficient creation of knowledge in business organizations. The model is based on the principle of creative chaos, redundancy, and requisite variety mentioned above; much emphasis is placed on the role of top and middle management for knowledge creation, which has been almost neglected in traditional accounts of managerial structure.

The essence of a traditional bureaucratic machine is top-down information processing using division of labor and hierarchy. Top managers create basic managerial concepts (the premises of decision making) and break them down hierarchically—in terms of objectives

and means—so that they can be implemented by subordinates. Top managers' concepts become operational conditions for middle managers who then decide how to realize the concepts. Again, middle managers' decisions constitute operational conditions for lower managers who implement their decisions. In consequence, the organization as a whole executes a huge amount of work that can never be done by individuals.

If we visualize the dyadic relations between top vs. middle managers, the middle vs. lower members, an organization assumes a tree-shaped or pyramidal structure. In this "top-down" model, it is desirable to organize the whole structure in the way it will conform to the above relations. To clearly break down the end-means relations, it is necessary to get rid of any ambiguity or equivocality in the concepts held by top managers. In sum, the concepts anchor on the premise that they only have one meaning. By corollary, the concepts are also strictly functional and pragmatic. An implicit assumption behind this traditional model of organization is that information and knowledge are processed most efficiently in a tree structure. The division of labor taking place within such a bureaucratic organization is associated with a hierarchical pattern of information processing. Moving from the bottom to the top of the organization, information is processed selectively so that people at the peak would get simple, processed information only. Moving in the reverse direction, on the other hand, information is processed and transformed from the general to the particular. It is this deductive transformation that enables human beings with limited information processing capacity to deal with a mass of information.

It should be noted that information processing by middle and lower members in this model is of minor relevance to knowledge creation. Only top managers are able and allowed to create information. Moreover, information created by these top managers exists for the sole purpose of implementation; therefore it is a tool rather than a product. On the contrary, in the bottom-up model, those who create information are not top managers, but middle and lower managers. In a typical bottom-up managed company, intracompany entrepreneurs or "intrapreneurs" (Pinchot 1985) are fostered and developed by the system. In reality there are not many larger firms that have bottom-up management style. In this model, top managers remain sponsors for individual employees who function as intracompany entrepreneurs—including knowledge creation. However, this model is also anchored on the critical role of the individual as independent, separate actor as in the top-down model.

Unlike the above two models, the middle-up-down model takes all members as important actors who work together horizontally and vertically. A major characteristic of the model regarding knowledge creation is the wide scope of cooperative relationships between top, middle, and lower managers. No one major department or group of experts has the exclusive responsibility for creating new knowledge.

But this is not to say that there is no differentiation among roles and responsibilities in this style of management. In the middle-up-down model, top management provides "visions for direction" and also the deadline by which the visions should be realized. Middle management translates these visions into middle-range visions, which are to be realized in the fields—the groups. Middle managers create their visions out of those from top and lower managers and materialize then vis-a-vis the two levels. In other words, while top management articulates the dreams of the firm, lower managers look at the reality. The gap between these two forms of perspectives is narrowed by and through middle management. In this sense, it is a leadership style that facilitates the parallel knowledge creation process taking place simultaneously at top, middle, and lower management respectively.

Table 1 summarizes the comparison of the three models, top-down, bottom-up, and middle-up-down management, in terms of knowledge creator, resource allocation, structural characteristics, process characteristics, knowledge accumulation, and inherent limitation. The roles and tasks of lower, top, and middle managers in the middle-up-down management will now be discussed in detail.

Frontline employees and lower managers are immersed in the day-to-day details of particular technologies, products, and markets. No one is more expert in the realities of a company's business than they are. But, while these employees and lower managers are deluged with highly specific information, they often find it extremely difficult to turn that information into useful knowledge. For one thing, signals from the marketplace can be vague and ambiguous. For another, employees and lower managers can become so caught up in their own narrow perspective, that they lose sight of the broader context. Moreover, even when they try to develop meaningful ideas and insights, it can still be difficult to communicate the importance of that information to others. People do not just passively receive new knowledge; they actively interpret it to fit their own situation and perspectives. Thus, what makes sense in one context can change or even lose its meaning when communicated to people in a different context.

**Table 1 A Comparison of Three Management Models**

	Top-Down	Middle-Up-Down	Bottom-Up
Agent of Knowledge Creation	top management	self-organizing team (with middle managers as team leaders)	entrepreneurial individual (intrapreneur)
Resource Allocation	hierarchically	from diverse viewpoints	self-organizing principle
Pursued Synergy	"synergy of money"	"synergy of knowledge"	"synergy of people"
Organization	big and powerful hq. staff use manuals	team-oriented affiliated firms by intrapreneurs	small hq. self-organizing suborganizations
Management Processes	leaders as commanders emphasis on information processing chaos not allowed	leaders as catalysts create organizational knowledge create / amplify chaos / noise	leaders as sponsors create personal information chaos / noise premised
Accumulated Knowledge	explicit computerized / documented	explicit and tacit shared in diverse forms	tacit incarnated in individuals
Weakness	high dependency on top management	human exhaustion lack of overall control of the organization	time consuming difficult to coordinate individuals

Source: from Nonaka (1988b).

The main job of top and middle managers in the model of middle-up-down management is to orient this chaotic situation toward purposeful knowledge creation. These managers do this by providing their subordinates with a conceptual framework that helps them make sense of their own experience.

In both top-down management and bottom-up management, a high degree of emphasis is given to charismatic leadership. By contrast, middle-up-down management views managers as catalysts. In this role as a "catalyst," top management sets the direction, provides the field of interaction, selects the participants in the field, establishes the guidelines and deadlines for projects, and supports the innovation process.

Top management gives voice to a company's future by articulating metaphors, symbols, and concepts that orient the knowledge-creating activities of employees. In other words, they give form to "organizational intention" that is beyond the personal intention of top management as an individual. This is achieved by asking the questions on behalf of the entire organization: What are we trying to learn? What do we need to

know? Where should we be going? Who are we? If the job of frontline employees and lower managers is to know "what is," then the job of top management is to know "what ought to be." In other words, the responsibility of top management in middle-up-down management is to articulate the company's "conceptual umbrella": the grand concepts expressed in highly universal and abstract terms identify the common features linking seemingly disparate activities or businesses into a coherent whole. Quinn (1992) called this conceptual umbrella a "future vision" that gives intellectual members of organizations some challenges for intellectual growth and develops their capacity for continuous change.

Another way in which top management provides employees with a sense of direction is by setting the standards for justifying the value of knowledge that is constantly being developed by the organization's members. As earlier comments on the "justification" of knowledge indicated, deciding which efforts to support and develop is a highly strategic task. In order to facilitate organizational knowledge creation, qualitative

factors such as truthfulness, beauty, or goodness are equal important to such qualitative, economic factors as efficiency, cost or ROI.

In addition to the umbrella concepts and qualitative criteria for justification, top management articulates concepts in the form of committed, equivocal visions, which are open-ended and susceptible to a variety of, and even conflicting, interpretations. If a vision is too sharply focused, it becomes more akin to an order or instruction, which will not foster the high degree of personal commitment. A more equivocal vision gives employees and self-organizing teams the freedom and autonomy to set their own goals. The final role of top management in middle-up-down management is to clear away any obstacles and prepare the ground for self-organizing teams headed by middle management. Knowledge creation, in this type of management, takes place intensively at the group level, at which middle managers embody top managers' visions. Middle managers are selected by top management, and therefore staffing is an important strategic consideration. Top managers should be able to provide middle managers with a sense of challenge or crisis and trust them.

As we have seen before, teams play a central role in the process of organizational knowledge creation. The main role of middle managers in middle-up-down management is to serve as a team leader who are at the intersection of the vertical and horizontal flows of information in the company. The most important knowledge creating individuals in this model are neither charismatic top managers nor the entrepreneur-like lower managers, but every employee who works in association with middle managers. It is the middle manager that takes a strategic position at which he or she combines strategic, macro, universal information and hands-on, micro, specific information. They work as a bridge between the visionary ideals of the top and the often chaotic reality on the frontline of business. By creating middle-level business and product concepts, middle managers mediate between "what is" and "what ought to be." They even remake reality according to the company's vision.

In addition, middle management forms the strategic knot that binds the top-down and bottom-up models. As the self-organizing team, headed by middle management moves up and down the organization, much redundancy and fluctuation can be created. As such, the organization with middle-up-down management naturally has a strong driver of self-reorganization. The middle management sometimes plays the role of "change-agent" for the self-revolution of the organization.

In sum, middle managers synthesize the tacit knowledge of both frontline employees and top management, make it explicit, and incorporate it into new technologies and products. They are the true "knowledge engineers" of the knowledge creating organizations.

#### **4.2. Hypertext Organization: A Design Prototype of a Knowledge Creating Organization**

Finally, an image can be presented of organizational design that provides a structural base for the process of organizational knowledge creation. Middle-up-down management becomes most efficient if supported by this infrastructure. The central requirement for the design of the knowledge-creating organization is to provide the organization with a strategic ability to acquire, create, exploit, and accumulate new knowledge continuously and repeatedly in a circular process. Earlier work has described an image of organizational design equipped with such a dynamic cycle of knowledge under the concept of a "hypertext organization," (Nonaka et al. 1992). This term is borrowed from a concept of computer software where "hypertext" allows users to search large quantities of text, data, and graphics by means of a friendly interface. It links related concepts and areas of knowledge to allow a problem to be viewed from many angles. In many ways, this is analogous to the ability of individuals to relate stories in different ways according to the nature of the audience. The same knowledge might be used but in different formats, making it easier to draw relationships between different sets of information.

The core feature of the hypertext organization is the ability to switch between the various "contexts" of knowledge creation to accommodate changing requirements from situations both inside and outside the organization. Within the process of organizational knowledge creation, it is possible to distinguish several "contexts" of knowledge creation such as the acquisition, generation, exploitation, and accumulation of knowledge. Each context has a distinctive way of organizing its knowledge creation activities. Nonhierarchical, or "heterarchical" self-organizing activities of teams are indispensable to generate new knowledge as well as to acquire "deep" knowledge through intensive, focused search. On the other hand, a hierarchical division of labor is more efficient and effective for implementation, exploitation, and accumulation of new knowledge as well as acquisition of various information through extensive, unfocused search.

Hypertext organization design first distinguishes the normal routine operation conducted by a hierarchical formal organization from the knowledge creating activ-

ities carried out by self-organizing teams. But it does not mean that the two activities need to operate separately and independently. Rather, it stresses the need for the careful design of the two activities which takes account of their distinctive contributions to knowledge creation. The important point to note is that the design of the hierarchy and self-organizing teams should enable the organization to shift efficiently and effectively between these two forms of knowledge creation. In terms of the theory of organizational knowledge creation, while hierarchical formal organization mainly carries out the task of combination and internalization, self-organizing teams perform the task of socialization and externalization. This also improves the ability of an organization to survive. By establishing the most appropriate organizational setting for the two activities, an organization can maximize the efficiency of its routine operation, which is determined by bureaucratic principles of division of labor and specialization, and also the effectiveness of its knowledge creation activities. In this type of organization, the knowledge creating activities of self-organizing teams work as a measure which serves to prevent the so-called "reverse function of bureaucracy" (Merton 1957).

Thus the hypertext organization combines the efficiency and stability of a hierarchical bureaucratic organization with the dynamism of the flat, cross-functional task-force organization. Nevertheless, it should be noted that a critical factor for the design of the hypertext organization lies in the coordination of time, space, and resources to realize the "requisite variety." Jacques (1979) pointed out that positions in the hierarchical organization have responsibility of different time-span. This implies that the hierarchical organization is a coordination device for these works of diverse time-span, and generates a "natural frequency" by "orchestrating" various rhythms. As the previous section indicated, each self-organizing team also creates its own "natural frequency" by synchronizing various rhythms brought into the field by members from diverse positions in hierarchical organization. The hypertext organization is an organizational structure that enables orchestration of different rhythms or "natural frequency" generated by various project teams and the hierarchical organization. It coordinates the allocation of time, space, and resource within the organization so as to compose an "organizational" rhythm that makes organizational knowledge creation more effective and efficient. In this sense, the hypertext organization is a structural device to build "requisite variety," which cannot be secured solely by middle-up-down management.

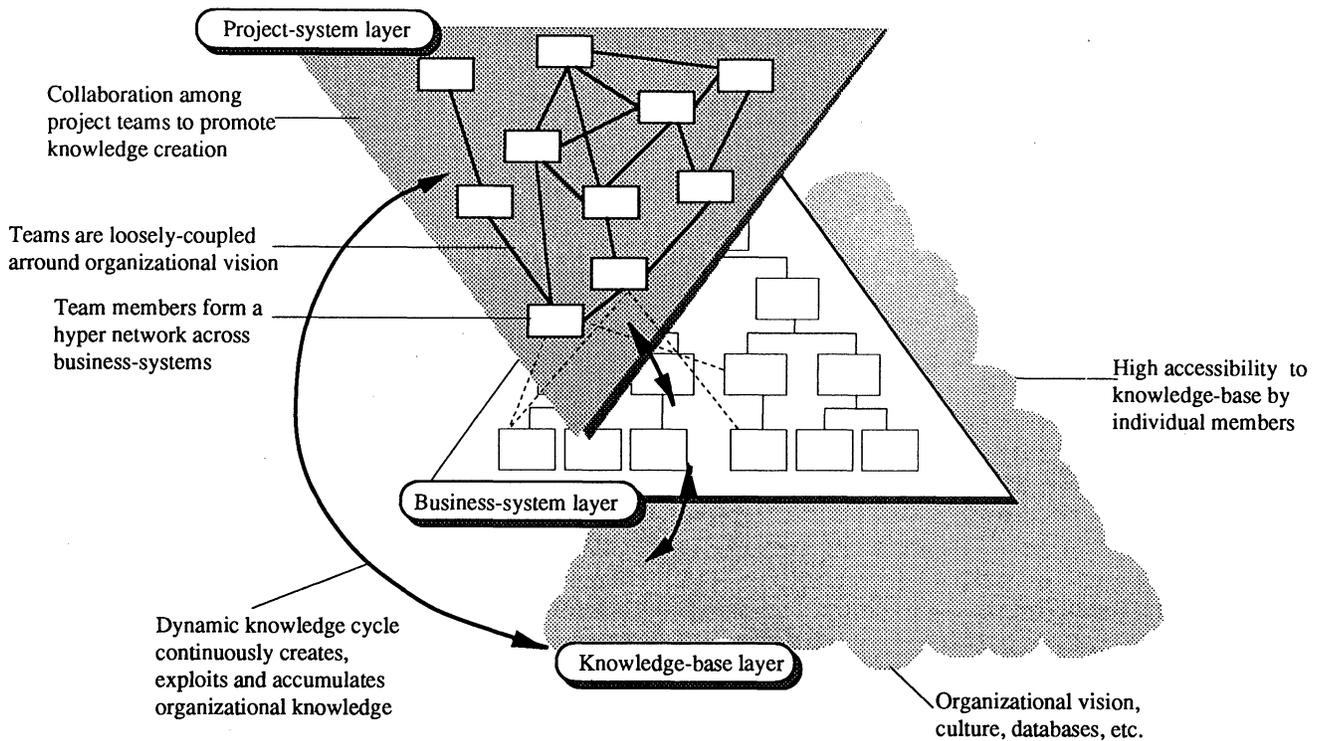
The image of the hypertext organization is illustrated in Figure 4. It can be visualized as a multilayered organization comprised of three layers; knowledge-base, business-system, and project team. At the bottom is the "knowledge-base" layer which embraces tacit knowledge, associated with organizational culture and procedures, as well as explicit knowledge in the form of documents, filing systems, computerized databases, etc. The function of this archival layer may be seen in terms of a "corporate university." The second layer is the "business-system" layer where normal routine operation is carried out by a formal, hierarchical, bureaucratic organization. The top layer relates to the area where multiple self-organizing project teams create knowledge. These teams are loosely linked to each other and share in the "joint creation of knowledge" using "corporate vision." Thus the hypertext organization takes different "forms," depending on the perspective from which it is observed.

The process of organizational knowledge creation is conceptualized as a dynamic cycle of knowledge and information traversing the three layers. Members of project teams on the top layer are selected from diverse functions and departments across the business-system layer. Based on the corporate vision presented by top management, they engage in knowledge creating activities interacting with other project teams. Once the task of a team is completed, members move "down" to the knowledge-base layer at the bottom and make an "inventory" of the knowledge acquired and created in the project. After categorizing, documenting, and indexing the new knowledge, they come back to upper business-system layer and engage in routine operation until they are called again for another project. A key design requirement in the hypertext organization is to form such a circular movement of organization members, who are the fundamental source and subject of organizational knowledge creation. From the vantage point of strategic management, the true "core competence" (Prahalad and Hamel 1990) of the organization, which produces sustainable competitive advantage, lies in its management capability to create relevant organizational knowledge (Nonaka 1989, 1991). This is a continuous process and the ability to switch swiftly and flexibly between the three layers in the hypertext organization is critical to its success.

## 5. Conclusion

The theory of organizational knowledge creation proposed here has been constructed mainly on the basis of hands-on research and practical experience of Japanese

**Figure 4** Hypertext Organization — An Interactive Model of Hierarchy and Nonhierarchy



Source: Nonaka, Konno, Tokuoka, and Kawamura (1992).

firms. Nevertheless, it should be stressed that the principles described have a more general application to any organization, either economic or social, private or public, manufacturing or service, in the coming age despite their field of activities as well as geographical and cultural location. The theory explains how knowledge held by individuals, organizations, and societies can be simultaneously enlarged and enriched through the spiral, interactive amplification of tacit and explicit knowledge held by individuals, organizations, and societies. The key for this synergetic expansion of knowledge is joint creation of knowledge by individuals and organizations. In this sense, the theory of organizational knowledge creation is at the same time a basic theory for building a truly "humanistic" knowledge society beyond the limitations of mere "economic rationality."

Organizations play a critical role in mobilizing tacit knowledge held by individuals and provide the forum for a "spiral of knowledge" creation through socialization, combination, externalization, and internalization. All of these conversion modes interact in a dynamic and continuous "entanglement" to drive the knowl-

edge creation process. These modes operate in the context of an organization and, while acknowledging the role of individuals as essential actors in creating new knowledge, the central theme of this paper has been to address the processes involved at an organizational level.

By concentrating on the concept of organizational knowledge creation, it has been possible to develop a perspective which goes beyond straightforward notions of "organizational learning." In the language of the present discussion, learning can be related to "internalization" which is but one of the four modes of conversion required to create new organizational knowledge. Taken by itself, learning has rather limited, static connotations whereas organizational knowledge creation is a more wide-ranging and dynamic concept.

Finally, hypertext and middle-up-down management have been offered as practical proposals for implementing more effective knowledge creation. As knowledge emerges as an ever more important feature of advanced industrial development, it is necessary to pay increased attention to the processes by which it is

created and the assessment of its quality and value both to the organization and society.

### Acknowledgements

The author would like to thank Arie Y. Lewin, John Seeley Brown, Takaya Kawamura, doctoral student at Hitotsubashi University, and Tim Ray for their insightful comments and assistance.

### Endnotes

<sup>1</sup> See Lewin and Stephens (1992) for arguments on challenges to and opportunities for organizational design in the post industrial society.

<sup>2</sup> Discussion on epistemology here is based on such classical accounts as Plato's *Theaetetus* and *Phaedo*, Descartes's *Discourse on Method*, Locke's *An Essay Concerning Human Understanding*, Hume's *An Enquiry Concerning Human Understanding*, and Kant's *Critique of Pure Reason*. For interpretation of these works, see Hospers (1967), Dancy (1985), Hallis (1985), Moser and Nat (1987), and Winograd and Flores (1986).

<sup>3</sup> See also Polanyi (1958) and Gelwick (1977).

<sup>4</sup> Metaphor should not be understood as mere rhetoric or an issue of expression; it is deeply connected with knowledge creation. For this point, see Black (1962) and McCormac (1985).

<sup>5</sup> For comprehensive discussion on metaphor, analogy, and model, see Leatherdale (1974) and Tsoukas (1991).

<sup>6</sup> The self-organizing team may be depicted by Maturana and Varela's (1980) concept of an "autopoietic system." Living organic systems are composed of various organs, which are again composed of numerous cells. Each unit, like an autonomous cell, is self-regulating. Moreover, each unit determines its boundary through self-reproduction, and is separate from the environment. This self-referential or self-reflecting nature is a quintessential feature of autopoietic systems.

<sup>7</sup> Gibson (1979) suggested an interesting hypothesis that knowledge lies in the environment itself, contrary to the traditional epistemological view that it exists inside the human brain. According to him, man perceives information ("affordance") which natural objects afford to human cognitive activity, i.e., according the degree of affordance of the environment. Information on chair, knife, and cliff are revealed when the actions of sitting, cutting, and falling are made, in other words, in the course of interactions between the subject and the object of perception.

<sup>8</sup> Jaikumar and Born (1986) pointed to this as the characteristic of Japanese firms' production methods. According to them, the production method for most American firms is clearly defined as the function of the basic manufacturing technology, assigned works, organizational goals, and environment. In this mode of production, then, workers are well aware of their work and thus simply follow the routine procedure. On the other hand, Japanese workers do not get prior knowledge and thus become part of the given work, rather than being separate from the work itself. Therefore, anomaly, or nonroutine nature, of the work itself becomes an important opportunity for learning.

<sup>9</sup> The development of these concepts are based on a series of theoretical and empirical research studies (Kagono et al. 1985, Takeuchi et al. 1986, and Nonaka 1988a).

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*Accepted by Arie Y. Lewin; received December 1992. This paper has been with the author for 1 revision.*