Organizational Knowledge Acquisition

Brian R. Gaines
Knowledge Science Institute
University of Calgary
Calgary, AB, Canada T2N 1N4

This article develops a model of organizational knowledge acquisition in terms of modern psychological, sociological, economic and management theories by deconstructing the terms involved: an *organization* as a collective agent having goals and capabilities to achieve them; *knowledge* as the hidden state variables imputed to an agent as the basis of its capabilities; and *acquisition* as the reproduction of dispositions. This form of model enables one to relate the knowledge processes involved to existing models of organizational processes, and to understand such phenomena as knowledge economics and knowledge management. The breadth of the notion of organization encompasses markets, firms and societies; the operational definition of knowledge clarifies its role and the utility of the notion; and the focus on reproduction of dispositions in knowledge acquisition enables the management of knowledge acquisition to be analyzed.

---

1. Introduction

The phrase, *organizational knowledge acquisition*, is deceptively simple if interpreted colloquially. We probably all believe that organizations acquire knowledge, and would be quite happy to explain or speculate about how they do so. However, if we attempt to do this in a professional context and to sustain our position through well-structured arguments we encounter many problems.

The notion of *organization* is a loose one that encompasses firms, markets, hierarchies, networks, territories and their infrastructure, governments, societies, and many other forms of collectivity and infrastructure. The notion of an *organization in general* needs careful delineation (Scott 1992; Thompson 1967), and it is not clear that there is meaning to the phrase *knowledge acquisition in organizations in general.*

The notion of *knowledge* is at least as problematic, another compendium term denoting a natural kind defined by our usage and not subject to precise definition (Gadamer 1972; Goodman and Fisher 1995). The recognition of knowledge as critical in distinguishing rational arguments from emotional ones was a major innovation of the Athenian enlightenment (Solmsen 1975). Havelock (1963) has argued that knowledge as an abstraction became possible through the transition from an oral to a literary culture, and Sullivan (1997; 1999; 2000) has traced the developing use of terms relating to human thought processes such as *phren*, *nous* and *psyche*, in the early Greek literature of Aeschylus, Sophocles and Euripides. Plato has Socrates ask *What is knowledge?* in *Theaetetus* (Plato and Cornford 1935) and note that *Herein lies the difficulty which I can never solve to my satisfaction* Developing an answer to this question was a major topic for philosophers in the seventeenth century enlightenment. In particular, Bacon's (1960) answer that knowledge must be based on empirical observation was major feature of the ideology inspiring the scientific revolution.

The notion of *acquisition* is normally easier to define in terms of the transfer of property rights (Alchian 1977; Barzel 1997), but not so easy when the property being acquired is as ill-defined as knowledge and the acquirer as ill-defined as an organization. As research in knowledge acquisition has developed it has been recognized that knowledge is not readily transferable both because it exhibits *stickiness* (Hippel 1994) at its source and and also because there is a need for *absorptive capacity* (Cohen and Levinthal 1990) in its intended recipient.

Thus, modeling knowledge acquisition by an organization presents some conceptual and terminological problems, and it is important to have operational definitions of the notions involved. However, it is also important not to define away the rich complexity of knowledge acquisition phenomena in the real world, and hence the next section will present the results of an empirical study of how managers approach knowledge acquisition in practice.

2. Mapping Concepts of Organizational Knowledge Acquisition

Managers involved in an ongoing project on knowledge modeling of manufacturing processes in small companies were asked to take a day away from the primary project and focus instead on the routine acquisition of knowledge that took place in their normal businesses. How did their organizations acquire knowledge? Seven of us brainstormed to develop a scenario in which key people might be leaving, new requirements were arising, new processes and materials had become available, and so on, and asked how the new knowledge necessary to cope with these changes would normally be acquired. Most of the possibilities had immediate referents in the experience of members of the group, including recollections of the most valuable sources of relevant knowledge.

The tool used to collect and organize the data, *KMap*, is a scriptable, multi-user concept mapping system (Gaines and Shaw 1995b) that we had previously used to model various manufacturing processes (Gaines and Shaw 1994b). For this application it was scripted to provide the supportive environment recommended by the Arizona University team (Nunamaker, Dennis, Valacich, Vogel and George 1991) in which possible topics can be proposed anonymously by several people simultaneously, freely discussed by the group, and accepted on a consensual basis or edited/put-on-hold if such acceptance proves difficult (Gallupe and Cooper 1993). Each user, or group, interacted with a large, central, shared screen through a local workstation that allows the user or group to develop and assess their ideas before posting them to the entire community. Figure 1 shows the central, shared screen listing the knowledge acquisition activities that had been elicited towards the end of the session. We discussed and refined them, editing the text where it was awkward or ambiguous, eventually reaching a consensus represented by Figure 1.

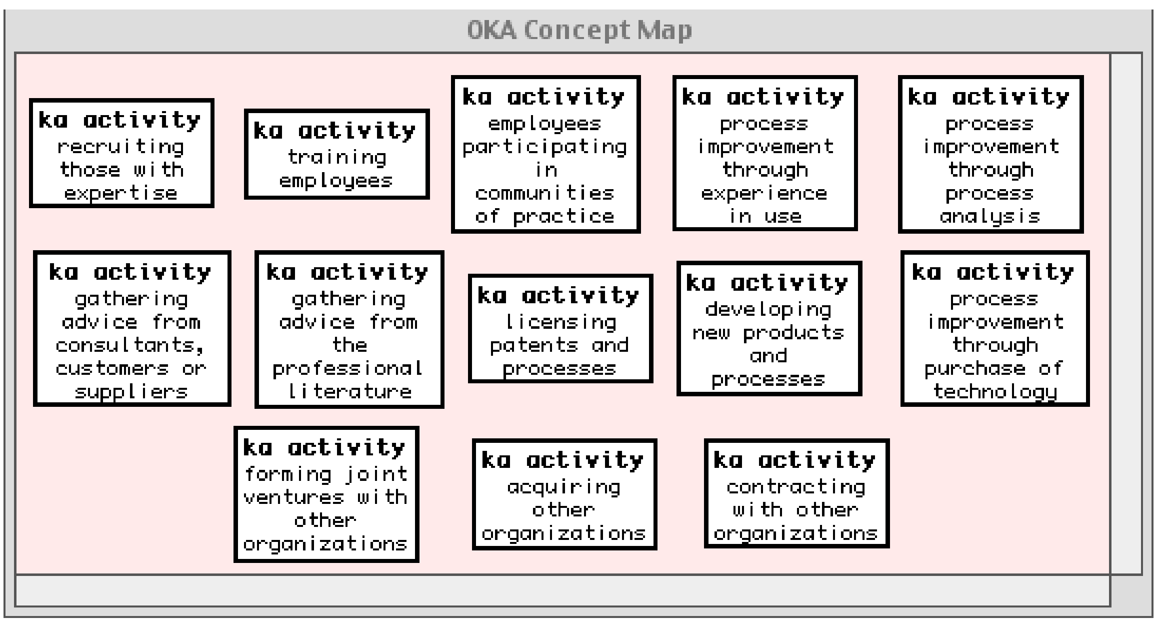

Figure 1 KMap showing consensus reached on routine knowledge acquisition activities

As usual there was a debate about the comprehensiveness of the list—did all our new knowledge come routinely through one of the routes shown? However, it was eventually agreed that the list covered most practical possibilities that we could exemplify, and that it would not be problematic to add to it later if appropriate. Experience in using the knowledge acquisition tools for knowledge modeling had left everyone comfortable with the notion that all knowledge is *provisional*—what had been elicited could be changed and edited. It was interesting to note how many of the knowledge acquisition activities involved human resources—knowledge management is as much a matter of people as of technology.

We now had a reasonably comprehensive list of knowledge acquisition activities that the organization used routinely in its operation, and wanted to model these in terms of their properties, similarities and differences. The tool we had used to model manufacturing processes in these terms was *WebGrid* (Gaines and Shaw 1997), an implementation of Kelly's (1955) *repertory grid* technique for eliciting the critical dimensions along which a related set of elements may be characterized. Kelly called these dimensions the *constructs* that enabled us to characterize the similarities and differences between the elements. He emphasized that these dimensions were not necessarily 'objective' features, but would often be idiosyncratic to individuals or communities, representing the cultural frameworks in which they operated.

From the early years of personal construct psychology, techniques have been developed to support the elicitation of the construct systems being used by individuals or groups and, since the 1970's, many of these have been embodied in interactive computer programs that elicit the elements and constructs, and represent logically and graphically the relations between them (Shaw 1980). WebGrid is the latest in a series of such programs (Mancuso and Shaw 1988). It operates through the World Wide Web to support distributed communities in collaborative knowledge acquisition activities. It had the advantage that our managers were already familiar with it in application to modeling their business processes, and had no difficulty transferring their experience to a different domain. Seven constructs were elicited from the group: *internal—external; same size—expand; process improvement—process development; coded—tacit; active—passive; transmitted—experiential;* and *technology—people*.

Figure 2 shows the *Map* facility in WebGrid used to perform a principal components analysis of the grid developed and plot it in two dimensions to show the relationships between the elements, in this case the knowledge acquisition activities of Figure 1, and the constructs or dimensions distinguishing them.

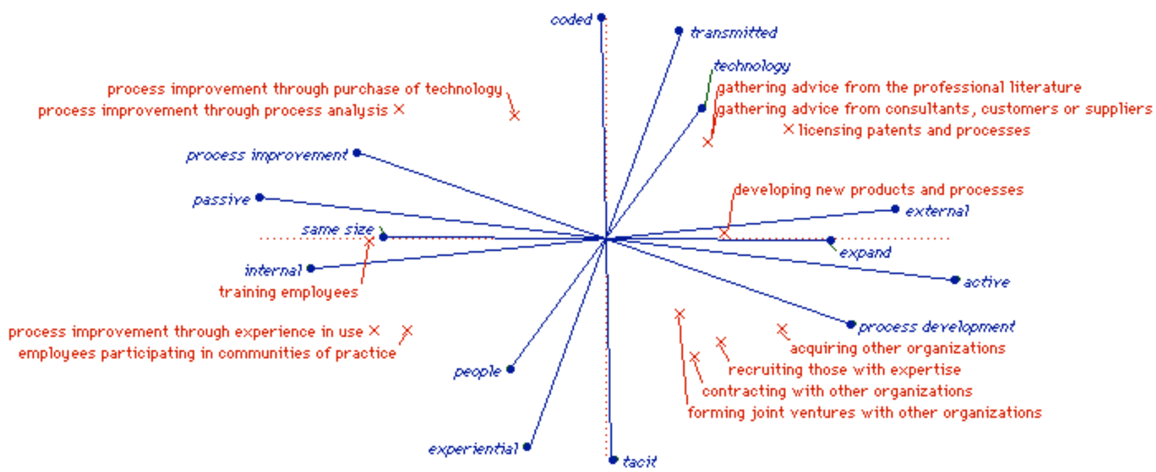

Figure 2 Map of repertory grid of constructs distinguishing knowledge acquisition activities

Two major constellations of dimensions are apparent in Figure 2: a horizontal one characterized by process improvement, passive knowledge acquisition, internal processes and keeping the organization the same size at one end and by process development, active knowledge acquisition, expanding the organization and external processes at the other; and a vertical one characterized by people, experiential knowledge acquisition and tacit knowledge at one end and by technology, transmitted knowledge acquisition and overt knowledge at the other.

3. Deconstructing Organizational Knowledge Acquisition

As noted in Section 1, the notion of knowledge has been subject to analysis since the fifth century B.C., and that analysis has had substantial impact on progress in science and technology. Beninger (1986) has documented the growth in industry since the industrial revolution that necessitated what he terms the *control revolution* leading to an *information society*, and Chandler (1977) has noted how it also lead to a *managerial revolution* imposing a *visible hand* on industry. Drucker (1993) has characterized the managerial revolution as one in which knowledge is being *applied to itself*, and this has stimulated developments in *scientific management* and *knowledge-based* or *expert systems*, and a focus on *knowledge management*.

3.1 Knowledge and capabilities

Recognition of the role of knowledge in the managerial revolution has drawn attention to the need to understand the nature of knowledge and knowledge processes in society with an emphasis on a pragmatic stance reminiscent of Peirce, James, Dewey, *et al*, that characterizes knowledge in terms of its *utility*. For example, in the artificial intelligence literature, Newell (1982) has analyzed what he terms the *knowledge level* and has situated knowledge in the epistemological processes of an observer attempting to model the behavior of another agent:

> *The observer treats the agent as a system at the knowledge level, i.e. ascribes knowledge and goals to it.*

emphasizing that:

> *The knowledge level permits predicting and understanding behavior without having an operational model of the processing that is actually being done by the agent.*

He defines knowledge as:

> *Whatever can be ascribed to an agent such that its behavior can be computed according to the principle of rationality.*

noting that:

> *Knowledge is that which makes the principle of rationality work as a law of behavior.*

and defining rationality in terms of the principle that:

> *If an agent has knowledge that one of its actions will lead to one of its goals, then the agent will select that action.*

That is, for Newell, knowledge is ascribed to an agent to explain its capabilities, and there is no knowledge without capabilities. However, note that knowledge as defined above need not be *communicable*. It can be *tacit* (Polanyi 1958) and not encoded as information that can be transmitted to another agent. Also note that Newell's definition applies equally whether the *agent* is an individual or an organization—indeed, it suggests a *collective stance* (Gaines 1994a) in which organizations are modeled as compound individuals.

Newell's definition has been formalized, in the educational literature by Doignon and Falmagne (1999) who provide a set-theoretic model of *knowledge space* for a given topic and procedures to determine a student's position in the space, and in the artificial intelligence literature by Gaines (1997) who shows that the natural axioms of knowledge space define a *system of logic*. He also shows that knowledge/capabilities acquisition may be expedited by a process that increases the difficulty of a task as the performance of the learner improves and requires no other knowledge of the learner's processes or the knowledge necessary to perform the task.

Newell's analysis of the knowledge level is important in providing a close link between knowledge and capabilities and demonstrating that knowledge management is a matter of *capabilities management*. Ultimately, the objective of knowledge acquisition is capabilities acquisition (Sanchez and Heene 1997). Bacon emphasized this aspect of knowledge also in his famous aphorism:

> *Human knowledge and human power meet in one; for where the cause is not known the effect cannot be produced. Nature to be commanded must be obeyed; and that which in contemplation is as the cause is in operation as the rule. (Bacon 1960)*

Similarly, Penrose (1959) in her analysis of the growth of the firm modeled it as a *bundle of resources* but emphasized that:-

> *Strictly speaking, it is never resources themselves that are the 'inputs' in the production process, but only the services that the resources can render.*

3.2 Classification of capabilities

There is a natural dependency structure among capabilities, that possessing one capability, or a combination of capabilities, normally entails possessing another. There are also differences in the value of various capabilities to an organization. Pralahad and Hamel (1990) have analyzed capabilities in terms of their roles in securing competitive advantage, and distinguished *core capabilities* as those which both give competitive advantage and are also difficult to acquire. Leonard-Barton (1995) has extended the classification:-

> *Supplemental capabilities are those that add value to core capabilities but could be imitated…Enabling capabilities are necessary but not sufficient in themselves to competitively distinguish a company*

It is tempting to extend this classification to the knowledge underlying the capabilities but this would be misleading since there is not a one-to-one relationship between knowledge and capabilities—usually, many different sets of knowledge can lead to the same capability.

There are a number of critical constructs that apply to knowledge and capabilities. The two which underlie the Pralahad/Hamel and Leonard-Barton analysis are: *easy to acquire—difficult to acquire*; *provides competitive advantage—does not provide competitive advantage*. Note that these are properties relative to an organization—what is easy to acquire for one organization may be difficult for another, and what provides competitive advantage for one may not for another, even in the same market sector.

Other critical constructs are: *abstract—concrete* capturing generality; *direct—meta* capturing level of operation; *individual—organizational* capturing location; *widely diffused—narrowly diffused* capturing accessibility; *tacit—coded* capturing communicability; *passive—active* capturing utility. Boisot (1995) has analyzed such constructs in depth, characterizing *information space* and modeling *knowledge assets* (1998) in terms of them.

Figure 3 uses a cross-plot of the *tacit—coded* and *passive—active* dimensions corresponding to the principal axes in Figure 2 in order to highlight important aspects of knowledge acquisition. Passive knowledge that is acquired but not used is *data* that just represents *experience* if it is tacit but becomes *information* if it is coded. Active knowledge that is used as a problem-solving capability supports a *skill* if it is tacit but becomes *know-how* (Kogut and Zander 1992) if it is coded.

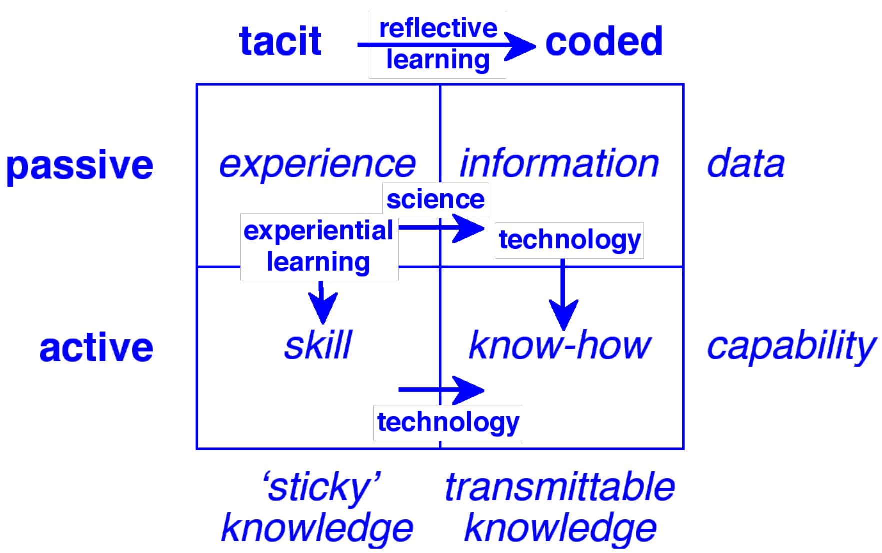

Figure 3 Constructs of knowledge

Bacon's prescription for science based on observation corresponds to reflective learning from experience to information. His 'knowledge is power' aphorism corresponds to the transition from information to know-how. This transition and that from skill to know-how underlie the development of *technology* and of human *technical culture* (Hall 1959). The latter transition is that emphasized by Nonaka and Takeuchi (1995) as underlying the *knowledge-creating company*, by Hall (1959) as underlying success in training civilian clerks in technical skills in World War II and by Gibbons et al (1994) as being a *Mode 2* method of knowledge acquisition underlying the *new production of knowledge*.

3.3 Expert systems technology—automating declarative-procedural transformation

Advances in knowledge representation tools supporting the transition from information to know-how and acquisition tools and techniques supporting the transition from tacit knowledge to coded knowledge triggered off a boom in industrial interest in *expert systems* in the 1980s:-

> *For the past 15 years, applied work in artificial intelligence has focused increasingly on the use of knowledge to build 'expert systems.' These systems achieve levels of performance in complex tasks that equal or even exceed that of human experts. Because they incorporate much human knowledge, these*

systems are called knowledge-based expert systems or, simply, knowledge systems…The industrialization of knowledge engineering began in 1981 with the formation of two commercial spin-offs from the Stanford university Heuristic Programming Project…Teknowledge focuses on industrial and commercial uses of knowledge engineering. Sales this year will be $3 million to $6 million. Hayes-Roth (1984)

Hayes-Roth also characterized situations that instigate knowledge engineering initiatives:-

1 *The organization requires more skilled people than it can recruit or retain.*
2 *Problems arise that require almost innumerable possibilities to be considered.*
3 *Job excellence requires a scope of knowledge exceeding reasonable demands on human training and continuing education.*
4 *Problem solving requires several people because no single person has the needed expertise.*
5 *The company's inability to apply its existing knowledge effectively now causes management to work around basic problems.*

The industrial application of expert systems has not has as much impact as first hoped, but many successes have been reported—for example, the April and July 2000 issues of *InTech Magazine* published by the Instrumentation, Systems and Automation Society, has a paper from Eli Lilly on the deployment in its fermentation plant of an expert system programmed in Gensym's G2:-

Within a few weeks, Phil was satisfied that the expert system reliably came to the same conclusions he would have by looking at the same data (i.e., the system did what it was purported to do, which was an application and validation objective). The expert system then took over this part of Phil's job, freeing up 40 hours per month of his time for other work. Of course, whenever G2 detected a problem fermentor, or one it was unsure of, Phil, or an assistant, would be immediately paged. This application became affectionately known as "Phil in a box." Phil retired from Lilly in 1993 when the company offered an early retirement program. In fact, many of the experienced fermentation personnel at this plant, as well as several at other Lilly plants, also retired. (Alford, Cairney, Higgs, Honsowetz, Huynh, Jines, Keates and Skelton 2000)

The importance of such projects is that the knowledge of a human expert has been successfully encoded as information in a declarative structure of *production rules* that automatically reproduced the human expertise when interpreted by the G2 expert system shell.

The commercial potential of expert systems technology was over-stated in the 1980s (Feigenbaum, McCorduck and Nii 1988) and they are not fashionable currently and do not have a significant role in the knowledge management literature. Figure 4 characterizes the growth of the literature in artificial intelligence (AI), expert systems (ES), knowledge acquisition (KA) and knowledge management (KM) through 2001 by plotting the number of books in the library catalog of a world-class university with strong AI and KM research areas.

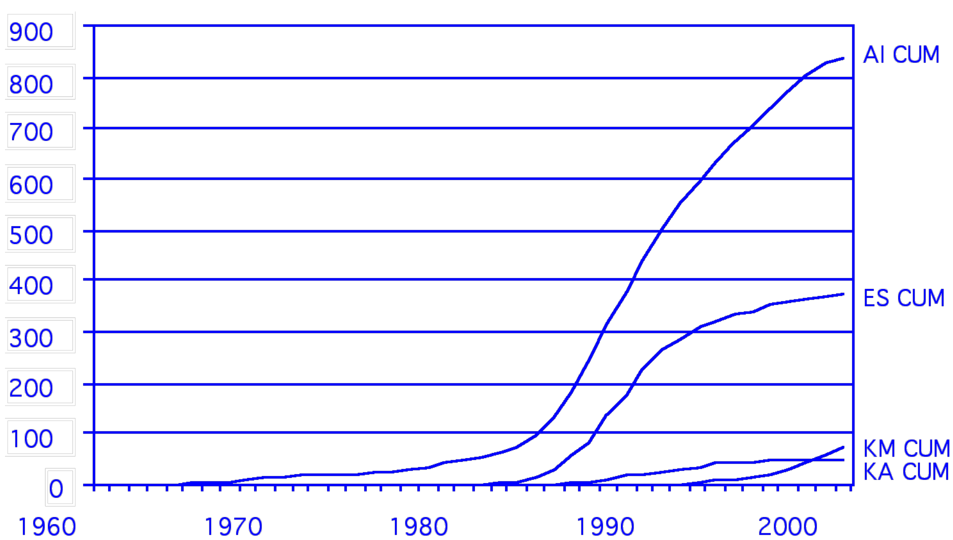

Figure 4 Growth in number of AI, ES, KA and KM books held in a library

The number of books with *expert system(s)* in the title shows a standard sigmoidal learning curve (Crane 1972), with the peak growth during the 1986 to 1992 period and publication waning thereafter. The number of books with *artificial intelligence* in the title is still growing and it is difficult to characterize accurately the peak growth period but the data so far is consistent with that being from 1986 through to 1998. The number of books with *knowledge acquisition* in the title follows the same pattern as for 'expert systems' and that for *knowledge management* appears to be at an early stage of take off, much as was artificial intelligence in the early 1980s.

Expert system concepts and technology are appearing in organizations in other guises. *Neuron Data*, one of the most innovative and successful of the original expert system companies, was taken over and now trades as *Blaze Software* (http://www.blazesoft.com/). It supports the *business rules* layer in the IBM/Microsoft multi-layer client server enterprise model through use of the powerful knowledge modeling tools that were developed for Neuron Data's expert system shell, *NEXPERT*. Seiler (1999), the founder of *Rule Machines Corporation*, shows the role of business rules within an enterprise architecture (Figure 5) and emphasizes that they are not *expert systems* or *database triggers* but rather a way in which end-user management can specify activities in terms of what he terms *business speak*. Kremer (1991) has shown how the procedures manual of a major oil company translates naturally into a system of rules and exceptions.

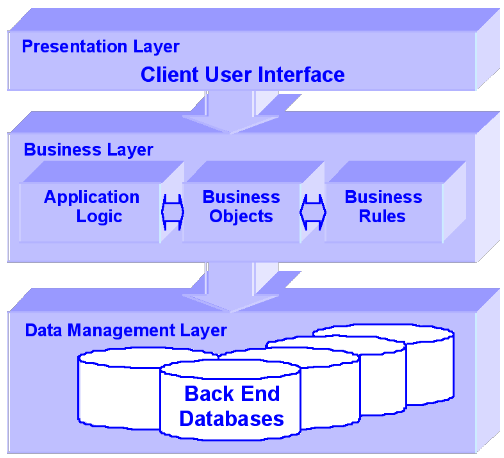

Figure 5 Business rules within n-tier application architecture (Seiler 1999)

3.4 E-learning

It is the *automation of human intelligence* that has proved slower to develop than predicted, and that part of the objectives of artificial intelligence research concerned with making knowledge overt as coded information remains of fundamental importance in knowledge management. It has always been the prime objective of science and technology, and if, in the short and medium term, computers cannot make the knowledge active and use it to solve problems then there is still the possibility that human learners, people and organizations, can use the more overt expression of knowledge do so.

Hayes-Roth's list of applications in the previous section overlaps with those of knowledge management initiatives, and much of what has been learned and developed in knowledge acquisition studies for both education and expert systems is relevant to knowledge management. For example, he emphasizes the role of expert systems *when an organization requires more skilled people than it can recruit or retain*, and a standard corporate approach to such labor shortages is through *training*. *E-learning*, on-line computer-based education and training, has developed extensively during the same period as expert systems and there is now a major industry supporting *corporate universities* (Meister 1998), and providing *on-the-job training* and *just-in-time learning* (Wills 1998). For example, the Learn4life division of SAIC, a $10B/year company, provides modules targeted on the full range of emergency services, law enforcement, fire service and search and rescue (http://www.Train4life.com/), and Motorola University offers courses in a wide range of core skills areas where recruitment is problematic such as software engineering (http://mu.motorola.com/).

There is much to be learned from the education and training literature that is relevant to organizational knowledge acquisition and knowledge management. For example, the analysis of *educational objectives* (Hauenstein 1998) that is used to structure e-learning provides taxonomies that may also be used to characterize organizational knowledge. Metfessel, Michael, and Kirsner (1969) provide tables that allow well-formed objectives to be generated in different domains through a 'buzz-word' process that is simple to implement with a computer and use to generate required organizational capabilities in statements of knowledge management objectives.

4. The Nature of Human Expertise

One outcome of the research effort directed at knowledge acquisition for expert systems has been to develop cognitive models of people and organizations based on empirical data and the application of psycho-social theory. In the early days of artificial intelligence, Dreyfus (1972) argued that human intelligent behavior could not be reproduced by information in a computer, and Dreyfus & Dreyfus (1986) have argued that

> *logic machines will always be inferior to people—whether teachers, managers, physicians, or professionals of any kind—as sources of insight, reflection, and real-world expertise.*

Their arguments against the possibility of artificial intelligence are based on Wittgenstein's (1953) analysis that suggests that the notion of human behavior *following a rule* is paradoxical:-

> *This was our paradox: no course of action could be determined by a rule, because every course of action could be made to accord with the rule…'obeying a rule' is a practice…If I have exhausted the justifications I have reached bedrock, and my spade is turned. Then I am inclined to say: "This is simply what I do." (Wittgenstein 1953)*

However, Kelly's (1955) *personal construct psychology* provides a constructivist model of *anticipation*, prediction and action, in human experience in which rules are *supervenient* on the process of construing experience, and there is no explicit representation or use of rules in human expertise. Wittgenstein's statement above is correct in personal construct psychology because the agent is not *obeying a rule* but rather making a choice based on past experience, usually attempting to maximize the probability of correct anticipation but, possibly, doing something entirely different (such as win an argument or confound an observer). Continuing construction of experience will change the apparent *rules and procedures* being followed without those rules and procedures having actuality or being subject to reflection; much as modeled by the *evolutionary theory* of economic systems of Nelson and Winter (1982) and the *behavioral theory of the firm* of Cyert and March (1963).

Personal construct psychology has been cited in the knowledge management literature by Loasby (1999) and Lant & Mezias (1996), and in the sociological literature by Luhman (1995) who notes:-

> *Everything that can be imagined is possible in reference to something else, and only thus can information be acquired and processed. A psychological theory adequate to this has been worked out by George A. Kelly. (1995)*

It has also been used to model knowledge acquisition and inference processes, and to develop tools to elicit knowledge and model it in operational form through *ontologies* represented in *semantic networks* (Gaines and Shaw 1993a).

It is salutary to examine the quality of judgement of experts and wonder whether it is as good as the attempts to emulate it through *expert systems* suggests. In a survey of studies of the accuracy of human subjective probability judgements, Tversky and Koehler conclude:

> *The evidence reported here and elsewhere indicates that both qualitative and quantitative assessments of uncertainty are not carried out in a logically coherent fashion, and one might be tempted to conclude that they should not be carried out at all. However, this is not a viable option because, in general, there are no alternative procedures for assessing uncertainty. (Tversky and Koehler 1994)*

In the domain of expertise in scientific research, Feyerabend (1975) has argued that there is no evidence of a rational methodology, and Fortun and Bernstein (1998) have provided a compelling account of scientific progress as *muddling through*. In *Voltaire's Bastards*, Saul argues:

> *Among the illusions which have invested our civilization is an absolute belief that the solution to our problems must be a more determined application of rationally structured expertise. The reality is that our problems are largely the product of that application. (Saul 1993)*

Gadamer has cast doubt upon the role of knowledge in expertise:

The nature of experience is conceived in terms of that which goes beyond it; for experience can never be science. It is in absolute antithesis to knowledge and to that kind of instruction that follows from general or theoretical knowledge. The truth of experience always contains an orientation towards new experience. That is why a person who is called 'expert' has become such not only through experiences, but is also open to new experiences. The perfection of his experience, the perfect form of what we call 'expert', does not consist in the fact that someone already knows everything and knows better than anyone else. Rather, the expert person proves to be, on the contrary, someone who is radically undogmatic; who, because of the many experiences he has had and the knowledge he draws from them is particularly equipped to have new experiences and learn from them. (Gadamer 1972)

and, in the artificial intelligence literature, Clancey has criticized approaches to expert system development based the assumption that expertise can be captured in overt knowledge, and comes to similar conclusions:

The new perspective, often called situated cognition*, claims that all processes of behaving, including speech, problem-solving, and physical skills, are generated on the spot, not by mechanical application of scripts or rules previously stored in the brain. Knowledge can be represented, but it cannot be exhaustively inventoried by statements of belief or scripts for behaving. Knowledge is a capacity to behave adaptively within an environment; it cannot be reduced to representations of behavior or the environment. (Clancey 1989)*

Bourdieu, the French philosopher and sociologist, has generated a major literature on human psychology, culture and sociology, that stemmed from consideration of Wittgenstein's discussion of the status of rules of human behavior:

I can say that all my thinking started from this point: how can behaviour be regulated without being the product of obedience to rules? (Bourdieu 1990)

Bourdieu's answer to this question is a constructivist one, that all human behavior is *generated* within a rich *background* (to use Searle's (1992) terminology) that is implicit and not consciously represented, and is constituted through acculturation processes that internalize the historic development of a particular society or institution.

Bourdieu builds on the previous analyses of Aristotle, Hegel, Nietzsche, Husserl, Schutz, Wiggenstein, Heidegger and Merleau-Ponty, to provide a very detailed analysis of socially-embedded human behavior in terms of three major constructs: *habitus* which is a system of *dispositions* extending Aristotle's (2000) analysis of *hexis*; *field* which is a network of influences and power relations extending Lewin's (1936) analysis of behavior within a social field; and *symbolic capital* abstracting and generalizing Marx's (1973) analysis of capital formation and Weber's (1968) extension of it to cultural domains. Bourdieu's output in books and papers is prolific, ranging from detailed ethnographic and statistical studies through sociological models of a wide range of institutions to deep theoretical analyses; a good starting point is the interviews and essay in Bourdieu (1990).

Bourdieu's model of *habitus* is particularly important to the modeling of human expertise:

I am talking about dispositions acquired through experience, thus variable from place to place and time to time. This 'feel for the game', as we call it, is what enables an infinite number of 'moves' to be made, adapted to the infinite number of possible situations which no rule, however complex, can foresee. Action guided by a 'feel for the game' has all the appearances of the rational action that an impartial observer, endowed with all the necessary information and capable of mastering it rationally, would deduce. And yet it is not based on reason. (Bourdieu 1990)

5. The Dynamics of Expertise Formation

How is it that imperfect human capabilities are construed as expertise and that muddling through is effective? One answer is that human expertise arises in the context of human action as a pragmatic process of dealing with present contingencies knowing that there will be further opportunities to deal with the consequences of our actions at a later stage. The decision to treat a customer in a certain way is an *experiment* that entails monitoring the consequences with a view to planning future interaction. Human action takes place in a control loop with imperfect information at each decision point, and with the unfolding process continually changing the state of play.

In many situations it is more important to act in a way that is not wildly wrong rather than to compute the optimum action, particularly when available information is inadequate, inaccurate, expensive to obtain, and so on. It is generally important to know who has the authority to act and who is accountable for monitoring the consequences, taking follow-up action, and so on. The giving, or taking, of the authority to be in control in a particular domain demarcates the abstract role of an *expert* in that domain relative to the social norms of the institution that accepts ownership of the domain.

A simple analysis of the phenomenon of such assignment of authority in a society of learning agents shows that actual expertise, in the sense of greater capabilities, arises naturally through the positive feedback processes involved in proto-experts having greater access to learning experiences (Gaines 1988).

Figure 6 is a diagram of the processes of expertise formation through a variety of feedback processes (Gaines 1989). The central loop showing the client-expert dialog derives from studies by Hawkins (1983) of industrial experts in mineral exploration, and emphasizes that the generation of advice is a feedback process of discourse and modeling. The upper and lower ovals showing the expert's interaction with his or her professional and client communities is what I would now want to describe in terms of the development of the expert's *habitus*, using Bourdieu's term deliberately to avoid any implication of the development within the expert of explicit knowledge.

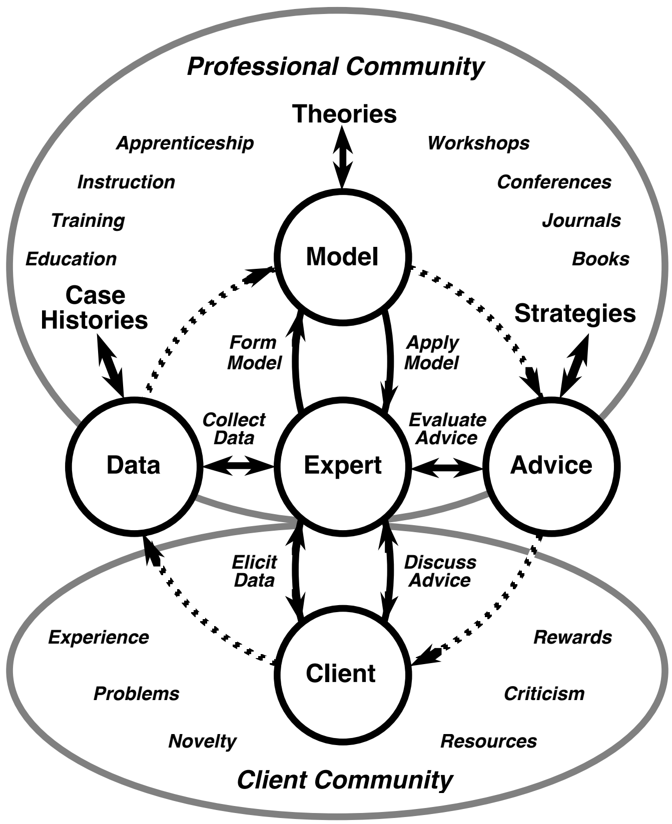

Figure 6 Expertise formation through expert-community interaction (Gaines 1989)

The dynamics of the professional community are ones of effective expertise development and transmission, of access through apprenticeship, case reports, evaluation of procedures, rationalization through links to existing models, related literatures and so on. Discourse is at the level of managing the formation of expertise and this may involve reflective processes raising *why* questions and addressing foundations, but note that the objective of these is to develop expertise, a coaching function, rather than to discover *truth* or uncover *reality*. Rationalizations are valid to the extent that they help the development of expertise, and that development does not necessarily leave any residue of the rationalization in the expert's mind. It is possible to have an effective knowledge-level approach to expertise development without basing it on a knowledge-level approach to expert performance (Vickers 1990).

Bourdieu's other dimensions of *field* and *social capital* may also be exemplified in terms of Figure 6. The expert acts in a specific situation within a social network of power relations with clients, colleagues, regulatory agencies, and so on, and competes within that field for symbolic capital that will affect his or her ongoing and future status within such fields. That is, the decisions and recommendations made are not just an outcome of the problem situation and the expert's dispositions through his or her habitus, but also reflect the interaction of habitus and field, in particular, the impact upon the expert's symbolic capital of the possible outcomes. The solution of any particular problem is situated within the processes of developing the overall competence of the community as a social network. Shapin (1994) has documented the importance of the power relations and symbolic capital in the development of science.

6. A Unified Model of Organizational Knowledge Acquisition

The preceding discussion emphasizes how important it is to be able to model social processes in expertise formation and organizational knowledge acquisition. The individual never acts alone but always in the context of what Wertsch (1991), following Bakhtin's (1981) discussion of the *dialogic imagination*, terms *voices of the mind*, the memories of past social discourse. We are agents in a distributed cognizant system, whether organization, group, person, role, module or neural complex. Simmel made this inter-relation of wholes and parts the central theme of his sociology:

> *Society strives to be a whole, an organic unit of which the individuals must be mere members. Society asks of the individual that he employ all his strength in the service of the special functions which he has to exercise as a member of it; that he so modify himself as to become the most suitable vehicle for this function….man has the capacity to decompose himself into parts and to feel any one of these as his proper self. (Simmel 1950)*

Simmel's insight that the group member is always a fragment of a person, a role created precisely to enable the person to enter the group has been developed by Wolff with his notions of *surrender* and *catch*:

> *From the standpoint of the world of everyday life, the mathematician, as we often put it, lives in the 'world of mathematics', dealing with 'nonreal' elements, notably numbers, whose relation to 'real' things, to 'reality', is not part of his concern. Analogously for the logician. What makes our subject-object approach to this attitude misleading is the fact that the subject, the student of mathematics or logic—his or her individuality, including motives and attitudes—is irrelevant for our understanding; the only thing that counts is the pursuit, with its results and questions.(Wolff 1976)*

He makes the key point that not only does the real world, the object, disappear to be replaced by the world of mathematics, but also that in entering into this world the person doing mathematics, the subject, also disappears to be replaced by a new entity, the mathematician.

In terms of Wolff's *object* Popper's concept of a *third world* of *statements in themselves* (Popper 1968) is a useful representation of that which we *catch*, emphasizing the distinct ontological status of *knowledge*:

> *I regard the third world as being essentially the product of the human mind. It is we who create third-world objects. That these objects have their own inherent or autonomous laws which create unintended and unforeseeable consequences is only one instance (although a very interesting one) of a more general rule, the rule that all our actions have such consequences.(Popper 1974)*

Popper terms the physical world, *World 1*, and the mental world, *World 2*, separating the objective knowledge of World 3 from the world represented and the agents doing the representation. Shaw (1985) has developed these notions to show how personal construct psychology accounts for the psychological processes not only of individuals but also for those of functional groups such as a product executive.

Figure 7 brings all these notions together to provide a conceptual framework for human psychology, sociology, action and knowledge. The central region presents a three-layer model of human agents and their supporting infrastructures, whether roles, people, groups, organizations or societies. At the bottom are the processes of interaction with the environment, of percepts, acts, reflexes, sensation, transducers, and so on. This is the level that is being emulated through neural networks (Elman, Bates, Johnson, Karmiloff-Smith, Parisi and Plunkett 1999). At the top are the processes of reason, of rationality, reflection, planning and so on. This is the level that is being emulated through digital computation. In the middle are the processes of practice, of culture, habitus and field characterizing the mental and the social, action, mimicry, reward and punishment. This is the level where neither neural networks nor digital computation have so far provided adequate emulation, and lack of such emulation of habitus is the greatest impediment to the development of expert systems.

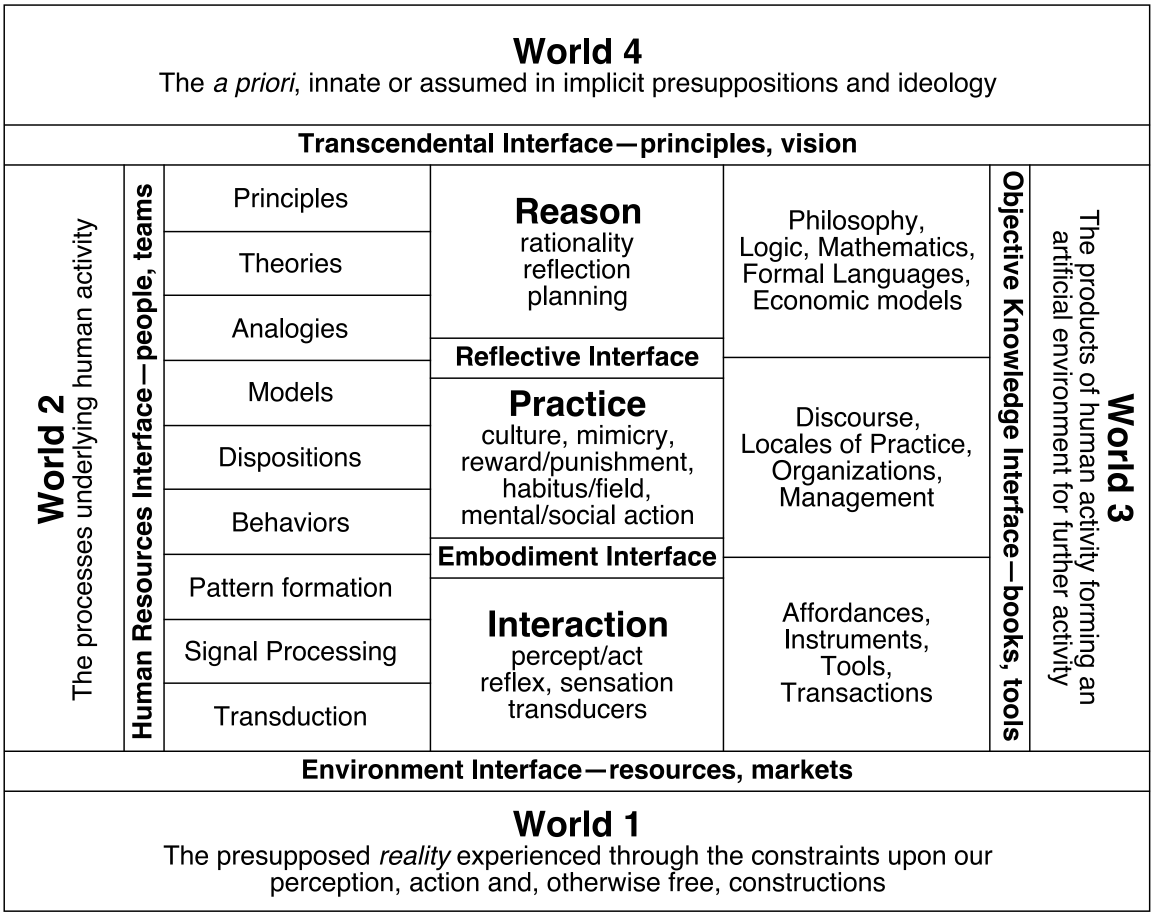

Figure 7 An integrated model of levels and worlds of being in organizational knowledge acquisition

The four surrounding boxes set human agents within the context of Popper's (1968) *three world*s, but adding a fourth world at the top to balance the presupposed World 1 of physical reality with an equally presupposed World 4 of transcendental *a priori* presuppositions and ideology. Popper would probably have placed this World 4 in his World 3, as a human artifact, but it is separated here to emphasize its psychological and cultural status as something presupposed not constructed. Friedman (1999) has presented a reconstruction of the work of the logical positivists, particularly Carnap, suggesting that their contribution is best understood as offering a new conception of *a priori* knowledge and its role in empirical knowledge, the link between our Worlds 4 and 1. Searle (1998) has argued that realism is based on a presupposition of a real world underlying all our further discourse and hence is not itself subject to empirical study, and there are other such presuppositions.

The box on the left of the central core attempts to situate in relation to the three layers of the core a hierarchy of World 2 levels of construction similar to those we previously derived from Klir's (1976) *epistemological hierarchy* generated through a system of distinctions (Gaines and Shaw 1984), and have used to model various forms of knowledge transfer in individuals and organizations (Gaines 1994a). The box on the right of the central core attempts to situate in relation to the three layers of the core some major World 3 products, with logic and economic models at the top, Giddens' (1986) *locales* of practice in the center, and Gibson's (1979) *affordances* at the bottom. One feature of this representation of World 3 in relation to World 2 is that it stresses how human activity is not just culturally situated in its habitus and socially situated in its field, but also artifactually situated in a humanly built world that exists in major part to trigger off the dispositions within a habitus. Our being is essentially embedded not only in the being of others with whom we interact but also in that of others who have left artifacts from their activities within which ours take place.

The interfaces to the four worlds that are shown are particularly important in a knowledge management context. The interface from the agent to World 4 is one of transcendental reason not necessarily grounded in rationality but reflecting human *principles* and *vision*. The interface from the agent to World 1 is one of interaction with the real world of *resources* and *markets*. That from the agent to World 2 is one of *human resources*, of people and organizations and their psycho-social processes. The interface from the agent to World 3 is one of *objective knowledg*e, of human artifacts embodied in books, tools and technologies. There are also internal interfaces in the three-layer agent model: a *reflective* interface mediating between practice and reason; and an *embodiment* interface mediating between practice and interaction with the world.

From a collective stance perspective the architecture of Figure 7 models any coherent cross-section of a society, a nation, an ethnic culture, an organization, a firm, a market, a team, an individual, or a role. Each level involves the processes represented in Figure 7, with some of the processes linking up in level, e.g. from individual to firm, and others linking down in level, e.g. from firm to individual. The *routines* and *procedures* studied by Nelson and Winter (1982) and by Cyert and March (1963) arise out of the *habitus* of the firm and structure those of its employees. Equally, through the process that Giddens (1986) terms *structuration*, the reciprocal process occurs in which the habitus of the firm is structured by those of its employees. The firm and the employees acquires *knowledge* through all processes that make that structuring effective including the internalization of principles, reinforcement learning and mimicry.

7. Managing Habitus

Managing organizational knowledge acquisition involves managing the entire infrastructure shown in Figure 7 with particular emphasis on the processes shown in Figure 3. There is not as yet an integrative theory of all the processes shown in Figure 7. It is probable that one will eventually be developed based on personal construct psychology used to model the way in which individuals, organizations and their artifacts interact with one another and the external world(s). In the central three-layer model, the top-level domain of reason is best understood, and the management of reflection and planning processes has a powerful literature ranging from the formality of Porter's (1980; 1985; 1986; 1990) analyses of the processes leading to competitive advantage to Schön's (1983; 1987; 1991) humanistic studies of the *reflective practitioner*. Argyris has also collaborated with Schön to develop an *action science* (Argyris, Putnam and Smith 1985) framework for organizational learning (Argyris and Schön 1978; Argyris and Schön 1996). The bottom-level domain of interaction is also comparatively well understood, and the management of manufacturing, market research and sales processes also has an extensive literature.

However, the management of the central region of *practice,* based on an organizational habitus of dispositions acquired through experience, is not well-understood except as a system that is extraordinarily difficult to manage but critical to sustainable competitive advantage. Human resource management has always had concerns with this level (Fombrun, Tichy and Devanna 1984; Mabey, Salaman and Storey 1998; Sofo 1999; Ulrich 1997). Competence-based (Nordhaug 1993) and economic (Becker 1993) models of human capital have modeled the importance of skilled people to organizations. There are also models of organizations (Foss and Knudsen 1996; Foss, Loasby and Richardson 1998; Foss and Mahnke 2000; Loasby 1999; Nooteboom 2000) being developed in terms of *transaction cost economics* (Williamson and Masten 1995) that could eventually provide a framework encompassing the management of an organization's habitus. There has also been increasing attention to modeling *organizational culture* (Harris 1994; Jones 1983; Leydesdorff 2000) and managing it for competitive advantage (Fiol 1991).

Polanyi's (1958) original book and literature deriving from it (Gill 2000) provide one important source of material on the tacit knowledge embedded in habitus. Bourdieu's (1977; 1989; 1990; 1993; 1998; 1992) massive collection of books and derivative literature (Calhoun, LiPuma and Postone 1993; Swartz 1997) provides a foundational resource. Baumard's (1999) *Tacit Knowledge in Organizations* and Wenger's (1998) *Communities of Practice* are currently the definitive source of management models and case histories relating to tacit knowledge in organizations. Nonaka, who first argued for the role of converting tacit to coded knowledge in the success of Japanese companies (Nonaka and Takeuchi 1995), has since published collections of related material (Nonaka and Nishiguchi 2001; Nonaka and Teece 2001). One very promising development has been that of *actor-network theory* (ANT) originally stemming from Latour and Woolgar's (1987; 1986) ethnographic studies of *Laboratory Life* and *Science in Action* but being extended by Law, Callon, *et al* (Law and Hassard 1999) to the phenomena of habitus in many other domains. An important feature of ANT is that it treats non-human entities, including technological artifacts, as first class members of social networks and examines, for example, their perspectives on events.

The primary dynamics of habitus within an organization depend on the constructs of those constituting the organization and its value chain, the extent to which these are generally shared, and the extent to which they correspond to the critical constructs of management at all levels. Management of the injection and diffusion of constructs within an organization is the main mechanism available with which to manage its habitus. Mimicry of role models, experiential learning, and learning through examples are the primary mechanisms for the injection of tacit constructs, together with descriptions of case histories for coded constructs. The management of personnel relationships and situations is the primary resource for influencing these processes. Managers play a key role in in this: through leadership they provides constructs that structure the meanings of experience for all employees and hence also for customers and suppliers (Smircich and Morgan 1982; Witt 1998); through personnel practices they influences the composition of the agents that constitute the organization and produce and reproduce its habitus; and through the situations they create they provide opportunities for experiential learning.

8. Tools to Support Organizational Knowledge Acquisition

The knowledge acquisition research community has developed a range of techniques and supporting tools to use for knowledge elicitation from experts and end users (Boose and Gaines 1988) that are also well-suited to organizational knowledge acquisition. Most of the tools have been derived from other domains such as education and psychology. Section 2 illustrated two such tools: *concept maps* deriving from education (Novak 1998; Novak and Gowin 1984) and *repertory grids* (Kelly 1955; Shaw 1980; Shaw 1981) deriving from clinical psychology. Concept maps represent mental models in terms of concepts and the relations between them. Repertory grids represent mental models in terms of construct systems, the distinctions made between entities in the domain being modeled.

Semantic networks (Lehmann 1992; Sowa 1991) are concept maps with strictly defined operational semantics that are used for the formal representation of knowledge as facts and theories. Tools have been developed for ease of development of both concept maps (Gaines, Norrie and Lapsley 1995; Gaines and Shaw 1994a; Gaines and Shaw 1995b) and semantic networks, some operating in groupware mode to support multiple users at different sites (Gaines and Shaw 1995a; Kremer and Gaines 1994) particularly on the World Wide Web (Gaines and Shaw 1995c; Kremer and Gaines 1996). Tools have also been developed for ease of development of semantic networks including inference from them (Gaines 1993a; Gaines 1993b; Gaines 1994b; Gaines and Shaw 1999). Similarly tools have been developed for the elicitation of personal construct systems (Gaines and Shaw 1993a; Gaines and Shaw 1993b) some of which operate on the World Wide Web to collect and compare mental models from multiple, distributed users (Gaines and Shaw 1996; Shaw and Gaines 1999).

One important feature of repertory grids is that techniques and tools have been developed to compare mental models in the same domain by comparing the distinctions made by constructs from different individuals. This allows pairs of constructs, one from each individual, to be allocated to the four quadrants shown in Figure 8, indicating consensus, conflict, correspondence and contrast (Gaines and Shaw 1989; Shaw and Gaines 1989).

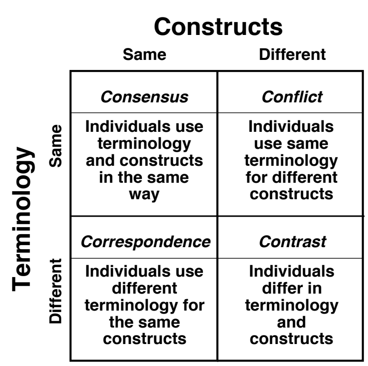

Figure 8 Consensus, conflict, correspondence and contrast in construct systems

It is also possible to compare complete grids in the same domain to determine the best matches for constructs in one grid in another, and *vice versa*. This results in asymmetric links between grids corresponding to one person being able to understand the constructs of another, and a *socionet* may be plotted based on such understanding (Shaw 1980).In a study of quality control at a garment factory where grids were elicited from plant operators and all levels of management, it was found that the socionet exactly reproduced the management hierarchy (Shaw and Gaines 1983)—each level of management could understand the constructs of the level below even if the knowledge involved was tacit.

9. Conclusions

As a socio-economic system approaches its optimum performance its system dynamics become increasingly unstable and subject to wild fluctuations (Anderson, Arrow and Pines 1988; Arthur, Durlauf and Lane 1997). As evidence has mounted that the global economic system is entering this state (D'Aveni and Gunther 1994; Doeringer 1991; Drucker 1978; Frank 1998; Ilinitch, Lewin and D'Aveni 1998), it has become increasingly important to those responsible for major organizations that they understand and manage organizational processes more effectively. This has led to interest in knowledge management, the nature of expertise, and the management of knowledge acquisition so as to enhance the capabilities of the organization.

This article has presented a unified model of organizational knowledge acquisition, linking it to a wide range of relevant literature and to management practices. The discussion draws on research in knowledge acquisition for expert systems, and the article recounts the background to such systems and the issues which limited their development. The model draws on personal construct psychology to provide a constructivist account of human agents and organizations, on Bourdieu's analysis of dispositions internalizing the history of experience to account for the construct systems underlying practice, on Giddens' structuration theory to account for the way in which organizational habitus is both structured by those of the individual in the organization and is in turn structured by them, and on Popper's theory of worlds to separate the physical, mental, objective knowledge and transcendental worlds.

The model is used to suggests ways in which the knowledge acquisition process can be managed, particularly that for the tacit knowledge which constitutes Bourdieu's habitus. It is suggested that concept mapping and repertory grid tools that were developed for knowledge acquisition for expert systems development will also prove useful in organizational knowledge acquisition.

Acknowledgment

Financial assistance for this work has been made available by the Natural Sciences and Engineering Research Council of Canada. I am grateful to Mildred Shaw and to colleagues in the GNOSIS international Intelligent Manufacturing Systems consortium for many stimulating discussions and for access to their data.

URLs

Further reports may be accessed at http://repgrid.com/reports/, WebGrid at http://repgrid.com/WebGrid/, and the author at mailto:gaines@ucalgary.ca

References

Alchian, A. A., *Economic Forces at Work*. Indianapolis: Liberty Press, 1977.

Alford, J., C. Cairney, R. Higgs, M. Honsowetz, V. Huynh, A. Jines, D. Keates and C. Skelton, "Real rewards from artificial intelligence," *InTech*,April, 52-55, 2000.

Anderson, P. W., K. J. Arrow and D. Pines, *The Economy as an Evolving Complex System*. Reading, MA: Addison-Wesley, 1988.

Argyris, C., R. Putnam and D. M. Smith, *Action science*. San Francisco: Jossey-Bass, 1985.

Argyris, C. and D. A. Schön, *Organizational Learning*. Reading, MA: Addison-Wesley, 1978.

Argyris, C. and D. A. Schön, *Organizational Learning II*. Reading, MA: Addison-Wesley, 1996.

Aristotle, *Nicomachean Ethics*. Cambridge: Cambridge University Press, 2000.

Arthur, W. B., S. N. Durlauf and D. A. Lane, *The Economy as an Evolving Complex System II*. Reading, MA: Addison-Wesley, 1997.

Bacon, F., *The New Organon, and Related Writings*: Liberal Arts Press, 1960.
Bakhtin, M., *The Dialogic Imagination: Four Essays by Michael Bakhtin*. Austin: University of Texas Press, 1981.
Barzel, Y., *Economic Analysis of Property Rights*. Cambridge: Cambridge University Press, 1997.
Baumard, P., *Tacit Knowledge in Organizations*. Thousand Oaks, CA: SAGE Publications, 1999.
Becker, G. S., *Human Capital (3rd Edition)*. Chicago: University of Chicago Press, 1993.
Beniger, J. R., *The Control Revolution: Technological and Economic Origins of the Information Society*. Cambridge, MA: Harvard University Press, 1986.
Boisot, M., *Information Space: A Framework for Learning in Organizations, Institutions, and Culture*. New York: Routledge, 1995.
Boisot, M., *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. Oxford: Oxford University Press, 1998.
Boose, J. H. and B. R. Gaines, Eds, *Knowledge Acquisition Tools for Expert Systems*. London: Academic Press, 1988.
Bourdieu, P., *Outline of a Theory of Practice*. Cambridge: Cambridge University Press, 1977.
Bourdieu, P., *The Logic of Practice*. Cambridge: Polity, 1989.
Bourdieu, P., *In Other Words: Essays Toward a Reflexive Sociology*. Oxford: Polity, 1990.
Bourdieu, P., *Sociology in Question*. London: Sage, 1993.
Bourdieu, P., *Practical Reason: On the Theory of Action*. Stanford: Stanford University Press, 1998.
Bourdieu, P. and L. J. D. Wacquant, *An Invitation to Reflexive Sociology*. Chicago: University of Chicago Press, 1992.
Calhoun, C. J., E. LiPuma and M. Postone, *Bourdieu: Critical Perspectives*. Cambridge: Polity Press, 1993.
Chandler, A. D., *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap Press, 1977.
Clancey, W. J., “Viewing knowledge bases as qualitative models,” *IEEE Expert*, 4,2, 9-23, 1989.
Cohen, W. M. and D. A. Levinthal, “Absorptive capacity: a new perspective on learning and innovation,” *Administrative Science Quarterly*, 35, 128-152, 1990.
Crane, D., *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: University of Chicago Press, 1972.
Cyert, R. M. and J. G. March, *A behavioral theory of the firm*. Englewood Cliffs, N.J.: Prentice-Hall, 1963.
D'Aveni, R. A. and R. E. Gunther, *Hypercompetition: Managing the Dynamics of Strategic Maneuvering*. New York: The Free Press, 1994.
Doeringer, P. B., *Turbulence in the American Workplace*. Oxford: Oxford University Press, 1991.
Doignon, J.-P. and J.-C. Falmagne, *Knowledge Spaces*. Berlin: Springer, 1999.
Dreyfus, H. L., *What Computers Can't Do: A Critique of Artificial Reason*. New York: Harper & Row, 1972.
Dreyfus, H. L. and S. E. Dreyfus, *Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*. New York: Free Press, 1986.
Drucker, P. F., *The Age of Discontinuity*. New York: Harper & Row, 1978.
Drucker, P. F., "From capitalism to knowledge society," *Post Capitalist Society*, New York: HarperBusiness, 19-47, 1993.
Elman, J. L., E. A. Bates, M. H. Johnson, A. Karmiloff-Smith, D. Parisi and K. Plunkett, *Rethinking Innateness: A Connectionist Perspective on Development*. Cambridge, MA: MIT Press, 1999.
Feigenbaum, E., P. McCorduck and H. P. Nii, *The Rise of the Expert Company*. New York: Times Books, 1988.
Feyerabend, P., Ed. *Against Method*. London: NLB, 1975.
Fiol, C. M., “Managing culture as a competitive resource: an identity-based view of sustainable competitive advantage,” *Journal of Management*, 17,1, 191-211, 1991.
Fombrun, C. J., N. M. Tichy and M. A. Devanna, *Strategic human resource management*. New York: Wiley, 1984.
Fortun, M. and H. J. Bernstein, *Muddling Through: Pursuing Science and Truths in the 21st Century*. Washington: Counterpoint, 1998.
Foss, N. J. and C. Knudsen, *Towards a Competence Theory of the Firm*. London: Routledge, 1996.
Foss, N. J., B. J. Loasby and G. B. Richardson, *Economic Organization, Capabilities and Coordination: Essays in Honour of G.B. Richardson*. London: Routledge, 1998.

Foss, N. J. and V. Mahnke, *Competence, Governance, and Entrepreneurship: Advances in Economic Strategy Research*. Oxford: Oxford University Press, 2000.
Frank, A. G., *ReOrient: Global Economy in the Asian Age*. Berkeley: University of California Press, 1998.
Friedman, M., *Reconsidering Logical Positivism*. Cambridge: Cambridge University Press, 1999.
Gadamer, H. G., *Wahrheit und Methode*. Tübingen: Mohr, 1972.
Gaines, B. R., "Positive feedback processes underlying the formation of expertise," *IEEE Transactions on Systems, Man & Cybernetics*, SMC-18,6, 1016-1020, 1988.
Gaines, B. R., "Social and cognitive processes in knowledge acquisition," *Knowledge Acquisition*, 1,1, 251-280, 1989.
Gaines, B. R., "A class library implementation of a principled open architecture knowledge representation server with plug-in data types," *IJCAI'93: Proceedings of the Thirteenth International Joint Conference on Artificial Intelligence*, San Mateo, California: Morgan Kaufmann, 504-509, 1993a.
Gaines, B. R., "Experience with a class library for organizational modeling and problem solving," *Integrated Computer-Aided Engineering*, 1,2, 93-107, 1993b.
Gaines, B. R., "The collective stance in modeling expertise in individuals and organizations," *International Journal of Expert Systems*, 7,1, 21-51, 1994a.
Gaines, B. R., "A situated classification solution of a resource allocation task represented in a visual language," *International Journal Human-Computer Studies*, 40,2, 243-271, 1994b.
Gaines, B. R., "Knowledge management in societies of intelligent adaptive agents," *Journal for Intelligent Information Systems*, 9,3, 277-298, 1997.
Gaines, B. R., D. H. Norrie and A. Z. Lapsley, "Mediator: an Intelligent Information System Supporting the Virtual Manufacturing Enterprise," *Proceedings of 1995 IEEE International Conference on Systems, Man and Cybernetics*, New York: IEEE, 95CH3576-7, 964-969, 1995.
Gaines, B. R. and M. L. G. Shaw, "Hierarchies of distinctions as generators of system theories," *Proceedings of the Society for General Systems Research International Conference.* A. W. Smith, Louisville, Kentucky: Society for General Systems Research, 559-566, 1984.
Gaines, B. R. and M. L. G. Shaw, "Comparing the conceptual systems of experts," *Proceedings of the Eleventh International Joint Conference on Artificial Intelligence*, San Mateo, California: Morgan Kaufmann, 633-638, 1989.
Gaines, B. R. and M. L. G. Shaw, "Basing knowledge acquisition tools in personal construct psychology," *Knowledge Engineering Review*, 8,1, 49-85, 1993a.
Gaines, B. R. and M. L. G. Shaw, "Eliciting knowledge and transferring it effectively to a knowledge-based systems," *IEEE Transactions on Knowledge and Data Engineering*, 5,1, 4-14, 1993b.
Gaines, B. R. and M. L. G. Shaw, "Concept maps indexing multimedia knowledge bases," *AAAI-94 Workshop: Indexing and Reuse in Multimedia Systems*, Menlo Park, California: AAAI, 36-45, 1994a.
Gaines, B. R. and M. L. G. Shaw, "Using knowledge acquisition and representation tools to support scientific communities," *AAAI'94: Proceedings of the Twelfth National Conference on Artificial Intelligence*, Menlo Park, California: AAAI Press/MIT Press, 707-714, 1994b.
Gaines, B. R. and M. L. G. Shaw, "Collaboration through concept maps," *Proceedings of CSCL95: Computer Support for Collaborative Learning.* J. L. Schnase and E. L. Cunnius, Mahwah, New Jersey: Lawrence Erlbaum, 135-138, 1995a.
Gaines, B. R. and M. L. G. Shaw, "Concept maps as hypermedia components," *International Journal Human-Computer Studies*, 43,3, 323-361, 1995b.
Gaines, B. R. and M. L. G. Shaw, "WebMap: concept mapping on the web," *World Wide Web Journal*, 1,1, 171-183, 1995c.
Gaines, B. R. and M. L. G. Shaw, "WebGrid: knowledge modeling and inference through the World Wide Web," *Proceedings of Tenth Knowledge Acquisition Workshop.* B. R. Gaines and M. A. Musen, 65-1-65-14 (http://ksi.cpsc.ucalgary.ca/KAW/KAW96/gaines/KMD.html), 1996.
Gaines, B. R. and M. L. G. Shaw, "Knowledge acquisition, modeling and inference through the World Wide Web," *International Journal of Human-Computer Studies*, 46,6, 729-759, 1997.
Gaines, B. R. and M. L. G. Shaw, "Embedding formal knowledge models in active documents," *Communications of the ACM*, 42,1, 57-63, 1999.
Gallupe, R. B. and W. H. Cooper, "Brainstorming electronically," *Sloan Management Review*, 27-36, 1993.

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott and M. Trow, *The New production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. Thousand Oaks, CA: SAGE Publications, 1994.

Gibson, J. J., *The Ecological Approach to Perception*. Boston: Houghton Mifflin, 1979.

Giddens, A., *The Constitution of Society: Outline of the Theory of Structuration*. California: University of California Press, 1986.

Gill, J. H., *The Tacit mode: Michael Polanyi's Postmodern Philosophy*. Albany: State University of New York Press, 2000.

Goodman, R. F. and W. R. Fisher, Eds, *Rethinking Knowledge: Reflections Across the Disciplines*. Albany: State University of New York Press, 1995.

Hall, E. T., *The Silent Language*. New York: Doubleday, 1959.

Harris, S. G., "Organizational culture and individual sensemaking: a schema-based perspective," *Organization Science*, 5,3, 309-321, 1994.

Hauenstein, A. D., *A Conceptual Framework for Educational Objectives: A Holistic Approach to Traditional Taxonomies*. Lanham, MD: University Press of America, 1998.

Havelock, E. A., *Preface to Plato*. Cambridge: Harvard University Press, 1963.

Hawkins, D., "An analysis of expert thinking," *International Journal of Man-Machine Studies*, 18,1, 1-47, 1983.

Hayes-Roth, F., "The industrialization of knowledge engineering," *Artificial Intelligence Applications for Business.* W. Reitman, Norwood, New Jersey: Ablex, 159-177, 1984.

Hippel, E. v., ""Sticky information" and the locus of problem solving: implications for invention," *Management Science*, 44,4, 429-439, 1994.

Ilinitch, A. Y., A. Y. Lewin and R. A. D'Aveni, *Managing in Times of Disorder: Hypercompetitive Organizational Responses*. Thousand Oaks: Sage, 1998.

Jones, G. R., "Transaction costs, property rights, and organizational culture: an exchange perspective," *Adminstrative Science Quarterly*, 28, 454-467, 1983.

Kelly, G. A., *The Psychology of Personal Constructs*. New York: Norton, 1955.

Klir, G. J., "Identification of generative structures in empirical data," *International Journal of General Systems*,, 3, 89-104, 1976.

Kogut, B. and U. Zander, "Knowledge of the firm, combinative capabilities, and the replication of technology," *Organization Science*, 3,3, 383-397, 1992.

Kremer, R., "Experience in applying KRS to an actual business problem," *Proceedings of the Sixth AAAI Knowledge Acquisition for Knowledge-Based Systems Workshop.* J. H. G. Boose, B.R., Calgary, Canada: University of Calgary, 11-1-11-12, 1991.

Kremer, R. and B. R. Gaines, "Groupware concept mapping techniques," *Proceedings SIGDOC'94: ACM 12th Annual International Conference on Systems Documentation*, New York: ACM, 156-165, 1994.

Kremer, R. and B. R. Gaines, "Embedded interactive concept maps in web documents," *Proceedings of WebNet96.* H. Maurer, Charlottesville, VA: Association for the Advancement of Computing in Education, 273-280, 1996.

Lant, T. K. and S. J. Mezias, "An organizational learning model of convergence and reorientation," *Organizational Learning.* M. D. Cohen and L. Sproull, Thousand Oaks: Sage, 1996.

Latour, B., *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, MA: Harvard University Press, 1987.

Latour, B. and S. Woolgar, *Laboratory Life: The Construction of Scientific Facts*. Princeton, N.J.: Princeton University Press, 1986.

Law, J. and J. Hassard, *Actor Network Theory and After*. Oxford: Blackwell, 1999.

Lehmann, F., Ed. *Semantic Networks in Artificial Intelligence*. Oxford: Pergamon Press, 1992.

Leonard-Barton, D., *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*. Boston, MA.: Harvard Business School Press, 1995.

Lewin, K., *Principles of Topological Psychology*. New York: McGraw-Hill, 1936.

Leydesdorff, L., *A model engine for the simulation of "lock-in," "break-out," and the dissemination of technological culture*. Proceedings of the 44th Annual Conference of the International Society for the System Sciences, Toronto, ISSS, 2000

Loasby, B. J., *Knowledge, Institutions, and Evolution in Economics*. London: Routledge, 1999.

Luhmann, N., *Social Systems*. Stanford, CA: Stanford University Press, 1995.

Mabey, C., G. Salaman and J. Storey, Eds, *Strategic Human Resource Management*. London: Sage and Open University, 1998.
Mancuso, J. C. and M. L. G. Shaw, Eds, *Cognition and Personal structure: Computer Access and Analysis*. New York: Praeger, 1988.
Marx, K., *On society and Social Change. With Selections by Friedrich Engels*. Chicago,: University of Chicago Press, 1973.
Meister, J. C., *Corporate Universities : Lessons in Building a World-class Work Force*. New York: McGraw-Hill, 1998.
Metfessel, N. S., W. B. Michael and D. A. Kirsner, "Instrumentation of Bloom's and Krathwohl's taxonomies for the writing of educational objectives," *Psychology in the Schools*, 6, 227-231, 1969.
Nelson, R. R. and S. G. Winter, *An Evolutionary Theory of Economic Change*. Cambridge, Massachusetts: Belknap Press, 1982.
Newell, A., "The knowledge Level," *Artificial Intelligence*, 18,1, 87-127, 1982.
Nonaka, I. and T. Nishiguchi, *Knowledge Emergence: Social, Technical, and Evolutionary Dimensions of Knowledge Creation*. Oxford: Oxford University Press, 2001.
Nonaka, I. and H. Takeuchi, *The Knowledge-Creating Company*. Oxford: Oxford University Press, 1995.
Nonaka, I. and D. J. Teece, *Managing Industrial Knowledge: Creation, Transfer and Utilization*. Thousand Oaks, CA: Sage, 2001.
Nooteboom, B., *Learning and Innovation in Organizations and Economies*. Oxford: Oxford University Press, 2000.
Nordhaug, O., *Human Capital in Organizations: Competence, Training and Learning*. Oslo: Scadinavian University Press, 1993.
Novak, J. D., *Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations*. Mahwah: Lawrence Erlbaum, 1998.
Novak, J. D. and D. B. Gowin, *Learning How to Learn*. Cambridge: Cambridge University Press, 1984.
Nunamaker, J. F., A. R. Dennis, J. S. Valacich, D. R. Vogel and J. F. George, "Electronic meetings to support group work," *Communications of the ACM*, 34,7, 40-61, 1991.
Penrose, E. T., *The Theory of the Growth of the Firm*. New York: Wiley, 1959.
Plato and F. M. Cornford, *Plato's Theory of Knowledge: the Theaetetus and the Sophist of Plato*. London: K. Paul Trench Trubner, 1935.
Polanyi, M., *Personal Knowledge: Towards a Post-critical Philosophy*. Chicago: University of Chicago Press, 1958.
Popper, K. R., "Epistemology without a knowing subject," *Logic, Methodology and Philosophy of Science III.* B. V. Rootselaar, Amsterdam: North-Holland, 333-373, 1968.
Popper, K. R., "Autobiography of Karl Popper," *The Philosophy of Karl Popper.* P. A. Schilpp, La Salle, Illinois: Open Court, 3-181, 1974.
Porter, M. E., *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: Free Press, 1980.
Porter, M. E., *Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press, 1985.
Porter, M. E., *Competition in Global Industries*. Boston: Harvard Business School Press, 1986.
Porter, M. E., *The Competetive Advantage of Nations*. New York: Free Press, 1990.
Pralahad, D. and G. Hamel, "The core competence of the corporation," *Harvard Business Review*, 79-91, 1990.
Sanchez, R. and A. Heene, *Strategic Learning and Knowledge Management*. New York: Wiley, 1997.
Saul, J. R., *Voltaire's Bastards: The Dictatorship of Reason in the West*. Toronto: Penguin, 1993.
Schön, D. A., *The Reflective Practitioner*. New York: Basic Books, 1983.
Schön, D. A., *Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions*. San Francisco: Jossey-Bass, 1987.
Schön, D. A., *The Reflective Turn: Case Studies in and on Educational Practice*. New York, 1991.
Scott, W. R., *Organizations: Rational, Natural and Open Systems (3rd Edition)*. Englewood Cliffs, New Jersey: Prentice-Hall, 1992.
Searle, J. R., *The Rediscovery of the Mind*. Cambridge, MA: MIT Press, 1992.
Searle, J. R., *Mind, Language and Society: Philosophy in the Real World*. New York, NY: Basic Books, 1998.

Seiler, H. (1999). Managing business rules: a repository-based approach. Indialantic, FL, Rule Machines Corporation.
Shapin, S., *A Social History of Truth: Civility and Science in Seventeenth-Century England*. Chicago: University of Chicago Press, 1994.
Shaw, M. L. G., *On Becoming A Personal Scientist: Interactive Computer Elicitation of Personal Models Of The World*. London: Academic Press, 1980.
Shaw, M. L. G., Ed. *Recent Advances in Personal Construct Technology*. London: Academic Press, 1981.
Shaw, M. L. G., "Communities of knowledge," *Anticipating Personal Construct Psychology.* F. Epting and A. W. Landfield, Lincoln, Nebraska: University of Nebraska Press, 25-35, 1985.
Shaw, M. L. G. and B. R. Gaines, "Eliciting the real problem," *Adequate Modeling of Systems.* H. Wedde, Berlin: Springer, 100-111, 1983.
Shaw, M. L. G. and B. R. Gaines, "A methodology for recognizing conflict, correspondence, consensus and contrast in a knowledge acquisition system," *Knowledge Acquisition*, 1,4, 341-363, 1989.
Shaw, M. L. G. and B. R. Gaines, "Modeling the social practices of users in Internet communities," *UM99: User Modeling: Proceedings of the Seventh International Conference.* J. Kay, New York: Springer, 77-86, 1999.
Simmel, G., *The Sociology of Georg Simmel*. New York: Free Press, 1950.
Smircich, L. and G. Morgan, "Leadership: the management of meaning," *Journal of Applied Behavioral Science*, 18,3, 257-273, 1982.
Sofo, F., *Human Resource Development*. Business and Professional Publishing: Australia, 1999.
Solmsen, F., *Intellectual Experiments of the Greek Enlightenment*. Princeton, N.J.: Princeton University Press, 1975.
Sowa, J. F., Ed. *Principles of Semantic Networks: Explorations in the Representation of Knowledge*. San Mateo, California: Morgan-Kaufman, 1991.
Sullivan, S. D., *Aeschylus' use of Psychological Terminology*. Montreal: McGill-Queen's University Press, 1997.
Sullivan, S. D., *Sophocles' use of Psychological Terminology*. Ottawa: Carleton University Press, 1999.
Sullivan, S. D., *Euripides' use of Psychological Terminology*. Montreal: McGill-Queen's University Press, 2000.
Swartz, D., *Culture & Power: The Sociology of Pierre Bourdieu*. Chicago: University of Chicago Press, 1997.
Thompson, J. D., *Organizations in Action: Social Science Bases of Administrative Theory*. New York: McGraw-Hill, 1967.
Tversky, A. and D. J. Koehler, "Support theory: a nonextensional representation of subjective probability," *Psychological Review*, 101,4, 547-567, 1994.
Ulrich, D., *Human Resource Champions: The Next Agenda for Adding Value and Delivering Results*. Boston: Harvard Business School Press, 1997.
Vickers, J. N., *Instructional Design for Teaching Physical Activities: A Knowledge Structures Approach*. Champaign, Illinois: Human Kinetics, 1990.
Weber, M., *Economy and Society: An Outline of Interpretive Sociology*. New York: Bedminster Press, 1968.
Wenger, E., *Communities of Practice: Learning, Meaning, and Identity*. Cambridge: Cambridge University Press, 1998.
Wertsch, J. V., Ed. *Voices of the Mind: A Sociocultural Approach to Mediated Action*. Cambridge, MA: Harvard University Press, 1991.
Williamson, O. E. and S. E. Masten, *Transaction Cost Economics*. Aldershot, Hants, England: Edward Elgar, 1995.
Wills, G., *The Knowledge Game: The Revolution in Learning and Communication in the Workplace*. London: Cassell, 1998.
Witt, U., "Imagination and leadership—the neglected dimension of an evolutionary theory of the firm," *Journal of Economic Behavior and Organization*, 35, 161-177, 1998.
Wittgenstein, L., *Philosophical Investigations*. Oxford: Blackwell, 1953.
Wolff, K. H., *Surrender and Catch: Experience and Enquiry Today*. Holland: Reidel, 1976.