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Twyoniak, S. (2005) Knowledge in four deformation dimensions. In *Proceedings EGOS Symposium*, Berlin.

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Paper under review at Organization (may 2006), an earlier version was presented at the 2005 EGOS Symposium, Berlin (June)

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Knowledge in four deformation dimensions

Abstract

This paper sketches out a complexity conceptualization of knowledge. Building from evolutionary theories, it defines knowledge as rules that reduce environmental uncertainty through connections between ideas and facts. Following, knowledge is conceived as a structure validated through action, a process contextualized in individual experience and a system contextualized in social and cultural experience. Knowledge exhibits four characteristics of of a complex system: it is ensitive to initial conditions, it exhibits multiple feedback loops, it is non-linear, and recursively symmetrical Four inter-dependent deformation dimensions of knowledge are identified (personal, common, tacit, and explicit) and their interactions are discussed. This conceptualization of knowledge as a complex system contributes to the knowledge-based theory of the firm by providing some micro-foundations to organizational knowledge, and it opens the opportunity to re-think theories about communities of practice, entrepreneurship and firm creation, the role of managers, and knowledge management.

Introduction

Research dealing with knowledge in organizations has highlighted two principal sets of polar opposites: on the one hand tacit versus explicit knowledge (e.g. Cowan, David & Foray, 2000), and on the other hand individual versus group knowledge (e.g. Brown & Duguid, 1998). To date, these have been conceptualized as *types* of knowledge, and much of the literature on knowledge management has been concerned with how to convert, translate or transform one type of knowledge into another (e.g. Nonaka & Takeuchi, 1995) and how to generate new knowledge from existing knowledge (e.g. Hargadon & Sutton, 1997) in order to generate innovations and gain competitive advantage. This is consistent with the assumptions underlying knowledge-based theories of the firm (e.g. Grant, 1996b): knowledge is arguably a firm's most valuable asset (Winter, 1987) because it may well be the only reliable source of competitive advantage in a post-industrial economy (Drucker, 1993). And also with dynamic capabilities theories of competitive advantage (e.g. Eisenhardt & Martin, 2000) in the sense that the creation of new knowledge, in other words organizational learning (Brown & Duguid, 1991), sustains the renewal of capabilities (Helfat & Peteraf, 2003). The above arguments have led to recommend that firms should actively manage their knowledge assets (Lei, Hitt & Bettis, 1996) thereby legitimizing knowledge management as a strategic activity (Alvesson & Karreman, 2001).

This broad literature on knowledge and organizations defines a field of research, but does not form an integrated and consistent theoretical paradigm (Kuhn, 1970) as it harbors significant debates and controversies. The way knowledge has been defined has been criticized at times for confusing knowledge and information (Potts, 2001: 424) or for its poor construction: "the logic seems to be as follows: «we don't know what knowledge is but it seems to solve problems in a functional way, so let's use it anyway»" (Alvesson & Karreman, 2001: 999). The distinction between tacit and explicit knowledge has been under attack as a misinterpretation of Polanyi's original argument that they are complementary (Polanyi, 1967), not substituable (Thompson & Walsham, 2004). Similarly, opposing individual and collective knowledge has been argued to make little sense as they are mutually defined (Tsoukas, 1996: 14) and knowledge-based theories of the firm have been criticized for failing to articulate clearly the build-up from individual to organizational knowledge (Foss, 1999: 741). Finally, the notion that knowledge is an asset has been critiqued as too narrow and static for it ignores the dynamic and processual perspectives on knowledge and learning (Chia, 2003).

In this paper, I offer some arguments for a re-thinking of the theories of knowledge and organization that goes some way towards addressing the above criticisms. Implicit in the majority of the research in the field is the assumption that relatively simple, linear, frameworks are appropriate to study and theorize about knowledge. Building on evolutionary theories, I present a conceptualization of knowledge as a complex system, for which non-linear models and concepts drawn from complexity theory are appropriate. In this perspective, tacit, explicit, personal, and common knowledge are defined as interdependent *deformation dimensions* that interact dynamically, rather than *types* of knowledge which can be substituted one for another. Proceeding in this way leads to challenge some conclusions and recommendations from established theories about knowledge and its management, the role of managers, and why knowledge is an appropriate foundation for a theory of the firm. This discussion incorporates complexity theory as a metaphor. Arguably, such a narrative approach is more appropriate to organizational analysis than a direct application of the models of complexity theory (e.g: McKelvey, 1999) because it allows to capture the evolutionary nature of organizational contexts (Thiétart & Forgues, 1995). There are two key arguments in favor of a qualitative, rather than quantitative, reference to complexity theory. First, firms do not emerge spontaneously, they are human creations, both in the sense that as legal institutions they are the product of interactions between individuals in the context of society (North, 1991), but also in the more immediate sense that they are created by entrepreneurs (Schumpeter, 1934). Second, organizations are more complex than living organisms in the sense that they are capable of structural change in ways that the models of complexity find difficult to account for (Thiétart & Forgues, 1995: 22).

In the first section, I define knowledge as an evolutionary and dynamic process of uncertainty reduction. In the second section I elaborate on this definition to present a conceptualization of knowledge as a complex system. In the third section, the interdependencies between tacit, explicit, personal and common knowledge are explored. Finally I conclude with a discussion of the implications of this re-thinking for management practice and research.

An evolutionary perspective on knowledge and uncertainty

By analogy with economic theories, evolutionary theories can be sorted according to their underlying assumptions about efficiency (Vromen, 1995: 60). On the one hand are neoDarwinian theories making "strongform" hypotheses about the efficiency of selection processes (Gould, 1982; Arrow, 1962) leading to model the selection process as the survival of the fittest and the systematic elimination of weak species, either in natural environments or in markets. Such "strongform" theories allow for equilibrium and optimization of performance. One of the arguments advanced against "strongform" evolutionary theories is that they ignore intentionality and purpose in evolutionary processes: environments may sometimes be responsible for extinction, but never for survival (Loasby, 2002; von Glasersfeld, 1984). This has led to formulating evolutionary theories with "weakform" assumptions about the efficiency of the selection process, where "selection discards what is not compatible with survival and reproduction" (Varela, Thompson & Rosch, 1993: 195) leading to a less stringent process retaining all those that fit, not merely the fittest. These evolutionary theories incorporating "weakform" assumptions allow for ambiguity and lead to satisficing rather than optimizing performance (Heiner, 1983). In the rest of this discussion, I will draw from "weakform" evolutionary theories.

A central feature of evolutionary processes is uncertainty. The main concern of living beings and organizations is how to secure survival in the context of an uncertain environment. Environmental uncertainty can be divided into two dimensions: procedural and fundamental uncertainty (Dequech, 2004). Procedural uncertainty is linked to the perceptual and cognitive limitations of actors. Sensory organs are selective about which environmental features they are sensitive to (Moreno, Umerez & Ibanez, 1997) implying that it is not possible to gather all potentially relevant information: the limitations of sensory organs thus engender perceptual uncertainty. Further, limitations of the cognitive apparatus -bounded rationality- imply that it is not possible to fully attend to the complexity of the environment, leading to inaccurate interpretations and predictions (McFadden, 1999). Fundamental uncertainty relates to the complexity and unpredictability of the environment. Environmental complexity implies that attribution of cause and effect is not always reliable, leading to unforeseen consequences (Perrow, 1984). Unpredictability implies that the probability of occurrence of events cannot always be precisely ascertained (Knight, 1921 [1971]). Thus, even if actors could be capable of accurate and complete perceptions and faultless information processing, they would not be able to select the most appropriate course of action due to the complexity and unpredictability of the environment (Heiner, 1983).

In evolutionary biology as well as economics, uncertainty is associated with lack of knowledge and the problem of survival (Dequech, 2004; Christensen & Hooker, 2000). Even in the context of "weakform" selection processes, survival is by no means assured: multiple and potentially conflicting objectives (e.g. sleeping versus gathering food) must be satisfied in time and space, within the context of an uncertain environment. Through trial and error, individuals progressively discover heuristics that provide satisfactory solutions to the problem of survival. At root, knowledge is thus a behavioral rule that has been tried and successfully implemented (Potts, 2001). Knowledge is different from facts and ideas in the sense that it consists of connections between ideas and facts. Knowledge reduces uncertainty by establishing such connections, and gains justification through successful action. In this sense, knowledge is "blind": the search for new knowledge is not random, it is directed by the intentionality to find a solution to a perceived problem, however its validity cannot be ascertained *ex-ante* (Campbell, 1960). This rejoins Ryle's insight that knowing "how" precedes knowing "that" (Ryle, 1949), in other words: "theory follows after, rather than being presupposed by, concrete accomplishment" (Rorty, 1991: 79).

Thus far we have a root definition of knowledge as a system of connections between facts and ideas that enable survival by reducing environmental uncertainty. For example, female mosquitoes resolve the environmental uncertainty of finding the "blood hosts" necessary to egg production by tracking heat and CO2 (Christensen & Hooker, 2000:12). In this case, the knowledge connections are structured as follows: heat + CO2 = blood host. However, the cognitive ability of the female mosquito is extremely limited: it is able to acquire knowledge about blood hosts by following only one uncertainty reduction process (tracking heat and CO2), and its knowledge remains wholly implicit. Other species have more extended capabilities, leading to a hierarchy of behavioral repertoires, from relatively simple and fixed behavioral patterns to increasingly complex activity, and greater flexibility to adjust behavior in the face of unforeseen events (Christensen & Hooker, 1999). Living beings with greater cognitive capacities are able to resort to a more varied repertoire of uncertainty reduction processes, and more importantly they are capable of generating new uncertainty reduction processes. For example, a cheetah is capable of evaluating its own performance when chasing a gazelle, and it can modify its behavior in order to achieve a successful outcome, by adapting its chase to the evasive moves of the gazelle. Thus, the cheetah exhibits what can be called first-order complexity in its ability to generate knowledge: it can learn about its prey (simple knowledge) and it can learn about generating new behavioral rules, generating new connections between facts and ideas, as it is attempting to resolve environmental uncertainty (in the case of chasing the gazelle, the uncertainty is about finding food). This distinction between simple knowledge and first order complex knowledge parallels Argyris and Schon's (1978) distinction between single loop and double loop learning. But knowledge generation is not limited to direct experience.

Living beings capable of sophisticated, abstract, symbolic communication display second-order complexity (Tsoukas & Hatch, 2001) in their generation of knowledge connections by using language and artifacts as scaffolds for cognitive activity (Anderson, 2003). Cognitive scaffolds are useful on two counts. First, they provide a reliable way to store previously acquired knowledge: memory differs from information retrieval because it involves the (re)construction of sense from past experience and allows for variations (Bartlett, 1932). For example, the very shape of a scythe indicates the proper move to cut wheat at harvest time. A tool thus embodies the knowledge that was used to create it, and using the tool is like remembering, it leads to the re-creation of that knowledge (Bachimont, 2005: 95). Second, cognitive scaffolds allow for the accumulation of ever greater quantities of knowledge, going beyond the cognitive ability of a single individual (Lorenz, 2001). Scaffolding allows knowledge generation in abstraction of direct experience, but it also influences how these knowledge-related activities are conducted and unfold. Knowledge of first-order complexity is contextualized in individual experience, knowledge of second-order complexity is contextualized in social and cultural experience, incorporated in artifacts, symbols and language. Therefore, knowledge of second-order complexity is not validated through direct successful experience but through social processes of intersubjectivity (Passeron, 1996). In that sense, knowledge is not "truthful" but "verisimilar" (Tsoukas & Hatch, 2001). This is consistent with the assumptions of procedural and fundamental uncertainty of the evolutionary perspective which imply that the uncertainty of the environment cannot be fully resolved.

Knowledge as a complex system

From the preceding discussion, knowledge appears in three forms: it is a structure, a process, and a system. Simple knowledge, that of the mosquito, consists of rule directing behavior instantiated in stable connections between facts and ideas. In this form, knowledge is a structure. Knowledge of first-order complexity incorporates feedback loops that allow for the emergence of new rules: knowledge is there seen as a process. Second-order complexity adds reflexivity: the scaffolding of cognitive activity through artifacts and language implies that knowledge is also a network of rule generating processes inter-linked through social interaction (Potts, 2001). Thus, the evolutionary perspective leads to a dynamic conceptualization of knowledge. In this light, knowledge exhibits characteristics of a complex system: it is sensitive to initial conditions, replete with feedback loops, non-linear, and recursively symmetrical (Holbrook, 2003). I discuss each in turn, with a particular emphasis on recursive symmetry, a topic not hitherto discussed.

Procedural and fundamental uncertainty combine to make the circumstances presiding to the emergence of new knowledge highly unpredictable. Knowledge processes unfold through space and time and are influenced by actors' intentions about the future, present actions and past experiences. Lane and Maxfield's (2005) account of technological innovation -arguably one instance of new knowledge generation- as a continuously re-interpreted narrative laden with surprises and new plot twists illustrates this sensitivity to initial conditions.

Knowledge as a process integrates many feedback loops. The evaluation of its performance compared to intentions or expectations (catching the gazelle) informs the learning of the cheetah (adjusting the chase to the evasive actions of the prey). At the level of second-order complexity, the validation of knowledge through social interaction also provides for powerful feedback loops: indeed, Latour (1987) even argues that the validation of new scientific knowledge has greater dependency on networks of social support than on the intrinsic qualities of the new theory.

Successfully reducing environmental uncertainty involves satisfying multiple and potentially conflicting criteria over time: this is an open-ended problem which does not lend itself to the formulation of an optimal solution ex-ante, but rather to the construction of a satisficing solution through a process of trial and error, where behavior is progressively tuned to attain successful performance (Christensen & Hooker, 2000). Such processes cannot be modeled through linear, cause-and-effect relationships, due to the impossibility of eliminating procedural and environmental uncertainty, thus calling for dynamical models (van Gelder, 1995).

Finally, knowledge is symmetrically recursive: it exhibits the same characteristics at different scales. At the level of individuals, knowledge consists of heuristics that reduce environmental uncertainty. Some of these heuristics give rise to social constructions: institutions (North, 1991), informal constraints and formal rules that emerge out of social interactions to stabilize behavior and reduce environmental uncertainty. These rules, sometimes also called routines (Becker, 2004) or conventions (Lewis, 1983) have been arbitrarily selected, and their value does not reside in their performative efficience, but in their relative stability in time and space. Heiner (1983) argues that the value attributed to stability is inversely related to the unpredictability of the environment: greater unpredictability is matched with greater behavioral stability, even at the expense of decreased performance, as the cost of finding an improved behavioral rule exceeds the potential gain in performance. Organizations, as a form of institution perform a second role in reducing uncertainty: they help alleviate some of the limitations inherent to individual cognition by operating a division of labor at the level of knowledge: they allow people to confront only a portion of environmental uncertainty, commensurate with the bounds of their cognitive abilities (Loasby, 1999). This division of labor implies that organizations are distributed knowledge systems, where everybody holds some of the collective knowledge but nobody holds all of it, and their successful operation implies the establishment of "collective mind" (Weick & Roberts, 1993). Organizations operating as collective minds face environmental uncertainty in much the same way that individuals do. Like individual living beings, organizations are dissipative systems: "organizations, thought to be stable, in fact keep falling apart and need elaborate maintenance systems to wards off threats to stability" (Weick, 1979: 58). Organizations need to secure resources in order to satisfy the conflicting needs of their stakeholders (Pfeffer & Salancik, 1978): just like individuals, organizations have to solve divergent problems that afford many satisficing solutions (Kogut & Zander, 1996: 514). They do so by finding satisficing routines through processes of trial and error (Cyert & March, 1963). In this process, organizations interact with each other and thus generate higher-level institutions: interactions between firms in markets lead to the emergence of "industry recipes" (Spender, 1983) where the successful knowledge generated by pioneering firms is imitated by others (DiMaggio & Powell, 1983). In this process, firms also establish networks of stable cooperative relationships which help to reduce uncertainty, and thus leverage and simultaneously constrain their actions (Gulati, Nohria & Zaheer, 2000). The relationships within these networks lead to the emergence of common understandings of industry practices and the replication of knowledge, mirroring the relationships established by individuals within communities of practice (Wenger, 1998). This leads to the establishment of behavioral regularities between organizations, which enable the coordination of their action. Networks thus do for organizations what organizations do for individuals: they operate a division of labor between firms, and reduce fundamental uncertainty by establishing predictable behaviors. Kogut (2000: 410) further notes that these behavioral regularities that emerge from these processes are "«irrational» from a perspective of economic organization": just like the routines that emerge between individuals, their value is in their relative stability, not in their performative efficience. Thus we find that knowledge as behavioral rules exhibits similar characteristics for individuals, organizations, and networks of organizations: it is symmetrically recursive. It is worth noting in this perspective that if uncertainty is reduced through division of labor and the imitation of successful heuristics at each level, it is not eliminated from the environment. Rather it is displaced to ever higher levels of integration: thus the concept of knowledge as a complex system is structured as a series of hierarchically nested levels which mirrors the structure of the universe in complexity theory (Holbrook, 2003: 22-23).

Conceptualizing knowledge in processual terms as a complex system leads to challenging traditional thinking about knowledge in terms of distinct, substituable types such as individual versus collective, or tacit versus explicit (Spender, 1998). Thinking in terms of substitutable types of knowledge appears to invariably lead to dismiss one of the terms of the alternative. For example, Nonaka & Takeuchi (1995: 239) dismiss the collective dimension of knowledge when they assert that "only individuals think". Similarly, Cowan et al. (2000) dismiss the tacit dimension of knowledge when they propose that all knowledge, potentially, may be codified. Such views have been criticized for over-simplifying knowledge: these "types" are interdependent and mutually constructed, rather than independent and substituable one from another (Nightingale, 2003). Thus it may be more appropriate to think of knowledge as consisting of interdependent dimensions. Complex systems are characterized by tolerance norms: they must remain within these boundaries, or otherwise collapse into chaos (Holbrook, 2003). The state of a complex system is informed by deformation dimensions that indicate how it has evolved relative to its initial state and its deformation limits (Ricordeau, 1997). Unlike traditional Euclidian coordinate dimensions that provide positions along a linear axis moving from infinity ($-\infty$) to infinity ($+\infty$), deformation dimensions provide positions moving between 0 and 1 on a circular axis. Figure 1 illustrates how deformation dimensions operate: the measure of the contrast of an image moves from 0 (all white -no contrast) to 1 (50% white, 50% black) back to 0 (all black, no contrast).

Insert Figure 1 about here

Thinking of knowledge in terms of deformation dimensions allows to capture the interdependence between tacit, explicit, personal and common knowledge: what matters may not be how much it is one or the other, but how much it has changed over time in each dimension. In the next section, I discuss each dimension in turn, then their relationships.

Four deformation dimensions of knowledge

The first dimension of knowledge is *personal* (Polanyi, 1962). The personal dimension refers to the embodiment of knowledge: it is nestled in an individual with differentiated perceptual and cognitive abilities. Personal knowledge consists of the behavioral rules developed by that particular individual through reduction of environmental uncertainty. This set of rules is evolutionary, but at the same time, it is relatively stable and defines identity.

The second dimension of knowledge is *common* (Lewis, 1983). This dimension captures the embeddedness of knowledge: knowledge is not generated in a vacuum, but in an interactive environment (Anderson, 2003). Second order complexity implies social interaction through language, symbols, and artifacts: the scaffolding of cognition that enables abstract knowledge is contextualized, and knowledge must be shared for intersubjective validation to occur.

Tacit is the third dimension. This captures the processual nature of knowledge: as we are generating new knowledge in action, we are not necessarily attentive to the knowledge for we are attending to the action (Chia, 2003). This reflects the bounds of cognition, and the fact that knowledge has a *from-to* structure: "we are attending from the theory to things seen in its light, and are aware of the theory, while using it, in terms of the spectacle that it serves to explain" (Polanyi, 1967: 17).

The fourth dimension is *explicit*. It refers to the retrospective unfolding of the knowledge process: once skilful performance has been achieved, it is possible to reflect and theorize about it (Ryle, 1949). Explicit knowledge thus leads to formalization and codification (Johnson, Lorenz & Lundvall, 2002).

As argued before, the four dimensions are interdependent and complementary, rather than independent and substituable. In the remainder of this section, I explore the relationships between the dimensions of knowledge. Relationships and interactions are operating on all dimensions simultaneously, but for the sake of clarity of exposition, this discussion will proceed by examining six pairs of interactions: personal - common, personal - tacit, personal - explicit, common - tacit, common - explicit, tacit - explicit. Together, these six pairs of relationships constitute a network of linkages, and provide an illustration of the systemic nature of knowledge.

Personal and common

Personal and common knowledge are mutually constituted. On the one hand, personal knowledge is built on common knowledge: classic research in psychology has shown that social interactions and language play a decisive influence in children's cognitive development (Piaget, 1976). Before it is possible for someone to learn to speak, there must be a language (Lorenz, 2001) in this instance, common knowledge precedes personal knowledge. Language acquisition is more than the mere learning of codes and symbols: it is a developmental process of differentiation and generalization, where conceptual thought progressively emerges: thought "does not merely find expression in speech: it finds its reality and form" (Vygotsky, 1962: 126). The processes of knowledge development at the individual level is are inseparable from artifacts and social interaction: personal knowledge is embedded in a wider socio-historical context which influences how it unfolds. On the other hand, common knowledge is progressively enriched by personal knowledge. Latour's (1987) studies of diffusion of scientific knowledge provide a template to describe how the process unfold. Scientific theory start as contestable assertions expressed by one researcher (or a small group of researchers) based on observations of laboratory experiments. These assertions are spread outside the laboratory through artifacts: publications, equipment, software, etc. These are then supported by networks of support: other researchers and institutions. Claims spread through these networks through the re-creation of the original experiments. The fate of individual claims is decided by the size of the networks and the variety of artifacts produced. Once challenges to theoretical claims stop, knowledge has been established: "the final transformation of a statement into a fact occurs when all traces of human agency are erased and replaced with a natural order. In this case, a statement has become so strong that it becomes part of the accepted background knowledge of science and perhaps society at large" (Ward, 1996: 100). Thus personal and common knowledge are mutually constituted, but this does not imply that they are the same: assuming that one individual, because her personal knowledge has been constructed from that of her social environment, holds in her knowledge all the knowledge of her society would assume potentially unlimited absorptive capacity (Cohen & Levinthal, 1990) and would dismiss the notion that common knowledge is distributed (Tsoukas, 1996). Conversely, assuming that an individual's knowledge only consists of the knowledge of his social environment would lead to negate his identity.

Personal and tacit

The interaction between these two dimensions highlights the experiential nature of knowledge: personal knowledge is embodied, and tacit knowledge is instantiated in action. According to Ryle (1949: 30) the interplay between these two dimensions of knowledge is the necessary precondition to the formulation of propositional knowledge: "it is therefore possible for people intelligently to perform some sorts of operations when they are not yet able to consider any propositions enjoining how they should be performed". Ryle further insists that the other sequence, involving theoretical knowledge guiding successful performance is absurd: if this were the case, then it would be impossible for anyone to create any new knowledge. The combination of personal and tacit knowledge thus highlight that knowledge is not only a set of rules linking facts and ideas, but also a capacity to act, an ability to apply the rules even when one is not aware of their explicit formulation (Chia, 2003).

Personal and explicit

If knowledge initially stems from successful physical action, it does not necessarily mean that all new knowledge is tacit before it is explicit. The level of second order complexity suggests that cognitive activity in itself is a valid way to generate new knowledge. However, this does not occur through the algorythmic manipulation of symbolic representation as argued by proponents of cybernetics or artificial intelligence (Anderson, 2003). Rather, another kind of symbolic manipulation, where the symbols are concrete rather than abstract, localized rather than universal is suggested by analogical reasoning (Gentner, 1983). This is when the properties of something already known are mapped onto a new object as a metaphor, in order to gain knowledge about the new object. It has been argued that such analogical reasoning, combining personal experience and symbolic manipulation of metaphors, is a rich source for new technological innovations (Magee, 2005), scientific theories (Cornelissen, 2005) and strategic breakthroughs (Gavetti, Levinthal & Rivkin, 2005).

Common and tacit

Organizations reduce uncertainty in two ways: by operating a division of labor at the level of knowledge, and by instituting stable behavioral patterns. This requires both coordination (Kogut & Zander, 1996) and cooperation (Grant, 1996a). Coordination is achieved through a set of shared conventions (Lewis, 1983), regularities in belief or action that everyone conforms to, and expects everyone else to conform to. As conventions are arbitrary, they are not necessarily the most efficient, but their stability provides for satisficing levels of performance. Cooperation is obtained through convergence on means, the operation of mutually beneficial actions. Weick (1979) suggests that this is achieved through stable patterns of interaction: interlocked behaviors. Over time, such interlocked behaviors give rise to routines, established in action and as such wholly tacit (Cohen & Bacdayan, 1994). Thus, knowledge that is both common and tacit is at the heart of the foundations of knowledge-based theories of the firm. In this perspective, firms exist because they allow to reduce uncertainty in ways that are complementary to other types of institutions (North, 1993), not because they are the outcome of "market failures" (Williamson, 1975), nor because they contain "more of it" (Kogut & Zander, 1996: 516).

Common and explicit

At the core of the interaction between the common and explicit dimensions of knowledge is Wittgenstein's insight that there can be no private language (Wittgenstein, 1953). Though common knowledge need not be explicit, much of our common knowledge is expressed formally. This is due to the fact that knowledge that is not experiential, knowledge of second-order complexity, finds justification not in successful action but through social processes of intersubjectivity. The processes of validation of scientific knowledge described by Latour (discussed above) rely crucially on artifacts: knowledge that has been formalized, and expressed in explicit ways.

Tacit and explicit

Polanyi's phenomenological approach to tacit knowledge is founded on the interplay between tacit and explicit knowledge. Because of the limitations of our cognitive apparatus, we can only focus consciously on one task at a time, and thus tacit knowledge is used to make sense of explicit knowledge: knowledge has a *from-to* structure (Polanyi, 1967: x). The interdependence between tacit and explicit knowledge at the level of individuals identified by Polanyi finds mirror images at the levels of organizations and networks of organizations: knowledge exhibits recursive symmetry, and so do the relationships between knowledge dimensions. Within organizations, tacit routines and conventions perform a critical role: as informal practices, they inform and frame the application of formal rules (Crozier, 1980) as no set of rules can envision all contingencies (Tsoukas, 1996: 16). Relationships between organizations within networks of wholly informal relationships, guided by implicit rules exhibit the same properties: "the network is itself knowledge, not in the sense of providing access to distributed information and capabilities, but in representing a form of coordination guided by enduring principles of coordination" (Kogut, 2000: 407).

This set of interactions allow to account for the richness of knowledge as a concept. The complexity conceptualization of knowledge also suggests that many contradictory results of extant research related to knowledge in organizations -for example that knowledge can be managed, provided that the appropriate systems and processes are in place (Soo, Devinney, Midgley & Deering, 2002) versus the view that it cannot be managed (Alvesson & Karreman, 2001)- are not necessarily the outcomes of mutually exclusive perspectives, but also reflect complementary, albeit partial, views of the same phenomena. The depth of the complexity perspective offers opportunities to re-frame and re-interpret past results, and to open new avenues for research. In the next section I explore some of these, and attend to communities of practice, entrepreneurship, the role of managers, and knowledge management from the complexity view of knowledge.

Contributions to a knowledge-based complexity theory of organizations

Dimensions of knowledge and communities of practice

The interactions between the four dimensions of knowledge provide the opportunity to enhance and extend the arguments put forward by researchers focusing on communities of practice. One of the salient features of shared workgroup identities is that they enable the integration of individual knowledge (Brown & Duguid, 1991). This shared context provides for the tacit cues that enable the sharing of knowledge, through the interpretation and re-interpretation of stories and narratives (Patriotta, 2003). The existence of these shared frames explains why knowledge is more easily shared within than between communities (Cook & Brown, 1999). Research on communities of practices thus explore the common, tacit, and explicit dimensions of knowledge. But this strand of research pays relatively less attention to the personal dimension of knowledge and the role of scaffolding and action in knowledge re-creation. The complexity perspective suggests that the process of knowledge sharing is not complete until knowledge has been re-enacted. The "war stories" shared by photocopier technicians (Orr, 1996) or call-center operators (Tsoukas & Vladimirou, 2001) only become salient in action, they are validated in a process similar to that of researchers when they re-construct in the laboratory the experimental results reported in scientific journals by their colleagues (Latour, 1987). Thus to acquire new knowledge on the basis of the experience of another member of the community, an individual must possess the background knowledge necessary to make sense of the narrative, and *then* re-create in action the experience that was related. Much like remembering for an individual involves the re-production of a memory, the process of sharing knowledge within a community of practice is only complete when it is re-created in action. The argumentation proposed here does not deny the relevance of communities of practice as a focus for analysis and research, but leads to a more measured view on some claims about knowledge sharing and transfer, in that sharing and interpreting narratives is only the first step of a process of knowledge re-creation. In this perspective it is worth remembering that communities embody only one level of knowledge processes (Crossan, Lane & White, 1999): the work of a community needs to be coordinated with that of the other units within the firm. Communities are embedded in a wider context (Nonaka & Konno, 1998) and their contributions cannot always be understood in isolation.

Initial conditions and entrepreneurship

Initial conditions have a critical influence on the evolution of firms as knowledge-based complex systems (Anderson, 1999: 217). Thus the complexity concept of knowledge has relevance for entrepreneurship and new business creation. Spender (1998: 247) argued that entrepreneurs select both the environmental uncertainty their new firm resolves and its initial endowment of components and structure. Organizational culture and identity then emerge from these initial conditions through the interactions of the components and the environment. The complexity concept of knowledge leads to reverse this perspective: the notion of organizations emerging out of interlocked behaviors suggests that people start to cooperate by converging on common means first: common ends come second (Weick, 1979: 90-95). In other words entrepreneurs start by creating a company, establishing shared values and identity before they select which products and services to offer (Collins & Porras, 1995: 81-87). In other words organizational culture and values shape the interactions with the environment (Tsoukas, 1998) before they evolve through feedback loops.

The manager's job

The perspective of complexity frames managers in a paradoxical situation: because they are part of the causal loops they try to comprehend, their understanding is imperfect and their actions impact with unintended consequences the processes they are trying to control (Tsoukas & Hatch, 2001). The knowledge-based theory of the firm suggests that organizations reduce environmental uncertainty through two mechanisms: first, they discover successful heuristics through processes of trial and error; second, they scaffold their search on the knowledge held by other organizations in their networks of relationships. This suggests two dimensions for the role of the manager.

The first dimension is rule distillation. This is an emergent process, drawing on reflexive observation of the interactions of the firm with its environment: rules proceed from successful performance, they do not precede it. By stepping back from the action, managers can best position themselves to reflect on the performance of their collaborators and devise rules for action. But the dynamic nature of knowledge processes implies that rules and routines are evolutionary and do not suffice in themselves to stabilize organizations. Cooperation is sustained by regularities in behavior, coordination is sustained by regularities in belief. Values form the background to make sense of organizational knowledge and action. This suggests that managers create value for their organizations by bestowing them values (Weick, 1995). As mentioned before, managerial actions interact with the processes they intend to manage: this suggests that organizations may be monitored -their performance can be recorded *ex-post*- but not controlled through the setting of targets *ex-ante*. This does not mean that managers should disregard objectives and targets, rather they should concern themselves with the values they embody.

The second dimension is boundary management. Previous research suggests that organizations develop one dominant knowledge process (Daft & Weick, 1984) and that knowledge exploration entails investments and processes incompatible with knowledge exploitation (Wright, Van Wijk & Bouty, 1995). Thus trying to accommodate different knowledge processes within the boundaries of the organization (e.g: Nonaka & Toyama, 2002) may not always be met with success. Rather, managers should think about organizational boundaries outwards as well as inwards: managers may find that network partners hold knowledge that complements their own (Kogut, 2000). In this respect, outsourcing knowledge work that is not well supported by the firm's dominant process makes sense (Quinn, 2000).

The complexity lens thus leads to define the manager's job in terms of shaping the context of organizational activity (rules, values, boundaries) rather than directing organizational action. By shaping the context of organizational action managers enable (and perhaps also sometimes disable) the performances of other organizational actors. It is in this respect that organizations are more than mere aggregations of teams and communities of practice: subgroupings may hold differentiated identities, but they also share common values. Organizations are contexts in which activity systems unfold, and corporate failures and "normal accidents" (Perrow, 1984) are not usually the result of faulty rules or individual failures, rather they are more likely the consequence of mindless cooperation and breakdowns in coordination (Weick & Roberts, 1993).

Implications for knowledge management

The previous section has far-reaching implications for knowledge management as an organizational activity: if organizations cannot be controlled, can knowledge be managed? If knowledge is not transferred, but re-created in action, can knowledge-processes be reliably directed? As such, it appears that knowledge cannot be managed in the functionalist sense of the term, and this is in great part reflected by the evolution of knowledge management theories since the early 1990s (cf. Snowden, 2002). Does this imply that organizations should give up on knowledge management?

The description of the manager's job suggests that knowledge management is like all other managerial activities: it requires second-order complex thinking and action. Managers cannot directly manage knowledge, but they can purposefully influence the contexts in which knowledge processes unfold. By acting indirectly on knowledge processes, managers can escape the chaotic loop of trying to control a process in which they are embedded. Paying attention to the four dimensions of knowledge is useful in this context: too often, knowledge management efforts emphasize the common and explicit dimensions because they appear more readily controllable. Our discussion suggests that the interaction of personal and explicit knowledge in analogical reasoning (as opposed to digital processing) may hold great potential for knowledge creation. Finally, the notion that the re-creation of knowledge in action is not a like-for-like process of reproduction suggests that the interaction between personal and tacit knowledge has also relevance for the management of creativity and innovation.

A complementary approach to the question of the management of knowledge is the question whether knowledge is an asset. If knowledge consists of connections between ideas and facts, then the growth of knowledge is effected through the creation of new connections, but also the destruction of connections. In other words, the evolution of knowledge cannot be tracked by the density of connections -greater density is not associated with more or better knowledge- neither is it associated to the stocks of facts or ideas, rather the evolution of knowledge is quite possibly independent of these -more facts and/or more ideas do not necessarily convert into more knowledge (Potts, 2001). Therefore thinking of knowledge in terms of a stock or asset makes little sense, and this is a second reason why knowledge cannot be managed.

Pfeffer and Sutton (1999) in a paper on knowledge management propose that high performance is driven by knowing "why", rather than knowing "how" or "what", a proposal consistent with the argumentation put forward in the preceding paragraph. The authors also argue that there is a “knowing-doing gap” (Pfeffer & Sutton, 1999: 85) between identified good practice and its implementation by organizations, implying that organizations know more than they do. They attribute this discrepancy to the difficulty of transferring knowledge and best practices between and within organizations, and to various forms of organizational inertia. But in doing so, Pfeffer & Sutton fall into the trap of believing that there is a "ghost in the machine" (Ryle, 1949): they assume that because explicit knowledge has been diffused then it can be applied -in other words that theory precedes action- and that it is enough for the CEO to order that a technique be implemented that it will -there is a central controller in the organization directing the work of other, a "brain" controlling the "body". In doing so, the authors are downplaying the complexity of knowledge, and the subtlety and dynamics of knowledge processes. As argued previously, the diffusion of explicit knowledge is only one step in the knowledge re-creation process. Successful knowledge re-creation also implies a shared cognitive frame, and the individual appropriation of knowledge through successful action. This suggests that the gap may well be the other way around: it could be a "doing-knowing" gap. Before they can adopt improved practices, organizations must first reflect on their existing routines and procedures and understand how these impact performance. This also suggests that organizations may also need to "forget" (de Holan, Phillips & Lawrence, 2004) before they can improve their performance.

Implications for research

The conceptualization of knowledge outlined in this paper also has implications for theory making as a knowledge process. The lens of knowledge as a complex system suggests that like that of the manager, the work of the researcher may be paradoxical. The complexity of multi-dimensional, complex, rich, knowledge processes call for multi-faceted, longitudinal, narrative case studies in order to capture the complexity of the phenomena they are attempting to study (Tsoukas & Hatch, 2001) and build longitudinal analytical frameworks to capture interactions over time (Langley, 1999). At first sight, the call to incorporate detailed, multi-faceted narratives in research under the complexity framework would seem to sacrifice simplicity for accuracy and generality. However, two arguments weigh in favor of another trade-off. First, the notion that complex systems are governed by simple rules implies that simplicity may not be sacrificed. Second, it can also be argued that organization studies cannot be purged of local contingencies: Tsoukas (2001: 10). So that theories should be tailored for local contexts: accurate and simple, but not necessarily general.

Mahoney and Sanchez (2004) put forward similar arguments and advocate a process of research and theory making where managers have a bigger place. The authors suggest that academic researchers make explicit the tacit knowledge managers have accumulated through action and incorporate it in their theories. They argue that this is a way to produce research with greater relevance and practical applicability. The theory of knowledge as a complex system suggests that there might be more to the research process, and that subordinating researchers' activities to managerial preoccupations may not be advisable at all times. This is not because research is a "noble" activity with a higher status than mundane managerial tasks, but because theories do not describe a world "out there" waiting to be discovered, but means to act in the world, and in doing so, shape it (Hatchuel, 2005). Theory making is about reflexive tool-building, involving recursive processes of trial-and-error, where skillful performance appears first, and then is generalized into a theory for action. The complexity frame calls for an evolutionary theorizing process, but not necessarily one that operates only in the head of the researcher (Weick, 1989). This is the second paradox of knowledge as a complex system: researchers need to act before they can theorize. This does not exclude intentionality and problem-solving goals, but requires for interactive research set-ups where managers are involved at all stages, for example action research (Reason & Bradbury, 2001). It is in a second phase that researchers can reflect and theorize, with the aim of informing future action.

Conclusion

The evolutionary perspective deployed in this paper has lead to define knowledge as a complex system made up of four deformation dimensions. In this view, knowledge is simultaneously:

- A structure: a set of connections between ideas and facts that reduce environmental uncertainty and produce heuristics guiding action. In that sense, knowledge is a capacity to act.
- A process: knowledge of first-order complexity incorporates feedback loops that enable the generation of new heuristics, it is contextualized in individual experience.
- A system: knowledge of second-order complexity scaffolds on artifacts language and symbols to enable reflexivity, it is contextualized in social experience.

This conceptualization offers elements of answers to some of the critiques that have been addressed at knowledge-based theories of the firm, and knowledge management:

- It provides a clearly articulated definition of knowledge, which explicits the relationships between knowledge in individuals and knowledge in organizations. As such, it can be argued that the concept of knowledge as a complex system emerging from uncertainty reduction provides the micro-foundations for a knowledge-based theory of the firm, where firms are devices that reduce uncertainty for individuals in two ways. Firms reduce procedural uncertainty by accommodating some of the cognitive limitations of individuals, and they reduce fundamental uncertainty by stabilizing individual behavior, making the actions of others less unpredictable. It is worth noting here that from this firms do not emerge because of behavioral characteristics of people (e.g. Conner & Prahalad, 1996), nor because other institutions are dysfunctional (e.g. Williamson, 1975).

- As a system of connections between fats and ideas, it is difficult to think of knowledge as an asset: the growth of new knowledge may involve the creation and destruction of connections, so it is possible that the growth of knowledge is accompanied by a decrease or an increase in connections. This is consistent with the conclusion that knowledge itself cannot be managed, only the context in which it unfolds. This conclusion does not deny the possibility and salience of knowledge-based assets, on the contrary, but it makes it cleat that the processes by which they are obtained cannot be reliably directed *ex-ante*, only recorded *ex-post*.

- Acknowledging the interdependence between the four deformation dimensions (personal, common, tacit, explicit) allows to account for the richness of the manifestations of knowledge, and does not lead to privilege one dimension over another.

- The notion that knowledge is a concept system allows to account for its procedural and dynamic nature.

- The perspective of complexity leads to think about the manager's role in terms of second-order complexity. This has led to outline the role of managers not as directing other people, but as enabling the performance of collaborators by shaping the organizational context (rules, values, boundaries).

Finally, it must be acknowledge that this conceptual discussion is only a first step towards a complexity theory of knowledge: the arguments put forward here have to be tested through action, and through intersubjective evaluation. Further, much work remains to be done: if the concepts proposed here are valid, then that many of the tools available in the social sciences at large, including economics and management, have to be revisited as they incorporate -at best- only partial concepts of knowledge.

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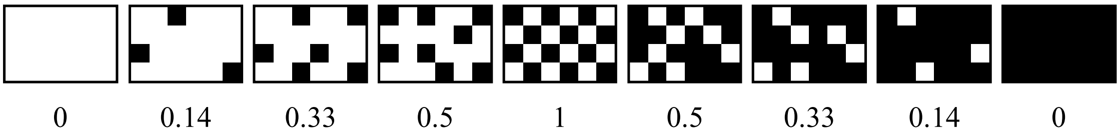
Figure 1: contrast as a deformation dimension



Adapted from Ricordeau (1997), available online at: www.quatuor.org/home.htm