Domains, Ontologies, Models and the Knowledge Creation Cycle

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Abstract

Corporate prosperity (or survival) depends on the ability of an organisation to learn about its environment. Learning focuses on the ability of an organisation to sense (or anticipate) dissonance in the interaction between an organisation and its environment, and to devise some appropriate response. The intellectual capital of an organisation provides the basis to learn, sense and respond. Each behavioural shift provides an opportunity to refresh the repository of intellectual capital.

Intellectual capital can be considered to be formed from some ensemble of knowledge assets. Knowledge, however, is an elusive commodity. Primarily, knowledge is held subconsciously in a tacit state defying any attempt at elicitation. The focus of this article is a conceptual exploration of various cognitive devices aimed at transforming knowledge from a tacit to an explicit state. The exploration is conducted from the perspective of the lifecycle trajectory of a knowledge asset. Of particular interest is the relationship between the epistemological and ontological dimensions of knowledge creation.

Knowledge elicitation depends crucially on the conventions adopted to express and arrange concepts that may have only a tenuous and fragmented presence. As a knowledge asset matures and becomes available for more rigorous and robust definition, the requirement emerges for more sophisticated means of articulation. Knowledge assets are represented as multi-faceted objects supporting a diversity of interrelated abstractions and perspectives specified by some modelling convention.

Paradigmatic focus and modelling conventions determine the semantics available for the articulation of a knowledge asset. Inappropriate semantics may introduce cognitive barriers to knowledge elicitation. Conversely, semantics reflecting better the complexities of a knowledge asset may result in comprehensive elicitation and provide extended opportunities for exploitation. The article concludes by providing a brief discourse on the models required to specify essential abstractions and perspectives describing a knowledge asset.

1. Introduction

The concept of knowledge invites various interpretations and definitions, many of which offer valuable perspectives and insights. Of particular interest for the purposes of this article are definitions seeking to establish the distinction between phenomena, data, information and knowledge.

An understanding of the nature of knowledge provides a foundation for exploring the dimensions of knowledge creation. The analysis commences with a brief account of the epistemological and ontological dimensions of Nonaka and Takeuchi's (1995) knowledge creation spiral. Of particular interest is the proposition that a knowledge asset is likely to encounter multiple ontologies during its spiral trajectory. Boisot (1995, 1998) provides an extended epistemological definition by introducing abstraction and codification dimensions to the dynamics of the knowledge creation cycle. Thus ontology is reconsidered in terms of the adopted abstraction and codification conventions.

Cognitive devices such as archetypes, metaphors, analogies and models are deployed to transform tacit knowledge into an explicit state. The success of this trajectory depends upon the judicious selection of appropriate abstraction and codification conventions to support a multiplicity of perspectives. Moreover, knowledge assets engage new ontologies as they are disseminated through the organisational strata of an enterprise. A description is provided of the role of models in the dissemination of knowledge.

An organisation's intellectual capital is maintained within a web of knowledge domains as an integrated series of functionally cohesive models. The structure and design of domains is described in some detail with particular emphasis on the necessity for them to support a variety of cognitive strategies. The basic architecture for a knowledge domain is described in terms of a framework comprising the series of models required to express a variety of perspectives of domain abstractions. Attention turns finally to the imperative to adopt (or devise) a modelling convention capable of expressing knowledge in an integrated network of abstractions and domains while maintaining a presence in multiple ontologies.

2. What exactly is knowledge?

The Concise Oxford Dictionary offers the following definitions: awareness or familiarity gained by experience; a person's range of information; a theoretical or practical understanding of a subject, language, etc; the sum of what is known; true, justified belief, certain understanding as opposed to opinion.

As with any substantive concept, it emerges that knowledge is a multi-faceted and interconnected entity. At some level of abstraction, knowledge represents what is known and is related to concepts such as awareness, familiarity, experience, information, theory, practice, understanding, belief and judgement, i.e. knowledge has context. But what exactly is this context and what is its intrinsic relationship to knowledge?

Rather intriguingly, Cleveland (1982) asserts that T.S. Eliot's poem 'The Rock' was the first reference to suggest some context for knowledge with the following extract:

> Where is the life we have lost in living?
> Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information?

Sharma provides an interesting account of the development of a definition for the context and structure of knowledge. Ackoff (1989) provides the following categorisation for 'the content of the human mind':

- Data: raw symbols that simply exist
- Information: data that is given meaning through relational connection
- Knowledge: useful collection of appropriate information
- Understanding: cognitive and analytical synthesis of new knowledge from existing knowledge
- Wisdom: to judge and by so doing produce understanding where there was no previous understanding

Ackoff adds a temporal dimension to the hierarchy claiming that information 'ages rapidly', knowledge 'has a longer life-span', understanding 'has an aura of permanence' and wisdom 'is permanent'. A view endorsed by Boisot's claim (1995) that entropy drains knowledge of any value as utility and scarcity are diminished.

Checkland and Howell (1998) define IS (Information Systems) as the context for IT (Information Technology), and proceed to express disquiet about the confusion characterising much of the literature on IS. Of concern are the absence of definitions for basic concepts such as data, information and knowledge, and theory predicated on redundant interpretations of 'management and organisation' (Brinklow, 2004). The focus for this report is to explore their approach to defining the distinctions between data, information and knowledge. Data is taken simply to represent facts about the world. Capta means 'to take' and represents that subset of data filtered for specific attention or further processing (Checkland, 1982); i.e. not all data is subject to particular scrutiny. Information represents the 'attribution of meaning' (Howell, 1989) to the capta by placing it in some context and thus enriching its significance; i.e. information is meaningful capta. Knowledge represents larger structures of information enjoying greater longevity than many items of information which are only 'ephemerally meaningful and relevant'. Checkland and Howell enjoy some resonance with Ackoff but fail to deliver a persuasive account of knowledge. Is knowledge simply a matter of size and longevity? Surely not!

Both Ackoff's, and Checkland and Howell's approach to defining knowledge pose conceptual difficulties. Bellinger *et al* (2004) prefer a hierarchy comprising simply data, information, knowledge and wisdom, with understanding achieving the transition through the categories.

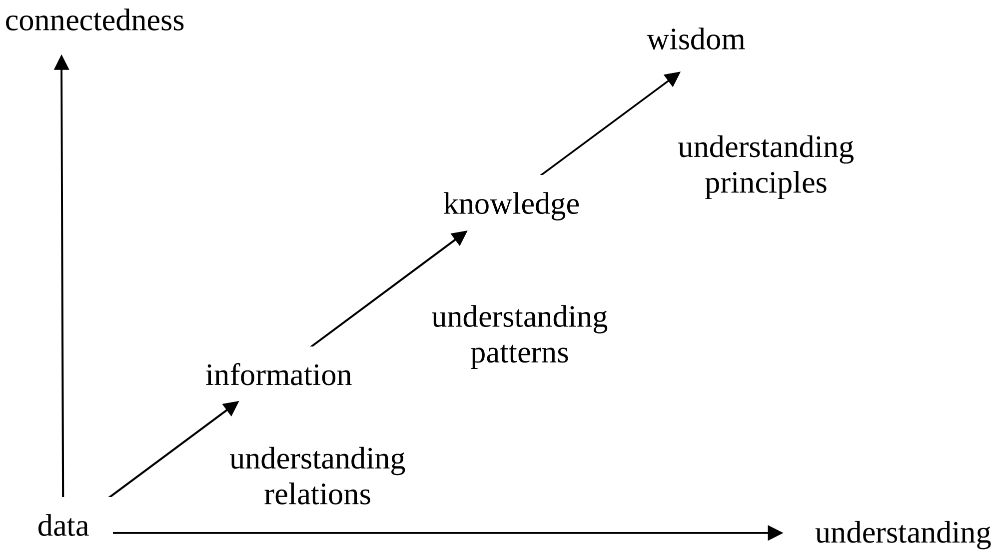

Figure 1. The data, information, knowledge and wisdom hierarchy (Bellinger *et al*, 2004)

The key to their hierarchy is achieving levels of understanding. In common with the earlier approaches, data may be viewed as some disconnected collection of facts about a domain that have little intrinsic interest. Information emerges from the domain when relationships between the facts are established and understood; this is somewhat richer than simply establishing a context for the facts. Knowledge emerges when the patterns of relationships are identified and understood; a quite different perspective from size and longevity. Finally wisdom (the pinnacle of understanding) uncovers the principles that describe the patterns of relationships. This approach is much more encouraging and yet fails still to capture the essence of knowledge. Another perspective is required, and for this it is necessary to turn to the Knowledge Management community.

Nonaka and Takeuchi (1995) offer three observations concerning the relationship between knowledge and information:

- Knowledge, unlike information, is about beliefs and commitment; it is a function of perspective and intention
- Knowledge, unlike information, is about action; it is purposeful
- Knowledge, like information, is about meaning; it has context and connectedness.

Knowledge is considered to be ‘a dynamic human process of justifying personal belief towards the “truth” ’. Bateson (1979) and Dretske (1981) hold that information carries signals providing the basis from which to elicit and express knowledge. Information therefore is a flow of messages yielding knowledge ‘anchored in the beliefs and commitments of the holder’.

Boisot (1998) recognises the imperative to establish the distinction between data, information and knowledge, and provides the following definitions:

- Data is simply the discernable difference between alternative states of a system.
- Information is data that modifies expectations or condition readiness of the observer. The more expectations are modified, the more the information quotient of the data.
- Knowledge is the set of expectations and a disposition to act held by an observer.

In summary, knowledge structures are modified by the arrival of new information extracted from data generated from phenomena.

3. The dimensions of knowledge creation

There are clear affinities between the work of Nonaka and Takeuchi (1995) and the earlier theories of organisational learning, but they make the point that these former hypotheses do not incorporate the concept of knowledge creation. In particular, Nonaka and Takeuchi take exception to the assumptions implicit in Argyris and Schön's theory of double-loop learning (Argyris & Schön, 1978; Schön, 1987 & 1991). They argue that the theory is predicated on an assumption of 'rightness' and the necessity for intervention from some internal agency; whereas, in reality, organisations continuously create new knowledge by reconstructing existing behaviour, perspectives, culture and beliefs. A broad criticism of literature addressing organisational learning is the absence of any guidance on how to actually create knowledge; by rectifying this deficiency, Nonaka and Takeuchi claim to establish the difference between a knowledge-creating company and a learning organisation.

For the knowledge-creating organisation, knowledge is believed to be created in a cyclical trajectory simultaneously between ontological and epistemological planes, with spiral progression defining the conversion and mobilisation of tacit knowledge (see Figure 2). In broad terms, ontology is taken to address the nature of being and reality, while epistemology explores the theory of knowledge with respect to validating what may be accepted as expressions of being and reality. Ontology is adopted to denote the dimension that represents the dissemination of knowledge throughout the diversity of strata describing an organisation. This is a quite profound denotation as it draws attention to the fact that ontology may change with the transition between strata. The orthogonal dimension of epistemology represents the dynamic relationship between tacit and explicit knowledge; in particular, the mutuality of tacit and explicit knowledge creation.

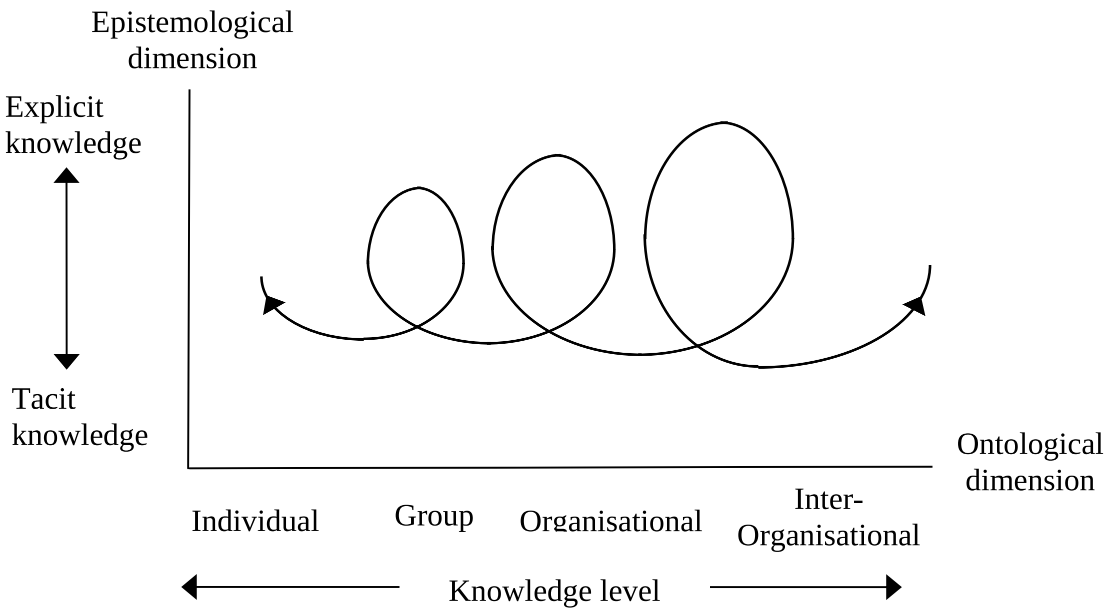

Figure 2. Nonaka and Takeuchi's Spiral of Organisational Knowledge Creation

Nonaka and Takeuchi succeed in providing an elegant expression of the dynamics of organisational knowledge creation in a 2-dimensional space. Boisot, however, transforms the epistemological dimension into a 2-dimensional space by applying the proposition that cognitive activity employs the two economising techniques to extract information from data: coding and abstraction. Therefore, following Boisot's approach, the dynamics of organisational knowledge creation must be expressed in a 3-dimensional space (see Figure 3).

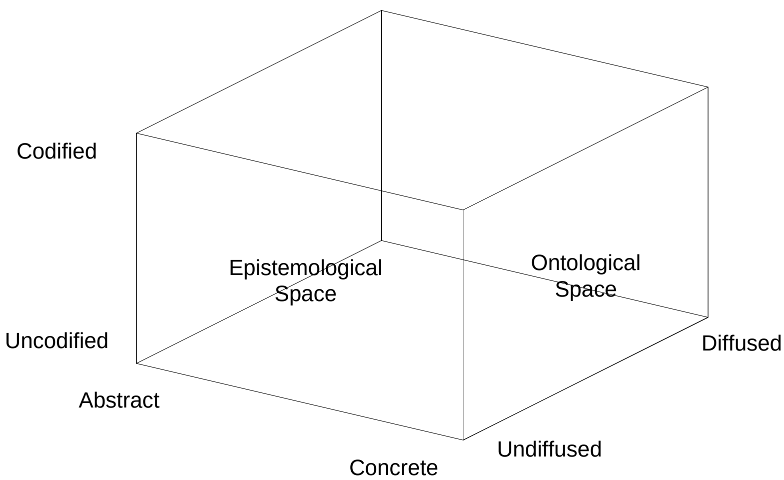

Figure 3. Boisot's Information (I)-Space (1995)

3.1 Codification within the I-space

Boisot holds that codification creates perceptual and conceptual categories facilitating the classification of phenomena (Boisot, 1998). Effective codification is taken to be 'partly a matter of intellectual and observational skill – an ability to discern contour and form in the data of experience'. Critically, the greater the number of distinctive attributes describing a phenomenon, the more complex the act of codification.

Codification seeks to select between competing perceptual and conceptual phenomena, with this act of selection associating complexity with codification. The level of data processing required to complete a task increases with complexity and with the absence of codification conventions. Uncodified knowledge requires a prohibitive amount of data to describe a phenomenon and is resistant to rational analysis and communication. By contrast, codified knowledge requires only minimal data to describe a phenomenon. Thus development of codification conventions entails moving away from the uncodified end and towards the codified end of the spectrum, 'from the inarticulate to the articulate, from the complex towards the simple'. Boisot makes the intriguing observation that while the pursuit of efficiency leads to higher levels of codification, the pursuit of effectiveness (or flexibility) exerts pressure in the opposite direction towards uncodified data.

3.2 Abstraction within the I-space

Codification is the result of perceptual and conceptual activity. However, perceptual activity is predicated on some conceptual framework and interpretation of what is perceived. Boisot argues that conceptual data is derived from organising perceptual data into abstract categories. Abstraction provides the second dimension to epistemological endeavour and is linked inextricably to codification. Abstraction and codification provides complementary perspectives to phenomena: codification provides form while abstraction offers structure.

Boisot describes abstraction as a form of reductionism where the few represent the many to shape the categories employed to interpret phenomena. Abstract and concrete knowledge define the polarities of the abstraction spectrum. Concrete knowledge is 'predominantly perceptual and local', yet rich in causal structures and meaning that may be impenetrable. In contrast, abstract knowledge supports conceptual and remote speculation, but at the cost of shedding richness and meaning.

3.3 Abstraction and Codification within the I-space

Abstraction and codification provide complementary strategies for managing complexity:

- Codification facilitates abstraction by enhancing the facility to provide categorical definitions for behaviour, structure and connectivity.
- Abstraction enhances codification by reducing and organising the number of categories under consideration.

The application of abstraction and codification transforms knowledge into an asset that is at once both expressible and shareable. Boisot draws from Popper (1972) to introduce the qualification that abstraction and codification introduce a ‘hypothetical flavour’ and ‘provisional quality’ to articulated knowledge and is thus always subject to revision.

3.4 Dissemination within the I-space

Diffusion is the term adopted by Boisot to express the dissemination of knowledge throughout an organisation and corresponds to Nonaka and Takeuchi’s ontological dimension. Boisot makes the distinction that diffusion addresses simply the availability of knowledge and not its adoption.

Boisot recognises that dissemination of knowledge is exposed to the problems identified by Shannon and Weaver (1949) that impact any communication process:

- Technical - is the message received the same as the message sent?
- Semantic - is the message received understood?
- Pragmatic - is the message received acted upon as understood?

Technical issues are involved with transmitting and receiving a message. The second problem is one of semantics: do the sender and receiver share the same abstraction and codification conventions, and are they interpreted and exploited in the same way? The pragmatic concern is whether the sender and receiver share not only the same abstraction and codification conventions, but also common values, attitudes and motivations.

Returning to Nonaka and Takeuchi’s definition of the ontological dimension, it is clear that Boisot’s diffusion spectrum shares the same characteristics; i.e. diffusion of knowledge commences with an individual to transcend progressively through the strata of an organisation and beyond to the external environment. The issue therefore is that each stratum provides a new ontology to engage the knowledge asset. Engagement may result in one of the following outcomes, the knowledge asset may be: absorbed, revised or rejected by the new ontology. Diffusion is thus dependent on the availability of knowledge to a given population, and the ontological absorption and exploitation of knowledge within that population.

4. The dynamics of knowledge creation

The dynamics of knowledge creation have been described previously (Brinklow, 2004) within the context of the epistemological space; this is, however, to neglect the dynamics of the ontological dimension. It was shown that systemic entropy deprives knowledge of essential utility and scarcity, creating the circumstances required to invoke a new cycle of knowledge creation. The ontological dimension provides a new insight into the origins of systemic entropy.

Transferring the concept of chaotic, ordered and complex organisational behaviour to the I-space, it is possible to translate the definition of knowledge creation within this framework. The chaotic zone (with maximum entropy where the value of knowledge is at a minimum) is where knowledge is uncodified, concrete and fully diffused. In contrast, the ordered zone (with minimum entropy where the value of knowledge is at a maximum) is where knowledge is codified, abstract and undiffused. The zone of complexity occupies the space between the chaotic and ordered zones.

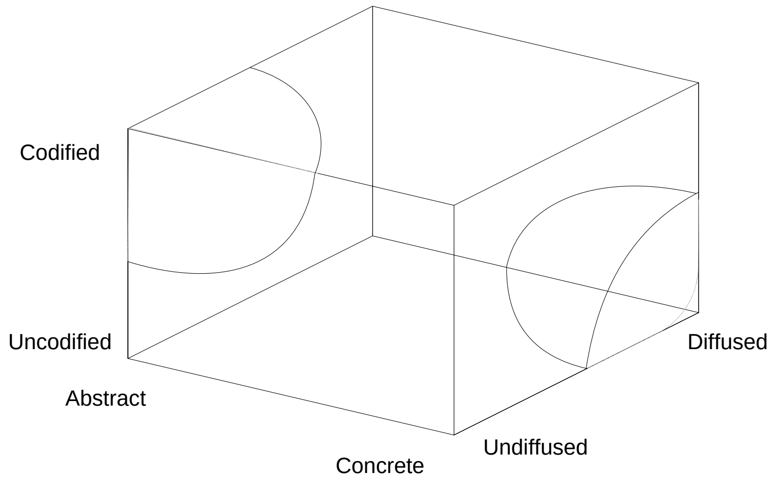

Figure 4. Zones of Order, Complexity and Chaos in Boisot's I-space (1998)

Knowledge asset value is created in the complex zone during the cognitive ascent from chaos to order, and exploited in the descent from order to chaos. A fully realised cyclical knowledge creation trajectory within the I-space is described as follows:

- The trajectory commences within the concrete and uncodified (i.e. chaotic) region of some remote ontology.
- The trajectory descends through the ontological strata to that of an individual and invokes tacit cognitive activity.
- The tacit cognitive activity yields a knowledge asset which moves through the zone of complexity (the value creation phase) towards the ordered region of abstract and codified enunciation, i.e. some representation of the knowledge asset becomes explicit.
- The knowledge asset now ascends through the ontological strata, with each transition offering the opportunity to exploit the potential value of the knowledge asset and progress to more remote ontological regions.
- At some point, a knowledge asset will encounter its ultimate ontology (beyond which is has no meaning) and descend to the region of chaos where its value is vulnerable to decay.
- A knowledge asset can, of course, continue to endure in interim ontologies and yield value before entropy beckons.
- Eventually, entropy ensures that the value of a knowledge asset will decay in all ontologies.

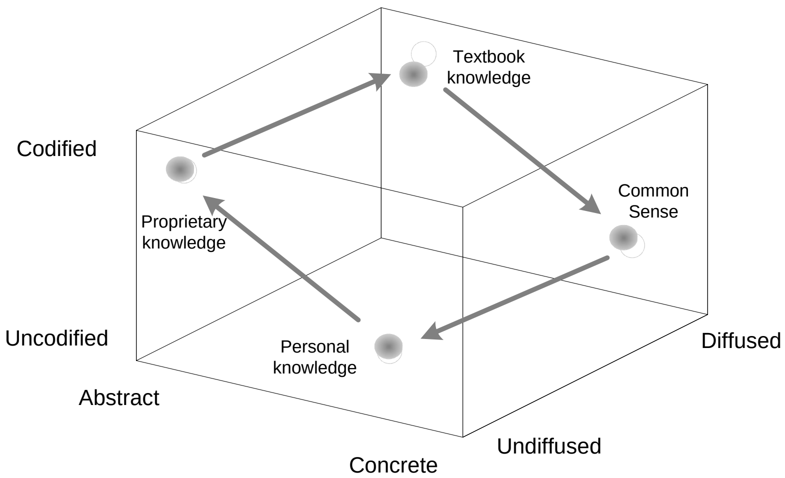

Figure 5. The knowledge creation cycle in Boisot's I-Space (1995)

Entropic influence is far more profound, however, than portrayed in this description. A knowledge creation cycle may be aborted, deflected, reformulated or even accelerated by environmental and ontological influences. Much depends on the commitment required to sustain the cognitive investment fully to create and exploit a knowledge asset. In turn, cognitive commitment is sensitive to conventions adopted to represent knowledge.

5. Modelling and the dissemination of knowledge

5.1 A note on archetypes

Kemeny et al (1994) consider effective systems thinking (and thus organisational learning) to be based on simultaneous reflection on: events, patterns of behaviour, systems, and mental models. Goodman and Kemeny advocate the use of archetypes as a mechanism for constructing credible and consistent hypotheses for comprehending systems and the associated mental models devised by domain experts (Goodman & Kemeny, 1994). An archetype is defined 'as nothing more than a mental model made visible' and may be used to redesign systems by introducing and removing nodes, and adding loops and breaking links between the nodes. When an organisation is defined by some constellation of archetypes, learning may become focused on breaking through organisational gridlock (Kim, 1993). Through the judicious use of archetypes to identify and define the systemic structures that describe corporate behaviour, organisational learning is achieved by:

- developing a shared vision to inform the redesign of systemic structures
- exploring mental models and team learning to confirm the assumptions underlying organisational behaviour, culture and beliefs
- performing scenario planning to evaluate assumptions about the future
- developing a personal vision and learning to see the world from a creative and interdependent perspective, and not merely from a reactive viewpoint

Senge (1990) comments that, for all their flaws, mental models provide a fertile source of knowledge that may be penetrated through the use of archetypes. The concept of knowledge penetration is possibly mistaken. A more likely explanation is that knowledge emerges discontinuously from mental models through a series of inferential leaps. Coupled with this emergence of knowledge is the reconstruction of new mental models from previous unconscious constructs that have suffered some disturbance of their earlier content.

Precise construction of archetypes is required to understand better those concepts consolidated from tacit knowledge. Nonaka and Takeuchi claim that archetypes are constructed by combining newly created explicit knowledge with existing explicit knowledge, and thus building archetypes becomes a process of combination. It is also acknowledged that this process is particularly complex requiring attention to detail and the dynamic cooperation of a variety of agents. A clear statement of organisational intention is considered to provide a basis for ensuring that the repertoire of archetypes converges towards a consolidated and consistent schema.

For all its potency, an archetype remains a primitive mental image of some phenomenon and is, necessarily, of limited utility when striving to articulate a concept with any degree of precision and capacity for communication. To elevate the efficacy of expression, one must turn to metaphors, analogies and models.

5.2 Metaphors, analogies and models

The transition from tacit knowledge to explicit concept is precarious and requires successful negotiation through a multiplicity of cognitive barriers. How is this cognitive transition to be achieved? Among many others, Nonaka and Takeuchi turn to the application of metaphors, analogies and models to articulate tacit knowledge. From Nisbet (1969), they note that much tacit knowledge is only expressible as metaphor, i.e. by understanding one thing by imaging another thing symbolically. According to Donnellon, Gray and Bougon (1986), metaphors enable perceptive and intuitive understanding by creating new realities that may reconcile 'differences in meaning'. Following Richards (1936), Nonaka and Takeuchi reason that metaphors encourage the creation of *networks* of (possibly) remote concepts, and the association of concrete concepts to abstract expressions. The role of analogy is to reconcile the contradictions inherent in metaphors (the source of their potency). Where metaphor relies on imagery, analogy appeals to the functional and structural characteristics of a concept. When analogies become available they may be used to construct logical models of a concept and reconcile any residual contradictions.

The adoption of metaphors represents the invocation of a cognitive endeavour to extract a concept from the 'ineffable domain' (Boisot, 1995), where tacit knowledge is held in a concrete and uncodified state. The transition from metaphor, through analogy to model resonates with the conversion of tacit knowledge into an explicit representation employing a highly codified and abstract notation. The adoption of some modelling convention propels tacit knowledge into the ordered zone (Brinklow, 2004) where it is available for transfer to an adjacent ontology and eventual exploitation. The representation of a knowledge asset according to some modelling convention also improves the prospect of exhaustive exploitation before descent to the chaotic zone.

This, of course, is to exaggerate the efficacy of models. Of primary concern is the fact that a model is predicated on compromise. Lovelock (1991) describes a model as a representation of a real system that provides sufficient detail to capture essential concepts while omitting incidental detail. Moreover, a model is constructed from the application of some semantic convention focussed on articulating a particular abstraction and perspective. To complicate matters further, a knowledge asset is represented as a multi-faceted object supporting a multiplicity of abstractions and perspectives. The choice of an inappropriate model may have the unfortunate consequence of concealing, fragmenting, dislocating or corrupting a knowledge asset.

It appears, therefore, that the articulation of a knowledge asset requires a variety of connected models, each representing orthogonally some coincidence of abstraction and perspective. One model is not sufficient to represent a knowledge asset; a variety of associated models is necessary, each containing some ensemble of objects.

5.3 Models as ontological abstractions

What models should be used to describe a knowledge asset? An answer may be found by considering the origins of the raw material required to create the knowledge asset. The obvious sources of knowledge are the products and services provided by the organisation, and the exploitation of technology to increase effectiveness and efficiency. The critical source of knowledge, though, is in the ability of processes to self-organise in response to environmental shifts; i.e. the ability of processes to learn, sense and respond to shifts in the interaction between an organisation and its environment. These responses determine the ability to introduce innovation, and technological effectiveness and efficiency to products and services. Knowledge creation commences with an exploration into behaviour; a view confirmed by Boisot's definition of knowledge as a set of expectations that an observer holds with respect to an event. Moreover, the focus for a knowledge asset is taken to be the need to execute a task.

Events invoke and terminate the execution of a process (or other forms of organisational functionality), and emit signals indicating shifts in environmental interaction. An essential model must therefore capture events and their associated processes; such a model would indicate the functional impact of some environmental shift. Of equal importance are the entity objects and organisational topology required to support the processes.

To summarise: the articulation of knowledge assets requires three fundamental orthogonal modelling abstractions: functions, entities and topologies. Abstractions are populated by an ensemble of objects connected according to semantics specified in some meta-model. Odell (1998) defines a meta-model to be 'a model of models containing object types whose instances are also object types'.

5.4 Models as ontological perspectives

The elicitation of a knowledge asset requires the four fundamental abstractions identified in the previous section. Each abstraction, however, is required also to support a multiplicity of perspectives representing a variety of concerns and priorities. The knowledge creation cycle suggests three perspectives:

- A knowledge creation invocation is considered to emerge from the tacit and explicit concepts embedded in concrete and uncodified knowledge. As the concepts evolve towards abstract and codified expression, they describe a logical perspective of a domain; a perspective that concentrates on formulating a response to an environmental shift, but omits any consideration of delivery of that response.
- The next stage of cognitive activity yields a physical perspective to a concept. This perspective focuses on finessing and translating the logical concept into delivery to the environment. The physical perspective introduces practical and pragmatic content to the concept.
- Finally, the concept is exposed to operational scrutiny and entropic impact. An operational concept provides the opportunity for value exploitation by achieving extended residence in the zone of complexity.

The representation of a knowledge asset has to support a multiplicity of perspectives, each with its own abstraction and codification conventions, i.e. meta-model. Perspectives are not discrete; indeed, perspectives would be deprived of any utility if they could only be considered in isolation. Meta-models must facilitate transition between perspectives by factoring equivalence, extensions and contractions into abstraction and codification conventions.

5.5 Knowledge dissemination

To summarise, the expression of a knowledge asset requires multiple abstractions and must support scrutiny from several perspectives. In fact, these properties represent essentially the minimal enabling conditions for knowledge dissemination. Compromise introduces cognitive barriers to knowledge dissemination.

6. The web of knowledge domains and domain models

From Herschfeld and Gel (1994), Gardner *et al* (1998) hold that a domain is 'an innate (perhaps partially acquired) kind of cognitive pattern used by a perceiving individual that identifies and interprets a class of phenomena assumed to share certain properties'. They provide the table of cognitive models:

Domains	Goals/principles/reasoning associated with recurring situations offering an explanatory structure
Frameworks	Domains with addition contextual content
Cognitive Maps	Frameworks oriented towards 'wayfinding'
Patterns	Specific instantiations of frameworks

Table 1. Types of Cognitive Models. Gardner *et al*, 1998)

From this definition, domains may be taken to provide some explanatory structure for a recurring situation, e.g. the execution of a task. It is rare for a task to be executed in isolation; the more probable context is a complex, dynamic and interdependent web of other activities forming a process. Perhaps the scope of a domain should be a process or beyond? The original task may now become obscured within the extended domain. What level of domain abstraction should constitute the focus for the knowledge creation invocation? The answer would appear to be multiple levels of abstraction; i.e both holistic and reductionist threads of inquiry are required.

6.1 Holism versus reductionism

Checkland describes Newton as the methodologist whose principle of reductionism has deeply permeated science for 350 years (Checkland, 1981). There are three senses in which, it is claimed, science is 'reductionist'. The real world is so diverse and complex, that to pursue a particular thread of inquiry, it is necessary to reduce the world by extracting just those features necessary for the investigation. There is an intellectual appeal in achieving logical coherence by reducing an explanation to consideration of an irreducible set of features. Finally, there is the dominant influence of scientific rationalism that argues for scientific thinking to be based on the precept of dismantling phenomena into component elements.

The 'reductionist' paradigm has also acted as a dominant influence in the analysis of business. Clearly, to understand fully the architecture of a business, it is necessary to define its characteristics at finer levels of granularity until components are rendered irreducible. Such an argument has obvious appeal where prescription is essential if deliverables are to be produced according to some schedule.

However, the limitations of the 'reductionist' paradigm have been apparent to the scientific community for some time. A particular source of disquiet is the unsuspected emergence of new phenomena at higher levels of complexity. Further scepticism is introduced by the distinction between 'restricted' and 'unrestricted' science (Pantin, 1968). With a restricted science, far-reaching hypotheses can be evaluated from a limited range of phenomena through 'well-designed reductionist experiments.' Conversely, with 'unrestricted' science, phenomena can be so complex that controlled experimentation is frequently impossible. From the systems perspective, a similar consternation is emerging. There is evidence that as organisations prepare to grapple with environmental turbulence; they are beginning to venture into realms beyond the conventional approaches to analysis. This reasoning poses a challenge to conventional approaches to analysis; they may need to be reconstructed such that they can address unverifiable assertions as well as the more familiar verifiable conjectures.

A system is considered to be holistic when it exhibits a property absent from its constituent elements; Checkland describes this as emergent phenomena. Rather than simply dissecting a phenomenon into a network of irreducible concepts, it is also possible to develop a complementary perspective based on the endless web of interdependencies defining the environment for the phenomena. Holistic investigation is, of course, deeply embedded in the sciences of chaos and complexity that are becoming increasingly influential in determining how organisations are apprehended. Cohen and Stewart warn, however, that holism is perhaps not quite what is needed; there is an apparent tendency to consider a system as a whole and ignore its context (Cohen & Stewart, 1994). The distinction between the two approaches to addressing problems is defined as follows:

- the reductionist pursues a thread of inquiry based on a step-by-step causality seeking to describe a domain in terms already associated with the domain
- the antireductionist is a pattern-seeker striving to describe a domain with terms available from other domains.

Following Cohen and Stewart, a dilemma is presented with a non-trivial domain; quite simply is the domain simple or complex. The answer is that it all depends on the context of the inquiry. It is likely that nothing is quite as simple or as complex as might be believed by first impressions. Reductionism and holism provide for complementary threads of inquiry.

6.2 Domains within domains

A knowledge creation invocation yields a cluster of knowledge assets exhibiting some degree of functional cohesion (connectivity). The utility and scarcity (the intrinsic value quotient) of the knowledge asset depends directly on the quality and extent of functional cohesion, opportunities for which are exposed through holistic and reductionist enquiry.

A cluster of knowledge assets must establish a presence in both holistic and reductionist domains, introducing the prospect of a conceptual hierarchy of domains. Indeed, domains are recursive in the sense that domains contain other domains exhibiting similar patterns of functional cohesion. At any level of intermediate abstraction, a domain is a member of and contains an ensemble of other domains with endlessly shifting contours and associations.

A cognitive endeavour is considered to commence in response to a (weak) signal reflecting some shift the interaction between an organisation and its environment. The focus is some incidence of functional turbulence, suggesting this might provide a useful orientation for combining and partitioning domains to form other domains. Boisot suggests that knowledge assets are created initially at the task level, where a task is an atomic (or at least very simple) activity. A task might be considered to be contained within a transaction, and executed within the context of a dynamic constellation of other tasks. A transaction might be considered similarly to be embedded within a process and so on. A hierarchy of activities emerges and provides a framework for structuring domains.

6.3 Towards a well-designed domain

The act of placing a knowledge asset within a domain does not of itself confer value. A knowledge asset may suffer a disparate existence and not evolve sufficiently to deliver any potential value. A well-designed domain might be expected to identify knowledge assets that should be relocated to another domain (or discarded altogether), or engaged fully in the structure of the domain.

Techniques familiar to software engineers provide guidelines for designing domain structures. According to Pressman (1992), 'landmark papers' by Wirth (1971), Parnas (1972), and Stevens, Myers and Constantine (1974) identified functional independence as the pre-eminent design feature for any software module; i.e. the module must exhibit modularity. Constantine and Yourdon (1979) develop further the concept of modularity by imposing the quality of loose coupling between logically cohesive objects; concepts now achieving mature expression in object-oriented design theory (Booch, 1994). Applying these qualities to knowledge domains, a well-designed domain might be expected to be populated by knowledge assets translated into logically independent and cohesive clusters of simple objects supporting complex connectivity with local and remote objects.

6.4 Domain models

A domain is a recursive structure containing an ensemble of objects representing a configuration of knowledge assets. Objects provide a framework for reasoning about some aspect of corporate endeavour, usually with an orientation towards corporate activity and processes. The next issues to consider are what type of objects are required to represent knowledge assets and how they should be organised.

Consideration of corporate activity and processes identifies the necessity for objects representing functions, the entities that act upon, and the organisational units involved in the acts. These objects are expressed through some form of codified abstractions. Domain models are introduced by imposing modular design on these objects. A knowledge asset achieves explicit expression through some configuration of function, entity and topological models. While the expression may not be exhaustive, these fundamental domain models provide an essential framework for further enquiry and articulation. Moreover, the structure and content of domain models yield existential criteria to establish the optimal context for knowledge assets; i.e. a particular model provides a superior context for a knowledge asset.

Following Zachman (1999), domain models may be required to support multiple perspectives; minimally, domain models should facilitate logical, physical and operational enquiry. The logical perspective is restricted to the essential detail of a domain omitting any consideration of the implementation of functions and entities. The physical perspective introduces details of how the logical concepts may be implemented in an operational environment. Domain objects in the production environment are described by the operational perspective.

		Codified abstractions		
		Function	Entity	Topology
Perspectives	Logical	How?	What?	Who?
	Physical			
	Operational			

Table 2. A reduced Zachman Framework

A knowledge creation invocation may originate in any cell in the framework. Validation of the knowledge asset requires that all other cells are visited to ensure that models and their associated perspectives remain consistent.

Zachman thus provides a convenient template for applying a cognitive structure to a domain. Further structure may be introduced by considering the contents of each cell. Objects can exist theoretically at any level of conceptual granularity providing they remain within the ontology of a cell. Objects may thus occupy any point within a spectrum delineated by some definition of genericity and specificity; i.e. an obvious example might be the classification of corporate activities into processes, transactions and tasks. The ability to isolate a cell (or cluster of cells) and then embark on a generic or specific thread of enquiry provides the essential requirement of the domain to support holistic and reductionist analysis.

6.5 Ontological transition and its implications

Ontology is determined largely by perspective. Some concepts may occupy the ontologies for all perspectives. More generally however, the presence of a concept within an ontology depends upon the balance between genericity and specificity; if the expression of a concept is too generic (or too specific) it may cease to exist in a particular ontology. Matters cannot rest there however. Nonaka and Takeuchi (1995) claim that as a knowledge asset progresses through organisational strata and beyond to the external environment, it engages new domains and ontologies. Ontological transition is thus a multi-dimensional odyssey.

Ontological transition depends on preserving the essence of a knowledge asset between perspectives and domains. If the essence is compromised in concept or expression, the introduction of cognitive barriers may impede, distort or terminate prematurely the ontological transition process. Any of these outcomes might serve to undermine the value of a knowledge asset.

The existential prospects for a knowledge asset are influenced by the choice of paradigm to describe the essential concepts. An impoverished paradigm might diminish the prospects for a fully realised articulation of a knowledge asset. Conversely, a cognitively sympathetic and enriched paradigm might yield unexpected opportunities for extended articulation and thus improve the prospects fully to exploit value inherent in the knowledge asset.

7. Conclusion – a framework for knowledge domain models

Corporate vigour depends upon how an organisation learns to sense and respond to change. Knowledge management differs from organisational learning in that it advocates a continuous commitment to knowledge acquisition and demurs from any concept of rightness. Both approaches are predicated on the realisation that knowledge held by an organisation's workforce is a commodity of unparalleled potency in the endless struggle to maintain competitive acuity.

As with many valuable commodities, knowledge is scarce, elusive, vulnerable and can suffer a precarious existence. One challenge therefore is to devise cognitive devices capable of providing a supporting framework to elicit, express, extend exploit and preserve knowledge. While many cognitive devices are available to articulate knowledge, it is usually with the formalism of some modelling convention that knowledge is transformed into a competitive asset.

It is argued in the article that the description of a knowledge asset may require a variety of abstractions each populated with an ensemble of functionally cohesive objects. Also, expression of the knowledge asset may need to support a variety of perspectives. The adopted modelling convention must therefore take account of the knowledge asset complexities and the associated epistemological and ontological implications.

Knowledge assets are of limited value if considered only in isolation. The prospect for substantive value is introduced when knowledge assets are provided with a context and thus opportunities for connectivity and consolidation. Domains provide the enabling context. Structures are provided for domains in the form of cognitive frameworks identifying a multiplicity of abstractions and perspectives to describe a knowledge asset.

The article concludes by describing a simple framework that could be used to provide a partial definition for a knowledge asset. Further research is required to determine the objects, models, methods and techniques associated with populating a domain. Another thread of inquiry might be the recursive structure of the domain framework and the implications for emergent knowledge.

Bibliography

1. Ackoff, R.L. (1989). From Data To Wisdom. Journal of Applied Systems Analysis. Volume 16. pp 3-9
2. Argyris, C., Schön, D. (1978). Organisational Learning: A Theory of Action in Perspective. Addison-Wesley
3. Bateson, G. (1979). Mind and Nature. A Necessary Unity. New York. Bantam Books
4. Bellinger, G., Castro, D., Mills, A. (2004). Data, Information, Knowledge and Wisdom, http://www.systems-thinking.org/dikw/dikw.htm
5. Boisot, M, H. (1995). Information Space: A framework for learning in organisations, institutions and culture. Routledge.
6. Boisot, M. (1998). Knowledge Assets. Securing Competitive Advantage in the Information Economy. Oxford.
7. Booch, G. (1994). Object-Oriented Analysis and Design (with Applications). 2nd Edition. Benjamin-Cummings Publishing Co.
8. Brinklow, A. (2004). In Pursuit of Complexity. Working Paper. University Of Brighton.
9. Checkland, P. (1981). Systems Thinking, Systems Practice. John Wiley & Sons
10. Checkland, P. (1982). An organised (?) research programme in information systems? Internal Discussion Paper 1/82, Department Of systems, Lancaster University (from (Checkland & Howell, 1998))
11. Checkland, P., Holwell, S. (1998). Information, Systems and Information Systems, Making Sense of The Field. Wiley
12. Cleveland, H. (1982). Information as Resource. The Futurist. December. December. pp 34-39
13. Cohen, J., Stewart, I. (1994). The Collapse of Chaos: Discovering Simplicity in a Complex World. Penguin Books
14. Constantine, L, L., Yourdon, E. (1979). Structured Design. Englewood Cliffs, NJ. Prentice-Hall
15. Donellon, , A., Gray, B., Bourgon, M. (1986). Communication, Meaning and Action. Administrative Science Quarterly
16. Dretske, F. (1981). Knowledge and the Flow of Information. Cambridge, MA: MIT Press
17. Eliot, T. S. (1934). The Rock. Faber and Faber.
18. Gardner, K.M., Rush, A., Crist, M. K., Konister, R., Teegarden., B. (1998). Cognitive Patterns. Problem-solving Frameworks for Object Technology. SIGS Books. Cambridge University Press.
19. Goodman, M., Kemeny, J. (1994). Archetypes in The Fifth Discipline Fieldbook. (Edited by P. Senge) Nicholas Brealey Publishing
20. Herschfeld, L.A., Gel, S.A. ed. (1994). Mapping the Mind: Domain Specificity in Cognition and Culture. London: Cambridge Press
21. Howell, S. (1989). Planning in Shell: joint learning through action research, MSc dissertation, Lancaster University (from (Checkland & Howell, 1998))
22. Kemeny, J., Goodman, M, Karash, R. (1994). Starting With Storytelling (Systems Thinking) in The Fifth Discipline Fieldbook. (Edited by P. Senge) Nicholas Brealey Publishing

23. Kim, D. (1993). Seven Steps for Breaking Through Organisational Gridlock. The Systems Thinker
24. Lovelock, J. (1991). Healing Gaia: Practical Medicine for the Planet. Harmony Books
25. Nisbet, R. (1969). Social Change and History. Aspects of the Western Theory of Development. Oxford University Press
26. Nonaka, I., Takeuchi, H. (1995). The Knowledge-Creating Company. Oxford University Press
27. Odell, J. (1998). Advanced Object-Oriented Analysis and Design. SIGS Reference Library. Cambridge.
28. Parnas, D, L. (1972). ‘On Criteria to be used in decomposing Systems into Modules’. CACM, Vol. 14. No 1, pp 221-227
29. Popper, K. (1972). Objective Knowledge: An Evolutionary Approach. Oxford University Press. London
30. Pressman, R, S. (1992). Software Engineering. A Practioner’s Approach. McGraw-Hill International Editions. Computer Science Series
31. Pressman, R. (1992). Software Engineering: A Practitioner’s Approach. McGraw-Hill
32. Richards, I, A. (1936). The Philosophy of Rhetoric. Oxford. Oxford University Press
33. Schön, D. (1987). Educating the Reflective Practitioner: Toward a new design for teaching and learning in the professions. San Francisco. Jossey-Bass
34. Schön, D. A. (1991). The Reflective Practitioner: How Professionals Think in Action. New York. Basic Books
35. Senge, P. (1990). The Fifth Discipline: The Art and Practice of the Learning Organisation. Century Business
36. Shannon, C. E., Weaver, W. (1949). The Mathematical Theory of Communication. Urbana: The University Of Illinois Press.
37. Sharma, N. The Origin of the Data Information Knowledge Wisdom Hierarchy. http://www-personal.si.umich.edu/~nsharma/diwk_origin.htm
38. Stevens,W., Myers, G., and Constantine, L. (1974). ‘Structured Design’. IBM Systems Journal. Vol. 13. No. 2. pp 115-139
39. Wirth, N. (1971). ‘Program Development by Stepwise Refinement’. CACM, Vol. 14. No. 4, pp. 221-227
40. Zachman, J. (1999). ‘A Framework for Information Systems Architecture’. IBM Systems Journal Vol. 38. Nos. 2 & 3

