PERGAMON

Expert Systems with Applications 20 (2001) 7–16

Expert Systems with Applications

www.elsevier.com/locate/eswa

Expert systems for knowledge management: crossing the chasm between information processing and sense making

Y. Malhotra*

Abstract

Based on insights from research in information systems, information science, business strategy and organization science, this paper develops the bases for advancing the paradigm of AI and expert systems technologies to account for two related issues: (a) dynamic radical discontinuous change impacting organizational performance; and (b) human sense-making processes that can complement the machine learning capabilities for designing and implementing more effective knowledge management systems. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Expert systems; Artificial intelligence; Knowledge management; Information systems; Information science; Business strategy; Discontinuous change; Sense making; Information processing

> "There has been an over-concentration on Shannon's definition of information in terms of uncertainty (a very good definition for the original purposes) with little attempt to understand how MEANING directs a message in a network. This, combined with a concentration on end-points (equilibria) rather than properties of the trajectory (move sequence) in games has lead to a very unsatisfactory treatment of the dynamics of organizations." — John H. Holland (personal communication, June 21, 1995)[1]

1. Introduction

The narrative cited above as an observation by the noted psychologist and computer scientist John Holland was in response to my query to him regarding the possibility of using intelligent information technologies for devising self-adaptive organizations. As meaning seems to be a crucial construct in understanding how humans convert *information* into *action* [and consequently *performance*], it is evident that information-processing based fields of artificial intelligence and expert systems could benefit from understanding how humans translate *information* into *meanings* that guide their *actions*. In essence, this issue is relevant to the design of both human- and machine-based knowledge management systems. Most such systems had been traditionally based on consensus and convergence-oriented information processing systems, often based on mathematical and computation models. Increasing radical discontinuous change (cf. Huber & Glick, 1993; Nadler, Shaw, & Walton, 1995) that characterizes business environments of today and tomorrow, however, requires systems that are capable of multiple — complementary and contradictory — interpretations.

Despite observations made by Churchman (1971) and Mason and Mitroff (1973), the paradigm of information systems, artificial intelligence (AI) and expert systems have yet to address the needs posed by *wicked environments* that defy the logic of pre-determination, prediction and pre-specification of information, control and performance systems (cf. Malhotra, 1997). Wicked

* Tel..
E-mail address: yogesh.malhotra@brint.com (Y. Malhotra).

[1] Considering organizational adaptation for survival and competence as the key driver for most organizational information and knowledge processes (cf. Malhotra, 2000a,b,c), it seemed logical to develop the model of IT-enabled self-adaptive organizations based upon technologies that are often considered as a benchmark for self-adaptive behavior. In this context, genetic algorithms (also referred to as adaptive computation) offer the closest archetype for devising technology-enabled organizations that could possibly exhibit self-adaptive behavior given the dynamically changing environment. By offering the basis for evolution of solutions to particular problems, controlling the generation, variation, adaptation and selection of possible solutions using genetically based processes, it seemed probable that genetic algorithms could offer the basis for self-adaptive *evolution* of organizations. As solutions alter and combine, the worst ones are discarded and the better ones survive to go on and produce even better solutions. Thus, genetic algorithms *breed* programs that solve problems even when no person can fully understand their structure.

PII: S0957-4174(00)00045-2

business environments — characterized by radical discontinuous change — impose upon organizations the need for capabilities for developing multiple meanings or interpretations and continuously renewing those meanings given the changing dynamics of the environment. Scholars in business strategy have advocated human and social processes such as 'creative abrasion' and 'creative conflict' (cf. Eisenhardt, Kahwajy, & Bourgeois, 1997; Leonard, 1997) for enabling the *interpretive flexibility* (Nonaka & Takeuchi, 1995) of the organization.

It is also evident that there is an imperative need for relating the *static* notion of information captured in databases or processed through computing machinery to the *dynamic* notion of human sense making. More importantly, our current understanding of information as the [indirect] enabler of performance can immensely benefit from unraveling the intervening processes of human sense making that are more directly related to action (or inaction) and resulting performance outcomes (or lack thereof).

Based upon a review of the current state of AI and expert systems research and practice in knowledge management, this article develops the bases for AI and expert systems researchers to develop knowledge management systems for addressing the above needs. Section 2 provides an overview of the state-of-the-art expert systems research and practice issues related to knowledge management highlighting key relationships with the key theses of the article. Section 3 offers a more current understanding of knowledge management as it relates to organizational adaptability and sustainability by drawing upon information systems and business strategy research. Section 4 highlights the contrast between the computational model of information processing and human sense making while recognizing both as valid meaning making processes. Finally, sense-making bases of human action and performance are discussed in Section 6, followed by conclusions and recommendations for future research in Section 8.

2. State of related research and practice in AI and expert systems

Faced with uncertain and unpredictable business environments, organizations have been turning to AI and expert systems to develop knowledge management systems that can provide the bases for future sustainability and competence. For instance, faced with competition and uncertainty in the finance industry, banks are using neural networks to make better sense of a plethora of data for functions such as asset management, trading, credit card fraud detection and portfolio management (Young, 1999). Similarly, insurance and underwriting industries are relying upon knowledge management and AI technologies to offer multiple channels for rapid response to customers (Rabkin & Tingley, 1999). Many such knowledge management implementations using AI and expert systems rely upon the meaning making and sense-making capabilities of AI and expert systems technologies and humans using them.

In recent years, there have been significant advances in endowing inanimate objects with limited sense-making capabilities characteristic of self-adaptive behavior of humans. For instance, some proponents of 'perceptual intelligence' (cf. Pentland, 2000) have suggested such capabilities derived from a computers' ability to isolate variables of interest by classifying any situation based on categorization heuristics for taking appropriate action. Their suggestion is that once a computer has the perceptual ability to know who, what, when, where and why, then the probabilistic rules derived by statistical learning methods are normally sufficient for the computer to determine a course of action. However, these models, though helpful for procedural decision making, need to advance beyond the static, pre-specified and pre-determined logic to account for dynamically changing environments that may require fundamental and radical redefinition of underlying rules as well as the behavior of the actors.

Similarly, research on 'perceptual interfaces' has been trying to unravel how people experience information that computers deliver (cf. Reeves & Nass, 2000). This stream of research is based on the premise that human experience with information is caused by stimulation of the senses. While paying attention to the chemical senses (taste and olfaction), the cutaneous senses (skin and its receptors), vision and hearing, this research has yet to take into consideration the interpretive, meaning making and sense-making processes that occur at a more cerebral level. The personal constructivist theory discussed in this article could help better relate information to meaning and consequent behavior (or actions) in above cases.

Simultaneously, the state-of-art research and practice in data mining, often described as "knowledge discovery from databases," "advanced data analysis," and machine learning, has been trying to decipher how computers might automatically learn from past experience to *predict* future outcomes (Mitchell, 1999). However, as explained later, current thinking in business strategy is imposing upon the organization the need to move beyond *prediction of future* to *anticipation of surprise* (Malhotra, 2000a,b). The most advanced machine learning capabilities — such as those of the most advanced chess-playing computer (cf. Campbell, 1999) — are still limited by pre-specified, pre-determined definition of problems that are solved based on the pre-specified rules of the game.

Though interesting, such capabilities may have limited use in the emerging game of strategy that is being redefined as it is being played. In such game, all "rules are up for grabs" even though computational machinery has yet to evolve to the stage of sensing changes that it has not been *pre-programmed* to sense and to re-evaluate the rules embedded in the logic devised by human programmers. In contrast to machine learning, humans are endowed with capabilities of imagination and insight that allow them to go beyond the information given (Bruner, 1973), thus making them more capable of making sense of non-routine and unstructured changes. Better understanding of the personal constructivist bases (cf. Kelly, 1955; Malhotra & Kirsch, 1996; Malhotra, 1999a) of human sense-making processes for *anticipation of surprise* (Kerr, 1995) could facilitate advances in data mining and discovery techniques that could be more useful to enterprises in an era of navigating turbulent competitive landscapes (Malhotra, 1999b).

Better understanding of the human sense-making processes will also contribute to advancing the extant state of knowledge of AI often evoked in questions by AI and expert systems' researchers about learning, knowledge and intelligence, such as: "What is human?" (cf. Berry, 1999; Kurzweil, 1999) or "How does machine intelligence compare with human intelligence?" (Goldberg, 2000). Better understanding of the personal constructive perspective of human sense making — based on a synthesis of human cognitive, affective and active processes — could also advance understanding of the distinction between computer-like reasoning and human-like reasoning (Spivey, 2000) that is of interest to AI and expert systems designers interested in knowledge management. This issue is intriguing given that it has only been recently realized that isolated representation of human affect by means of the 'emotion engine' requires enormous computing horsepower (Oka & Suzuoki, 1999).

The above observations from the state-of-art AI and expert systems applications in various knowledge management related applications provide only a representative sample of issues pertinent to this article. However, based on this sample one can appreciate how such applications can benefit from better understanding of human sense-making processes in the context of dynamic radical and discontinuous change.

Given these observations, it is difficult to predict when computers will imitate human sense-making capabilities — in terms of the personal constructivist bases that explain how humans endow *information* with *meaning*. Anyhow, better understanding of what it means to be a human could help in more effective knowledge management implementations based on synergy between the data and information processing capabilities of technologies and sense-making capabilities of humans (Malhotra, 1998, 1997).

3. Changing dynamics of organizational sustainability and performance

The information-processing view characteristic of most AI and expert system-based knowledge management systems has been prevalent in information systems practice and research over the last few decades. Some interpretations of knowledge management that are representative of this view are listed in Table 1.

Table 1
Knowledge management: the information processing paradigm

The process of collecting, organizing, classifying and disseminating information throughout an organization, so as to make it purposeful to those who need it. (*Midrange Systems*: Albert, 1998)
Policies, procedures and technologies employed for operating a continuously updated linked pair of networked databases. (*Computerworld:* Anthes, 1991)
Partly as a reaction to downsizing, some organizations are now trying to use technology to capture the knowledge residing in the minds of their employees so it can be easily shared across the enterprise. Knowledge management aims to capture the knowledge that employees really need in a central repository and filter out the surplus. (*Forbes*: Bair, 1997)
Ensuring a complete development and implementation environment designed for use in a specific function requiring expert systems support. (*International Journal of Bank Marketing*: Chorafas, 1987)
Knowledge management IT concerns organizing and analyzing information in a company's computer databases so this knowledge can be readily shared throughout a company, instead of languishing in the department where it was created, inaccessible to other employees. (*CPA Journal*, 1998)
Identification of categories of knowledge needed to support the overall business strategy, assessment of current state of the firm's knowledge and transformation of the current knowledge base into a new and more powerful knowledge base by filling knowledge gaps. (*Computerworld*: Gopal & Gagnon, 1995)
Combining indexing, searching, and push technology to help companies organize data stored in multiple sources and deliver only relevant information to users. (*Information Week*: Hibbard, 1997)
Knowledge management in general tries to organize and make available important know-how, wherever and whenever it's needed. This includes processes, procedures, patents, reference works, formulas, "best practices," forecasts and fixes. Technologically, intranets, groupware, data warehouses, networks, bulletin boards videoconferencing are key tools for storing and distributing this intelligence. (*Computerworld*: Maglitta, 1996)
Mapping knowledge and information resources both on-line and off-line; training, guiding and equipping users with knowledge access tools; monitoring outside news and information. (*Computerworld*: Maglitta, 1995)
Knowledge management incorporates intelligent searching, categorization and accessing of data from disparate databases, E- mail and files. (*Computer Reseller News*: Willett and Copeland, 1998)
Understanding the relationships of data; identifying and documenting rules for managing data; and assuring that data are accurate and maintain integrity. (*Software Magazine*: Strapko, 1990)
Facilitation of autonomous coordinability of decentralized subsystems that can state and adapt their own objectives. (*Human Systems Management*, Zeleny, 1987)

This perspective originated in the era when business environment was less vacillating, organizations' products and services and the corresponding core competencies had a long multi-year shelf life, and the organizational and industry boundaries were clearly demarcated over the foreseeable future. Given the context of relatively predictable scope of the business game as well as the rules of the game, AI and expert systems focused on compilation of *historical* data, schemas and procedural logic to guide *future* actions. Knowledge representation and reasoning involved defining explicit descriptions of the world in such a way that a computer would be able to draw appropriate conclusions about the world by manipulating them.

Such machine-based *intelligence* has been defined in terms of rule sets that were related using inferential logic, thus requiring a pre-definition of the scope of the business game, the entities in the business game as well as the rules that guided their behavior. The key management challenge was to seek optimization-driven efficiencies by *minimizing variance* in a diversity of interpretations of any given set of information. Therefore, AI and expert system driven knowledge representation and reasoning served an important purpose by providing a framework for efficient delineation of questions and efficient search for pre-specified answers and solutions based on inferential logic. Most interpretations of knowledge management for this era focused on the homogeneity of information and interpreted most decisions in terms of symbolic data processing machinery (cf. Hannabuss, 1987; Strapko, 1990). The relatively structured and predictable business and competitive environment rewarded firms' focus on optimization, efficiencies and economies of scale. Such economies of scale were possible in the absence of impending threat of rapid obsolescence of product and service definitions, as well as demarcations of existing organizational and industry boundaries that are more representative of the new business environment (Mathur & Kenyon, 1997).

As evident, the emphasis of such AI- and expert system-based knowledge management systems has generally been on well-structured problem solutions including:

(a) well-structured problem situations for which there exists strong *consensual* position on the nature of the problem situation;
(b) well-structured problems for which there exists an analytic formulation with a solution.

Following Churchman (1971), type (a) systems are classified as Lockean inquiry systems and type (b) systems are classified as Leibnitzian inquiry systems. Leibnitzian systems are closed systems without access to the external environment: they operate based on *given* axioms and may fall into competency traps based on diminishing returns from the 'tried and tested' heuristics embedded in the inquiry processes. In contrast, the Lockean systems are based on consensual agreement and aim to reduce equivocality embedded in the diverse interpretations of the world-view. However, in the absence of a consensus, these inquiry systems also tend to fail.

The *convergent* and *consensus building* emphasis is suited for stable and predictable organizational environments. However, such *consensus building* systems are generally capable of providing "only one view of the problem," and hence are not very suitable for discontinuously changing environments (Mason & Mitroff, 1973, p. 481). Knowledge management systems designed to ensure *compliance* of rules might ensure that the rules and procedures are exactly followed, i.e. the variance between the *pre-specified* rules and the actual execution is minimized. However, they do not ensure the detection of error (Landau & Stout, 1979, p. 153). Unquestioning obedience to rules is synonymous with avoidance of errors: it motivates the reduction of "the risk of error through conformance to existing patterns of meaning" (Landau, 1973, p. 540). In this model, "information is selectively processed so as to minimize the rate and extent of change required, [and] the repertoire of response remains impervious to experience" (Landau, 1973, p. 540).

In contrast, dynamic environments not only require multiple perspectives of solutions to a given problem, but also diverse interpretations of the problem based upon multiple views of future. The wicked environment characterized by discontinuous change (Nadler & Shaw, 1995) and *wide range of potential surprise* (Landau & Stout, 1979) imposes the need for variety and complexity of the interpretations that are necessary for deciphering the multiple world-views of the uncertain and unpredictable future. Such an environment defeats the traditional organizational response of *predicting* and *reacting* based on pre-programmed heuristics. Instead, it demands more *anticipatory* responses from the organization members who need to carry out the mandate of a faster cycle of knowledge-creation and action based on the new knowledge (Nadler & Shaw, 1995).

Given the changing dynamics of the business environments, *information* needs to be continuously reinterpreted for its *meaning* — or for its *multiple meanings* — necessitated by increasing divergence of the future views of the business environment. Until the post-industrial era, prediction and pre-specification of the meaning of information and the rules guiding the meaning making could be done with some certainty and predictability. However, in increasingly wicked environments, any given representation of information needs to be counter-balanced with alternative complementary and contradictory representations. Such emphasis on multiple meanings guiding potential future courses of action has resulted in emphasis on concepts such as 'creative abrasion' and 'creative conflict' in current strategic thought (cf. Eisenhardt et al., 1997; Leonard, 1997).

4. Transition from information processing to sense making

The Lockean and Leibnitzian inquiry systems characterized by static representations of various data items, as well as their interrelationships and governing rules, are conducive to *static* representation of knowledge as well as its utilization based upon pre-determined and pre-defined criteria. However, the new world of information-enabled business is often defined as a 'world of re-everything' (cf. Arthur, 1996). In this new world of business, most enterprises' success or failure would depend upon their ability to incessantly question and adapt their programmed logic underpinning the business models and business processes to the sustained dynamic and radical changes in the business environment. (The new business environment and its implications for the model of knowledge management proposed here is explained in greater depth in Malhotra, 2000a,b,c.) The 'old world' of pre-determined and pre-defined *recipes of success* would still exist side-by-side with the world of *re-everything* in most business enterprises. However, most companies' competitive survival and ongoing sustenance would primarily depend on their ability to continuously redefine and adapt organizational goals, purposes and an organization's "way of doing things."

The contrast between the old world of business and the new world of re-everything may be illustrated by the example of the famous chess match between the supercomputer Deep Blue and the reigning human chess champion Garry Kasparov. The games in the supercomputer's database represent a rough consensus, developed over decades of play, of the best opening moves known. The past moves played by Grandmasters are considered good and the moves that yielded success in the past are considered as predictors of success in the future (Campbell, 1999). The chess board with its *static* 8×8 configuration of black and white squares with a half-dozen types of actors moving based on pre-determined and pre-defined rules encapsulates in it the old world of business that can be *programmed* into the memory of a supercomputer with the aid of massive databases containing historical information. However, such conception of 'knowledge discovery' systems seems to be a poor base for defining the logic of enterprises that need to radically redefine the game as well as the rules governing it to leverage the most high return business opportunities. Emergence of business ecosystems that defy traditional categorization based on simplistic SIC codes, mutations and symbiosis of business activities of corporations across diverse industries, virtualization of products and services that are created and channeled through multiple channels and array of diverse providers along the supply chains represent a more complex and unpredictable environment. In this discontinuously changing dynamic environment all rules are up for grabs: the game may be redefined while it is being played as the actors also change their behavior defying the logic of a pre-programmed, pre-defined and predictable moves within a game bounded by pre-defined assumptions and rules.

Interestingly, Churchman had suggested alternative kinds of information system that are suited for such 'wicked' environments. He had proposed two alternative kinds of inquiry system that are particularly suited for multiplicity of world-views needed for radically changing environments: Kantian inquiry systems and Hegelian inquiry systems. Kantian inquiry systems attempt to give multiple *explicit* views of *complementary* nature and are best suited for moderate ill-structured problems. However, given that there is no explicit opposition to the multiple views, these systems may also be afflicted by competency traps characterized by *plurality* of *complementary* solutions. In contrast, Hegelian inquiry systems are based on synthesis of *multiple completely antithetical* representations that are characterized by intense conflict because of the contrary underlying assumptions. Knowledge management systems based upon the Hegelian inquiry systems, would facilitate multiple and contradictory interpretations of the focal information.

Instead of emphasizing unquestioning adherence to pre-specified goals or procedures, such inquiring systems do not encourage conformity with pre-specified behavior (Cooper, Hayes, & Wolf, 1981, p. 179):

> *Not* requiring consistency in behavior may be achieved by encouraging playfulness in the choice process in organizations, allowing intuition to guide action without sanction.

Instead of blind compliance of pre-specified and institutionalized 'best practices,' such systems encourage ongoing and continual re-assessment and modification of such practices to ensure dynamic adaptability to the rapidly changing business environment. This process is facilitated by treating goals as hypotheses, treating intuition as real, treating organizational memory as enemy and treating experience as a theory which requires ongoing reassessment (Landau, 1973; March, 1971). Playfulness creates an environment conducive to the subjective, interpretative and constructive aspects of knowledge creation that are guided by individual and organizational 'sense making' (Weick, 1990).

5. Implications of the contrast

The information-processing model of knowledge management embedded in most AI and expert systems technologies is often based on avoidance of errors by meticulous obedience of pre-specified plans, goals, procedures, rules, etc. Characterized by "*overdefinition* of rules and *overspecification* of tasks" (Landau & Stout, 1979, p. 153), this model nurtures conformance to the rules regardless of the results. While errors are informational, compliance is not. Knowledge management systems designed to ensure compliance might ensure that the rules and procedures are exactly followed, i.e. the variance between the *pre-specified* rules and the actual execution is minimized. However, as noted earlier, unquestioning obedience to rules is synonymous with avoidance of errors: it motivates reduction of "the risk of error through conformance to existing patterns of meaning" (Landau, 1973, p. 540). In this model, "information is selectively processed so as to minimize the rate and extent of change required, [and] the repertoire of response remains impervious to experience" (Landau, 1973, p. 540). In the absence of *explicit* recommendation for providing contrary [or complementary] alternatives, legitimization of *any kind* of 'practices' by embedding them in technology is expected to result in the above outcome. It is essentially a negative activity since it defines "what *cannot be done*" (Stout, 1980, p. 90). Hence, such practices reinforce a process of single loop learning with its primary emphasis on error avoidance (Argyris, 1994). The explicit bias for seeking compliance makes such systems inadequate for motivating divergence-oriented interpretations that are necessary for ill-structured and complex environments.

In contrast, the proposed model of knowledge management is based upon "unprogrammed processes for monitoring errors [which] utilize discontent and emit signals through dissent, complaint, discontent, and controversy" (Hedberg, Nystrom, & Starbuck, 1976, p. 58). The key processes are those of error detection and error correction that seek to identify "what *can* be done" (Stout, 1980, p. 90) within the constraints imposed by the task environment. These distinguishing features facilitate development of a large repertoire of organizational responses, as well as diverse approaches for implementing related solutions to problems. Unlike the information-processing perspective that assumes a problem as given and the solution as based upon a "preset algorithm", the proposed model constructs the definition of the problem "from the knowledge available at a certain point in time and context" (Nonaka & Takeuchi, 1995, p. 79). While individual autonomy in the proposed model facilitates divergence of individual meanings, the organizational vision facilitates the various views to converge in a given direction. This process avoids premature closure or convergence while enabling interpretive flexibility necessary for sustaining creativity and innovation.

Given the emphasis of current strategic thought on 'creative abrasion' and 'constructive conflict', the proposed model of knowledge management seems better suited to detecting changes in external environment and taking corrective action. The distinguishing characteristics of the proposed model of knowledge management with divergence of meaning that continuously assesses the validity of fundamental assumptions thus provide means for balancing the optimization-based, consensus-oriented focus on efficiency.

In addition to suggesting the need for divergence-oriented systems for wicked environments, Churchman had also asserted that (Churchman, 1971, p. 10): "knowledge resides in the user and not in the collection of information… it is how the user reacts to a collection of information that matters". In contrast to the static representation of knowledge embedded in rule based logic and fixed representations of data, Churchman's emphasis on the human nature of knowledge creation seems more pertinent today than it seemed three decades ago given the increasing prevalence of wicked environment. In prior discussion, these two key features were the primary distinguishing characteristics of the *sense-making paradigm* of knowledge management in contrast to the *information-processing paradigm* of knowledge management that has served as a base for most AI- and expert systems-related implementations. Subsequent discussion further develops the *sense-making paradigm* based on the personal construction theory, also known as the theory of meaning, that posits a synergistic view of the rational and affective aspects of human intelligence.

6. Sense-making bases of human action and performance

To understand how information gets translated into knowledge, action and performance, we need to reflect upon the processes that underlie human sense making leading to action [or inaction] and performance. Understanding of human sense-making processes could help one develop a better appreciation of the link between information and resulting actions. It could also help us understand the gap between performance expectations based on design of information technologies and performance yields of such systems when they are appropriated by human users. Better understanding of human sense-making processes is critical for understanding how information processed through information systems is appropriated by human users and converted into knowledge and resulting action and performance.

The contrast between the sense-making perspective and the information processing perspective discussed above can be further appreciated by relating to the construct of *meaning*. In the computational metaphor, "information is indifferent with respect to the message… [it] comprises an already precoded message… meaning is preassigned to messages" (Bruner, 1986, p. 4). In this perspective, there is no role for the human mind in constructing any meaning out of such information. Most definitions of "information" in this paradigm are devoid of any explicit reference to the "meaningfulness" of information at the individual or social level. Such definitions ignore the relational character of information.

However, an analysis of human processes underlying the translation of information into meaning suggests a completely different picture. When the individual interacts with characters scrawled in a specific format or with pixels arranged in a specific manner, the meaning is assigned depending upon the existing systems of personal constructs. It is only through the interpretation of a receiver that they are taken to convey a certain meaning (Rapp, 1986). These meanings would not exist "if human beings would not have created the objects and entities" in them (Strombach, 1986, p. 77). Something would make sense only if it can be related or connected to some existing link. "To grasp the meaning of a thing, an event, or a situation is to see it in its *relations* to other things…" (Dewey, 1933, p. 137). Individual *sense* is a cognitive construction that is imposed upon the facts to better organize understanding — *sense is not intrinsic in the reality, but is constructed by the individual* (Ropohl, 1986, p. 69). In congruence with Churchman's view of knowledge as *not resident* in information, the sense-making paradigm views knowledge as embedded in human and social processes. It is personal and social constructions based on information-based interactions that provide the richness inherent in diversity of *meanings*. Hence, in contrast to the information processing view, the sense-making perspective would not concur with propositions of *knowledge* as being embedded in computer-based databases, computer memories or programmed logic of inference. The sense-making paradigm for the world of re-everything also challenges simplistic assumptions implied by assertions such as the following (Applegate, Cash, & Millis, 1988, p. 44; italics added for emphasis):

> Information systems will maintain the corporate history, experience and expertise that long-term employees now hold. The information systems themselves — *not the people* — can become the stable structure of the organization. *People will be free to come and go, but the value of their experience will be incorporated in the systems* that help them and their successors run the business.

The notion of *meanings* as detached from processed *information* can be further understood from human learning from the sense-making perspective. This view of learning and sense making could also establish the bases for understanding the differences between machine learning and processes of human learning and sense making. In the proposed view, learning entails interaction between the individual's existing system of constructs and newer experiences. New experiences are interpreted with reference to the existing system of constructs that is in turn modified by newer experiences. The syntactic dimension of information, which has been the primary focus of information theory, is nothing but a carrier of semantic and pragmatic dimensions (Morris, 1938). The semantic dimension is the individual's interpretation of the syntactic dimension based upon one's existing system of constructs; it represents the *personal* meaning ascribed to information. The pragmatic dimension translates personal interpretation of information into the actualization of a specific behavior or action. This process is moderated by the interaction of the individual rational and affective characteristics.

7. Personal constructivist bases of sense making

The personal construct theory gives explicit recognition to the individual as a whole: comprising *both* rational *and* affective dimensions. Or, as noted by the original proponent of personal constructivism, George Kelly (1969, p. 140):

> I have been careful not to use either of the terms, 'emotional' or 'affective'. I have been equally careful not to invoke the notion of 'cognition'. The classic distinction which separates the two constructs has become, in the manner of most classic distinctions that once were useful, a barrier to sensitive, psychological inquiry.

The fundamental postulate of the personal construct theory is that constructs (*meanings*) are created from an individual's experience in order to anticipate future events: "a person's processes are psychologically channelized by ways in which he [or she] anticipates [future] events" (Kelly, 1963, p. 46). Kelly (1963) describes individual construction as a series of choices based on prediction of the outcome or results: "a person chooses that which will extend and define the system" (p. 64). The process of construction, which is highly individualized and based on one's existing system of personal constructs, is aimed at finding meaning and making sense of the situations. Individuals use constructs to make sense of the world and anticipate events by "construing their replications" — by erecting constructs of similarity and contrast for the various elements that are construed. Kelly uses the analogy of listening to music to describe this process of replication — he emphasizes that replication is something that emerges from the interpretation of the individual (Bannister & Fransella, 1971, p. 20, 1986, p. 9).

Since constructs are specific to individuals, in the constructivist view, unlike in the behaviorist perspective, behavior is highly individualized. This issue has significant implications for the rule-based homogenized logic of AI and expert systems. Contradicting the stimulus–response connection suggested by behaviorist psychology, Kelly suggests that humans respond to "what they interpret the stimulus to be" which is a function of the constructs one detects or imposes upon one's world (Bannister & Fransella, 1971, p. 21, 1986, p. 10). It is possible for two persons who are involved in the same events to experience them differently because they construe them differently. Furthermore, because they construe the events differently, they will anticipate them differently and will behave differently based upon those anticipations (Kelly, 1963, p. 90). Individuals adjust their constructs to match the environment better *to improve predictions of their actions*: "all of our present interpretations of the universe are subject to revision or replacement… there are always some alternative constructions available to choose among in dealing with the world" (p. 15). Based upon the unfolding events, the individual validates one's [initial] assumptions and revises them in case they do not match the expected outcomes.

In this view, individuals differ from each other not only in the events that they seek to anticipate, but also in their individual approaches to the anticipation of the same events (Kelly, 1963, p. 55). The individuals differ with respect to how they perceive or interpret a situation, what they consider important about it and what they consider its implications to be: "Each of us lives in what is ultimately a unique world, because it is uniquely interpreted and thereby uniquely experienced" (Bannister & Fransella, 1986, p. 10). This perspective accounts for the diversity of individual interpretations as well as ongoing renewal of existing meanings based on the individual's cumulative experiences.

Although, there are individual differences in the construction of events, yet sharing of experiences among persons could occur "through construing the experiences of [one's] neighbors along with [one's] own [experience]" (Kelly, 1963, p. 56). In the case that the persons are guided by different cultural identifications or personal considerations, they may exist in the same reality "but in altogether different subjective worlds" (p. 56). However, there may be some shared (common) aspect among the two individuals about which they may construe similarly, i.e. "discriminate, interpret, see the implications of events, in similar ways" (Bannister & Fransella, 1971): "They are similar in so far as, and with respect to, events which have the same meaning for them" (p. 30). To that extent of commonality of the construction of experience, the psychological processes may be construed as similar between the two persons (Kelly, 1963, p. 91).

To play a role in the social process involving another individual, one needs to effectively construe the construction process of another (Kelly, 1963, p. 95). It does not imply that the two persons' construction processes should be similar — it only implies that the individual's construct system gives one a meaningful understanding of the other's construct system. This does not "make role a purely social construct, that is, see it as the acting out of a dialogue written for the two persons by the society in which they [are]" (Bannister & Fransella, 1971, p. 31). Rather, individual reality is tuned to the socially accepted interpretation and this process of individual's adjustments of one's constructs may entail considerable anxiety and unrest.

The individual experiences certain predominant feelings during each phase of constructing new information into an individualized system of personal constructs. On encountering an unfamiliar concept, the individual's system of constructs is unable to incorporate it and the individual feels confused and perplexed: "almost everything new starts in some moment of confusion" (Maher, 1969, p. 151). The prospect of the unknown may have a threatening effect on the individual. The individual may choose to reject the idea in this phase which is characterized as: "the threshold between confusion and certainty, between anxiety and boredom… [when] we are most tempted to turn back" (Maher, 1969, p. 152). Or else, the individual may choose to formulate a hypothesis that can enable one to break through this moment of threat to get on with the task of testing to confirm or reject the hypothesis. The last phase of this "cycle of sensemaking" (Kelly, 1963) involves assessing the result of the action and using that information to reconstruct or to assimilate the new construct in the existing system of constructs.

The primary emphasis of this theory is upon the individual's active role in the construction process motivated by the anticipation of future events. On encountering a new situation, the individual may feel uncertain, anxious and confused, and may formulate a hypothesis or a 'plan of action' to reduce uncertainty and anxiety. The hypothesis is translated into action and the results are compared with the initial anticipations. One person's construction may not be same as that of other individuals comprising the same reality.

In summary, the personal constructivist theory views transformation of information into human action and performance as an active, engaging process driven by feelings interacting with thoughts and actions. Affective experience plays a key role in guiding cognition and action throughout the construction process. This delineation of the organic process of sense making underlying creation, renewal and utilization of knowledge presents an interesting contrast to the information processing view that is often depicted in the information processing view adopted by AI and expert systems processes of knowledge acquisition, knowledge representation, knowledge capture and knowledge dissemination.

8. Conclusion and issues for future research

The motivation of this article was the need to suggest how AI and expert systems research and practice can improve their relevance for the design of effective knowledge management systems implementations by addressing issues that are critical to business performance. Based upon information science, strategy and organizational science practice and research, this article underscores the need for designing AI and expert systems for knowledge management by accounting for *wicked* business environments that defy the programmed logic based upon pre-specification, prediction and pre-determination. In addition, the article also develops an in-depth bases of human sense making processes that characterize human meaning making capabilities underlying the translation of information into knowledge and finally into performance. For advancing the state of research and practice on AI and expert systems as related to knowledge management, the article also answered the questions: what's being human? and what is the contrast between human learning and machine learning?

The personal constructivist theory was suggested as one foundation for understanding the processes of meaning making in human beings. The related sense-making model of human meaning making is also supported by observations of other scholars who have approached it from other psychological perspectives. For instance, Bruner (1986) has suggested that humans often (pp. 51–52) "*suspend disbelief*"… in order to construct "multiple perspectives and possible worlds…" and considers the individual as (p. 3) "one who actively selects information, forms… hypotheses and on occasion distorts the input in the service of reducing surprise and of attaining [understanding]". In congruence with the observations of the PCT, he is also critical of the existing conceptual split between the constructs of thought, action and emotion currently prevalent in the information processing view. To him the three aspects represent an integrated whole (Bruner, 1986, pp. 117–118):

> Emotion is not usefully isolated from the knowledge of the situation that arouses it. Cognition is not a form of pure knowing to which emotion is added… [and] action is a final common path based on what one knows and feels. The three constitute a unified whole… To isolate each is like studying the planes of a crystal separately, losing sight of the crystal that gives them being.

He also underscores the importance of linkages "between emotion, arousal, drive on the one side and learning, problem solving, thinking on the other" (1986, p. 113) for developing an understanding of how humans construct meanings.

The essence of the discussion is that the world of business is encountering not only unprecedented pace of change but also radical discontinuities in such change that make yesterday's *proven* rules of behavior and models underlying such behavior increasingly vulnerable. The information processing view, evident in scores of definitions of knowledge management in the trade press and academic texts, has often considered organizational memory of the past as a reliable predictor of the dynamically and discontinuously changing business environment. Most such interpretations have also made simplistic assumptions about storing *past* knowledge of individuals in the form of routinized programmable logic, rules-of-thumb and archived best practices in data bases for guiding *future* action. However, as discussed in the article, there are major problems that are attributable to the information-processing view of information systems.

The current paradigm of AI and expert systems technologies needs to overcome the constraints of their rule-based and model-based characteristics of Lockean and Leibnitzian systems. Future evolution of these technologies needs to overcome the limitations inherent in the information processing logic. Based on the discussions in the article, three areas of research are recommended to address existing gaps in knowledge and conflicting inter-disciplinary assumptions about knowledge and its management with the aid of new information technologies.

First, AI- and expert systems-based knowledge management technologies are often purported to deliver *the right information to the right person at the right time.* However, new business models marked by radical and discontinuous changes make the task of predicting the right information, the right person or the right time challenging as the notion of "right" keeps shifting.

Second, AI and expert systems technologies are often based upon the assumptions of storing human intelligence and experience. However, prior discussion that contrasted the information processing and sense-making views suggests otherwise. Technologies such as databases and groupware applications store *static* bits and pixels of data, but they cannot store the rich schemas that people possess for making *dynamic* sense of data bits. Also, the *static* representations of data in databases, inferential logic of computer programs and computer memories lack inherent *dynamic* meaning making capabilities that are increasingly relevant for emerging business environments. In contrast, given the dynamic subjective nature of human construction of meaning and the diversity of personal constructions, different meanings could be constructed from the same assemblage of data at the same time by different individuals. Likewise, different meanings could be construed at different times, or by consideration of different contexts by the same person. Hence, storing a static representation of the explicit representation of a person's tacit knowledge in the form of data bits — assuming one has the willingness and the ability to part with it — cannot be considered tantamount to storing human intelligence and experience.

Finally, it has been often asserted that AI and expert system technologies can distribute human intelligence. Again, this assumes that companies can predict the right information to distribute and the right people to distribute it to. Even when information is archived in a database or intranet, or it is *pushed* to individuals' mailboxes or desktops, it may be ignored as increasingly *attention is the scarce resource* often overwhelmed with *information overload*. Moreover, the data archived in technological 'knowledge repositories' is rational, static and without context, and such systems cannot account for *renewal of existing knowledge* and *creation of new knowledge*.

References

Albert, S. (1998). Knowledge management tries to live up to the hype. *Midrange Systems*, (September 7).

Anthes, G. H. (1991). A step beyond a database. *Computerworld*, *25* (9), 28.

Applegate, L., Cash, J., & Mills, D. Q. (1988). Information technology and tomorrow's manager. In M. G. McGowan, *Revolution in real time: Managing information technology in the 1990s* (pp. 33–48). Boston, MA: Harvard Business School Press.

Argyris, C. (1994). Good communication that blocks learning. *Harvard Business Review*, 77–85 (July–August).

Arthur, W. B. (1996). Increasing returns and the new world of business. *Harvard Business Review*, *74* (4), 100–109 (July–August).

Bair, J. (1997). What is knowledge management? *Forbes ASAP*, (April 7).

Bannister, D., & Fransella, F. (1971). *Inquiring man: The theory of personal constructs*, New York: Penguin.

Bannister, D., & Fransella, F. (1986). *Inquiring man: The psychology of personal constructs*, (3rd ed.) London: Croom Helm.

Berry, S. (1999). Technology and human thought drive future communications systems. *Signal*, *54* (4), 29–32 (December).

Bruner, J. (1973). In J. M. Arglin, *Beyond the information given: Studies in psychology of knowing* New York: Norton.

Bruner, J. (1986). *Actual minds, possible worlds*, Cambridge, MA: Harvard University Press.

Campbell, M. (1999). Knowledge discovery in Deep Blue. *Communications of the ACM*, *42* (11), 65–67 (November).

Chorafas, D. N. (1987). Expert systems at the Banker's reach. *International Journal of Bank Marketing*, *5* (4), 72–81.

Churchman, C. W. (1971). *The design of inquiring systems*, New York: Basic Books.

Cooper, D. J., Hayes, D., & Wolf, F. (1981). Accounting in organized anarchies: understanding and designing accounting systems in ambiguous situations. *Accounting, Organizations and Society*, *6* (3), 175–191.

Dewey, J. (1933). *How we think*, Boston, MA: Heath.

Eisenhardt, K. M., Kahwajy, J. L., & Bourgeois III, L. J. (1997). *How management teams can have a good fight*, Harvard Business Review (July–August).

Goldberg, C. (2000). The age of spiritual machines: when computers exceed human intelligence. *Science News*, *157* (4), 22 (January).

Gopal, C., & Gagnon, J. (1995). Knowledge, information, learning and the IS manager. *Computerworld (Leadership Series)*, *1* (5), 1–7.

Hannabuss, S. (1987). Knowledge management. *Library Management*, *8* (5), 1–50.

Hedberg, B., Nystrom, P. C., & Starbuck, W. H. (1976). Camping on seesaws: prescriptions for a self-designing organization. *Administrative Science Quarterly*, *21*, 41–65.

Hibbard, J. (1997). In the know. *Information Week*, (October 23).

Huber, G. P., & Glick, W. H. (1993). *Organizational change and redesign: Ideas and insights for improving performance*, New York: Oxford University Press.

Kelly, G. A. (1955). *Principles of personal construct psychology*, New York: Norton.

Kelly, G. A. (1963). *A theory of personality: the psychology of personal constructs*, New York: Norton.

Kelly, G. A. (1969). Humanistic methodology in psychological research. In B. Maher, *Clinical psychology and personality: The selected papers of George Kelly* (pp. 133–146). John Wiley.

Kerr, S. (1995). Creating the boundaryless organization: the radical reconstruction of organization capabilities. *Planning Review*, 41–45 (September–October).

Kurzweil, R. (1999). Spiritual machines: the merging of man and machine. *The Futurist*, *33* (9), 16–21 (November).

Landau, M. (1973). On the concept of self-correcting organizations. *Public Administration Review*, 533–542 (November/December).

Landau, M., & Stout Jr., R. (1979). To manage is not to control: or the folly of type II errors. *Public Administration Review*, 148–156 (March/April).

Leonard, D. (1997). Putting your company's whole brain to work. *Harvard Business Review*, (July–August).

Maglitta, J. (1995). Smarten up! *Computerworld*, *29* (23), 84–86 (June 5, 1995).

Maglitta, J. (1996). Know-how, Inc. *Computerworld*, *30* (1) (January 15, 1996).

Maher, B. (1969). *Clinical psychology and personality: The selected papers of George Kelly*, New York: Wiley.

Malhotra, Y. (1997) Knowledge management in inquiring organizations. *Proceedings of 3rd Americas Conference on Information Systems (Philosophy of Information Systems Mini-track)*, Indianapolis, IN, August 15–17, 1997. Accessible online at: http://www.brint.com/km/km.htm.

Malhotra, Y. (1998). *Journal for Quality and Participation*, 58–60 (July/August).

Malhotra, Y. (1999a). Bringing the adopter back into the adoption process: a personal construction framework of information technology adoption. *Journal of High Technology Management Research*, *10* (1), 79–104.

Malhotra, Y. (1999b). Knowledge management for organizational white waters: an ecological framework. *Knowledge Management (UK)*, *2* (6), 18–21.

Malhotra, Y. (2000a). From information management to knowledge management: beyond the 'hi-tech hidebound' systems. In K. Srikantaiah & M. E. D. Koenig, *Knowledge management for the information professional* (pp. 37–61). Medford, NJ: Information Today Inc.

Malhotra, Y. (2000b). Knowledge management and new organization forms: a framework for business model innovation. *Information Resources Management Journal*, *13* (1), 5–14 (January–March).

Malhotra, Y. (2000c). Knowledge management for e-business performance: advancing information strategy to 'Internet Time'. *Information Strategy: The Executive's Journal*, *16* (4), 5–16.

Malhotra, Y., Kirsch, L. (1996). Personal construct analysis of self-control in IS adoption: empirical evidence from comparative case studies of IS users and IS champions. *Proceedings of the First INFORMS Conference on Information Systems and Technology (Organizational Adoption and Learning)*, Washington DC, May 5–8, 1996, (pp. 105–114).

March, J. G. (1971). The technology of foolishness. *Civilokonomen*, 7–12 (May).

Mason, R. O., & Mitroff, I. I. (1973). A program for research on management information systems. *Management Science*, *19* (5), 475–487 (January).

Mathur, S. S., & Kenyon, A. (1997). Our strategy is what we sell. *Long Range Planning*, *30*.

Mitchell, T. M. (1999). Machine learning and data mining. *Communications of the ACM*, *42* (11), 30–36.

Morris, C. W. (1938). *Foundations of the theory of signs*, Chicago, IL: University of Chicago Press.

Nadler, D. A., & Shaw, R. B. (1995). Change leadership: core competency for the twenty-first century. In D. A. Nadler, R. B. Shaw & A. E. Walton, *Discontinuous change: Leading organizational transformation* San Franscisco, CA: Jossey-Bass.

Nadler, D. A., Shaw, R. B. & Walton, A. E. (1995). Discontinuous change: Leading organizational transformation San Francisco, CA: Jossey-Bass.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company*, New York: Oxford University Press.

Oka, M., & Suzuoki, M. (1999). Designing and programming the emotion engine. *IEEE Micro*, *19* (6), 20–28.

Pentland, A. (2000). Perceptual intelligence. *Communications of the ACM*, *43* (3), 35–44.

Rabkin, B., & Tingley, M. (1999). Tech-savvy customers want quick response. *National Underwriter*, 12–21 (Oct 4).

Rapp, F. (1986). The theory-ladenness of information. In C. Mitcham & A. Huning, *Philosophy and technology II: Information technology and computers in theory and practice* Dordrecht, Holland: D. Reidel Publishing Co.

Reeves, B., & Nass, C. (2000). Perceptual bandwidth. *Communications of the ACM*, *43* (3), 65–70.

Ropohl, G. (1986). Information does not make sense or: the relevance gap in information technology and its social dangers. In C. Mitcham & A. Huning, *Information technology and computers in theory and practice Philosophy and technology*, vol. II. Dordrecht: Reidel.

Spivey, M. J. (2000). Turning the tables on the Turing test: the Spivey test. *Connection Science*, *12* (1), 91–94.

Stout Jr., R. (1980). *Management or control? The organizational challenge*, Bloomington, IN: Indiana University Press.

Strapko, W. (1990). Knowledge management. *Software Magazine*, *10* (13), 63–66.

Strombach, W. (1986). Information in epistemological and ontological perspective. In C. Mitcham & A. Huning, *Information technology and computers in theory and practice*. *Philosophy and technology*, vol. II. Dordrecht: Reidel.

Weick, K. E. (1990). Cognitive processes in organizations. In L. L. Cummings & B. M. Staw, *Information and cognition in organizations*-Greenwich, CT: JAI Press.

Willett, S., & Copeland, L. (1998). Knowledge management key to IBM's enterprise plan. *Computer Reseller News*, *800*, 1–6 (July).

Young, K. (1999). A learning process. *The Banker (London)*, 65–66.

Zeleny, M. (1987). Management support systems. *Human Systems Management*, *7* (1), 59–70.