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Introduction

Effective organizations configure their internal resources and capabilities to meet environmental demands (Andrews 1971, Barney 1991, Grant 1991, Lawrence and Lorsch 1968, Peteraf 1993, Thompson 1968). Information-processing (I/P) models of organizations prescribe organizing to provide an I/P capacity sufficient to deal with the communication requirements generated by the environment, described in information-based terms such as complexity and uncertainty (e.g, Driver and Streufert 1969, Galbraith 1973, Tushman and Nadler 1978).

These models, while useful, have two shortcomings. First, organizations process *knowledge* as well as information (Demsetz 1988, Grant 1996a, Kogut and Zander 1992, Penrose 1959, Spender 1996, Teece 1980). While I/P models assume an ability to interpret messages uniformly and unambiguously, in actuality, events can range widely in meaningfulness and explicability depending on an organization's intellectual resources. Second, uncertainty, complexity, and similar terms used to describe the perceived determinacy (or indeterminacy) of the environment have been inconsistently defined in the literature (Zack and McKenney 1988).

This paper describes a taxonomy of "knowledge problems" addressing these issues. To provide a broader and more coherent description of the environment in knowledge-based terms, I propose the attributes complexity, uncertainty, ambiguity, and equivocality. I argue that each poses a unique challenge and opportunity for applying information technology.

Four Knowledge Processing

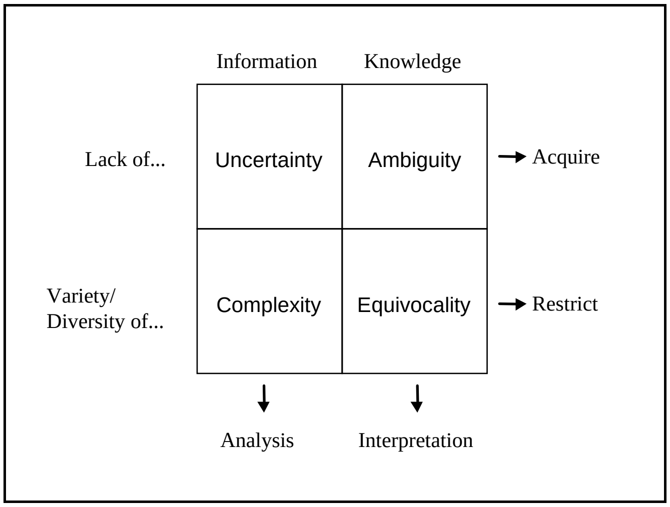
Complexity is simply "a large number of parts that interact in a nonsimple way" (Simon 1969, p. 195). It reflects the ability (or lack thereof) to simultaneously consider the numerosity and diversity of a set of well-defined situational elements (variables, issues, competitors, etc.) and the intricacy of their relationship (Simon 1969, Weaver 1948). Knowledge provides an ability to process greater complexity by allowing an issue to be regarded as a familiar whole rather than dealing with each of its individual parts (Huber 1984, Miller 1956, Nelson and Winter 1982, Pentland and Reuter 1994, Schank 1990, Stabell 1978). Therefore, organizations facing complexity must develop the capability to locate, develop and bring appropriate knowledge, expertise, and skills to bear on those issues, or to restructure their problems, roles and routines to render them more familiar.

Uncertainty represents a lack of information, or factual "knowledge about" a set of current and future states, preferences and appropriate actions (Garner 1962, Kaheneman and Tversky 1982, March 1977, Raiffa 1968, Shannon 1949). Uncertainty is tolerated by predicting, inferring, estimating, or assuming values for missing information with some level of confidence and reliability based on existing contextual knowledge (Bruner 1973); utilizing resource and information buffers (Galbraith 1973, Wildavsky 1983); or developing an ability to respond quickly and flexibly to unanticipated events (Galbraith 1973, March and Simon 1958, Thompson 1967). Uncertainty can be reduced by acquiring additional factual knowledge about something or by acquiring or developing through experience and learning contextual knowledge to improve ability to predict. To manage uncertainty, then, organizations must develop the intellectual resources and capabilities to infer, estimate, predict, and learn. They must develop the structural capabilities, especially their communication networks, to flexibly respond and adapt to the unexpected. They must develop their organizational and technical capabilities to locate, refine, store, and communicate factual knowledge.

Ambiguity represents an inability to interpret something (Machlup 1980, MacKay 1969, Weick 1969). *Surface* ambiguity represents having interpretive knowledge but either not being able to retrieve it, or activation of an inappropriate interpretation, usually because of insufficient informational cues. *Deep* ambiguity represents a complete lack of interpretive knowledge. Events are perceived as so new and unfamiliar that one cannot even make a vague guess about what is important or about what may happen (Brunnson 1985, Weick 1993). Ambiguity is resoved by reframing a situation to something meaningful, by acquiring or developing contextual or explanatory knowledge, or by having an interpretation imposed by others. Surface ambiguity may require only a small amount of additional factual information to retrieve the appropriate contextual knowledge. Resolving deep ambiguity typically requires iterative cycles of interpretation via face-to-face conversation to develop explanation, providing a meaningful context for action (Schank 1987, Weick 1969).

Equivocality refers to multiple interpretations of the same thing (Aristotle 350BC, Daft and Macintosh 1981, Machlup 1980, Weick 1969). Equivocality requires cycles of interpretation, discussion, and negotiation using rich communication channels such as face-to-face conversation to converge on a definition of reality (McCaskey 1982, Mintzberg, Raisinghani and Theoret 1976, Weick 1969).

These four knowledge problems can be distinguished by the nature of the knowledge being processed, and whether the requirement is to acquire more knowledge or to place restrictions on what exists (see the figure). The first distinction is that of processing factual "knowledge-about," which is more akin to the notion of information, vs. the richer, more complex knowledge structures that support interpreting that information and building inferences and explanations about how and why things work (Kogut and Zander 1992). Information processing is associated with managing uncertain and complex situations within some agreed-on and meaningful knowledge context, and is amenable to analysis, manipulation and communication of facts. Processing knowledge is associated with resolving or managing ambiguous and equivocal situations, requiring interpreting, creating, sharing, and negotiating meaning.



The four problems may also be distinguished by the notion of restrictive vs. acquisitive processing. Complexity and equivocality require restrictive processing to limit, impose, or enact structure and meaning, the first on factual information and the second on diverse viewpoints or interpretations. Uncertainty requires the acquisition (or generation by inference) of factual information, while ambiguity requires the acquisition of knowledge or interpretive frames. Thus restrictive processing is generally internally focused (work with or make sense of what information and knowledge you already have), while acquisitive processing requires external search for more information or knowledge.

The four knowledge problems can be ordered by ability to interpret or define a situation, event or process. The most "wicked" of the problems is ambiguity, having no framework or means to interpret or define something. Equivocality, representing multiple interpretive frames and definitions, is slightly less wicked. Each, however, similarly involves managing and processing knowledge. More tractable is the case of uncertainty, where one unique interpretation has been defined, although instantiated only within some degree of confidence or predictability. Finally, even a single interpretation defined with certainty may still require considering many elements and linkages, fostering complexity. Ultimately, pure simplicity represents one well-defined and certain definition that is familiar enough to chunk as a small number of elements. These states are not mutually exclusive. For example, once an ambiguous situation has been interpreted, it may reveal itself also to be uncertain, complex or both. However, based on extensive field observations, the four problems do exhibit a patterned sequence. Meaning must be established and sufficiently negotiated prior to acting on uncertainty and complexity. Ambiguity must be resolved first, often leading to equivocality as multiple interpretations emerge. Resolving equivocality creates a shared context for dealing with uncertainty or complexity, and ongoing systematic learning.

The Role of Information Technology

This framework can be used to identify areas where the technology may make its most useful contribution. The key distinction is between those problems oriented towards factual information - complexity and uncertainty - and those oriented towards richer knowledge - ambiguity and equivocality.

The capability to convey the ambiguity of some observed reality depends on the richness and variety of the language being used. Rich, expressive languages enable communicating ambiguity better than precise languages (Daft and Wiginton 1979). Similarly, highly equivocal situations require face-to-face communication for their resolution or negotiation, while well-defined situations can rely on leaner, more structured modes of communication. Precise media might prematurely impose false clarity on communication about equivocal or ambiguous events (Daft and Lengel 1986). Overly rich communication, on the other hand, may create ambiguity or equivocality where none previously existed (McCaskey 1982), therefore matching the richness and interactivity of the communication medium to the requirements at hand is important to effective communication (Zack 1993).

Information technology, then, can be used effectively in situations where the information is more factual, where a high degree of rich interaction is not required, or where the communicators share an interpretive context (Zack 1993), that is for managing uncertainty and complexity. This typically takes the form of decision support systems and expert systems able to process large numbers of facts, variables and relationships; database management systems having large-capacity information storage, retrieval and manipulation capabilities; shared document-centric repositories containing, for example, best-practices; or computer-mediated communication systems that support rapid and flexible information search, routing and communication patterns. Ambiguity and equivocality are best managed by frequent face-to-face communication, and relying on a flexible and responsive network of personal contacts to serve as a source of information, knowledge, and expertise.

While information technology is less applicable to dealing with ambiguity and equivocality, it still may provide value. As multimedia technologies expand the art of the possible regarding richness and interactivity, these technologies may become applicable to moderately ambiguous or equivocal situations. However, they still fall short of face-to-face interaction today. For example, desktop videoconferencing is emerging as a potential complement to face-to-face conversation, although the speed and quality of transmission is not yet sufficient to replicate that level of richness and interactivity. Information technology can also help to locate others with which one might need to hold a conversation. It can be used to catalog the experience and expertise of organizational members, enabling easier search for knowledge when needing assistance in making sense of something. It also enables individuals to coordinate the logistics of face-to-face meetings. Computer-mediated communication can help to maintain continuity and connection between conversations, especially for those who are not closely located.

Regardless of how information technology is applied to resolving ambiguity and equivocality, organizations must provide ample opportunity for conversation, personal interaction and shared experience to allow deep knowledge to be exchanged and developed (Brown and Duguid 1991, Lave and Wenger 1991, Nonaka 1994). The knowledge and assumptions, including labels, procedures, causalities, and relationships, typically embedded into particular applications of information technology often impose false or erroneous clarity on ambiguous or equivocal situations, creating problems at a later time.

Conclusion

I have identified four knowledge problems:

- *Complexity*: Too many situational elements and relationships to coordinate or consider simultaneously.
- *Uncertainty:* Not enough reliable, factual knowledge (information) about the goal, situation or task, and some lack of confidence in the resulting inferences or estimates required.
- *Ambiguity*: Inadequate knowledge about, explanation for, or understanding of the goal, situation or task.
- *Equivocality*: Multiple interpretations of the goal, situation or task.

Organizations that consider their environment complex but predictable typically organize hierarchically and attempt to collect and distribute specific expertise to where needed as problems arise. Managing complexity has been the underlying issue addressed by most current knowledge management initiatives, typically with repositories of explicated knowledge maintained by technologies such as Lotus Notes, the Web or expert systems.

Uncertainty, requiring the ability to dynamically move information to where needed when needed in unanticipated ways, places a huge strain on the capacity of a hierarchical organization designed for managing complexity. Hierarchy assumes that the cross-unit communication load will not be great. However, even companies adopting organic forms to better deal with uncertain environments, still assume that the world is known and that it is known consistently and coherently across the organization. The problem is only to get enough information about the world to describe it today or predict its state tomorrow. Given enough information about the actual behavior of our products, customers, channels, and competitors, we can determine how to best supply and dominate the market. This assumption underlies the shift from "make-and-sell" to "sense-and-respond" models of information management (Heackel 1995, Haeckel and Nolan 1993) as well as quick response, continuous replenishment, agile manufacturing and other approaches to supply chain management. It has also driven the information technology industry of late in the form of, for example, customer support systems, electronic commerce, data warehouses, and data mining technologies.

Both sense-and-respond and make-and-sell approaches suffer from assuming a known or knowable world. For example, mining customer feedback information requires knowing what questions to ask, how to interpret and share the results, and what actions to take. Doing this well requires the ability to learn over time and to share that learning with others in the organization. Learning and sharing, when the assumption is that the world is neither clearly known nor knowledge easily communicated, requires new approaches and organizational forms that encourage rich interaction among those who need to create, share and integrate knowledge rather than information (Brown and Duguid 1991, Quinn, Andersen and Finkelstein 1996).

Organizations have begun to move from managing based on what they think they know, to discovering what they actually know. What will be more difficult is accepting that there are things they don't know and acting accordingly. The challenges of complexity and uncertainty have not gone away. However, in today's dynamic competitive environment, they have been augmented by equivocality and ambiguity. The truly knowledge-based firm must maintain the capability to handle the entire scope of knowledge problems defined here.

References

References are available upon request from the author.