STRATEGIC MANAGEMENT OF KNOWLEDGE FOR DESIGNERS: META-THEORETICAL HIERARCHY AS A FOUNDATION FOR KNOWLEDGE MANAGEMENT TOOLS

Abstract. *This paper describes the use of a meta-theoretical hierarchy model as the basis for building conceptual toolsets for strategically managing knowledge used by designers. The paper uses two examples - cataloguing knowledge management theories, and computerising knowledge management – to demonstrate the scope for using the meta-theoretical hierarchy model for assisting with knowledge management processes in innovative situations.*

1. Introduction

Knowledge management to support designers becomes considerably more complex and difficult when it includes qualitative issues, human values and social, environmental and ethical factors (Love, 1998b, pp 11-14, 98-106). The strategic management of knowledge requires the characteristics of knowledge elements to be well defined, and the relationships (rule-based or fuzzy) between them to be well identified (see, for example, Carrico et al., 1989, Black, 1987, p. 48, Zack, 1999).

This is relatively unproblematic in technical domains where knowledge elements are theoretical abstractions describing physical elements and their behaviours: as in, for example, engineering, economics, physics and other physical or pseudo-physical realms. Pioneers in automating designing, and bringing artificial intelligence have, in general, avoided the theoretical complexities associated with including qualitative factors and knowledge management into the computer assisted designing arena. When qualitative factors and human values have been included into technical knowledge management systems, they have been done so by treating them as if they were physical phenomena, via attribute/criteria weightings or similar measures: methods subject to criticism of their validity and usefulness (see, for example, Crane, 1989, Chopra, 1998, Voogd, 1997, Poyhonen, 1998).

Knowledge management systems that avoid addressing qualitative factors and human values in an epistemologically appropriate manner are not likely to be comprehensive enough for commercial contexts. For example, the Delphi Research Group has identified that:

- Cultural issues (strongly qualitative) are the main strategic obstacle to the use of knowledge management systems (Kozlowski, 1997)
- 'Experiential, subjective and personal knowledge' is strategically an organisation's most valuable knowledge (Kozlowski, 1998)
- Supporting collaboration between individuals is the most important role of knowledge management systems (Kozlowski, 1999).

Qualitative subjective issues involving human values dominate each of these considerations.

This paper addresses these issues by proposing the use of a meta-theoretical hierarchy as a basis for including qualitative and quantitative knowledge in knowledge management systems. This meta-theoretical approach also offers the basis for building knowledge managing 'tools' to assist with the integration and management of knowledge in systems for assisting with the designing of human futures.

2. Theoretical Abstractions in Knowledge Management Systems

Knowledge systems store and manage representations of theoretical abstractions such as labels, objects, object properties, theories, rules about interactions between objects, worldviews, and human values.

There is a lack of differentiation between the epistemological characteristics of the knowledge elements forming the semantic and syntactical basis for knowledge systems to support designing. Currently, knowledge systems address all knowledge objects as if they are similar sorts of entities, ignoring epistemological differences between them. For example, a rule-based shell stores and manages knowledge elements such as 'automobile', 'driver', 'cognitive process', and 'perception of road' in similar ways. This situation contrasts with that of philosophical analysis (an alternative form of knowledge management and storage) that makes clear epistemological distinctions between such knowledge elements.

There are several factors implicated in this relative neglect of the epistemological differences between different sorts of entities in knowledge management. These include:

- Computer-based tools such as rule-based shells, implementations of UML (Universal Modeling Language), the rapid cultural transfer to object oriented modalities of representation, and the relative neglect in the design field of conceptual epistemological issues, have led to all and every element of knowledge and relationships being regarded as

epistemologically similar because they can be represented in these systems in similar ways.

- Prior emphasis on physical phenomena has led to the issue being overlooked because the ability to differentiate between subtly different physical concepts is an essential and deeply embedded part of the education of engineers and technical designers. In other words, technical experts take for granted their skill at differentiating between subtly different sorts of physical concepts and overlook that these quantitatively specific skills do not apply to non-technical qualitative knowledge.
- The conversion of concepts and relationships into *mathematical* representations for manipulation has led to all knowledge elements being converted to a similar epistemological status – variables or operators in mathematical functions.
- Tools of knowledge management such as object-based models and neural nets focus on changes in states of object characteristics, hence neglecting other epistemologically differentiating factors.
- Human designers are able to mix and match epistemologically different knowledge types in ways that are not problematic. Many knowledge management systems are based on models of human knowledge management that erroneously assume that humans use a singular rational process, whereas current evidence shows that human knowledge processing consists of many parallel processes operating in epistemologically, ontologically and physically different ways.

This lack of epistemological differentiation between 'apples' and 'oranges' of knowledge is problematic in situations that involve qualitative issues, human values and human activities. These human aspects of knowledge management operate in epistemologically different ways for technical and qualitative factors.

The meta-theoretical hierarchy model described in this paper offers a way of structuring knowledge elements so that their epistemological differences become apparent. The model also offers benefits in providing structural and axiomatic foundations for building computerised knowledge management systems that include qualitative data.

3. Meta-theoretical hierarchies and Strategic Knowledge

The meta-theoretical hierarchy described below has nine levels. Technical knowledge issues lie mainly in levels 2 and 3. Strategic non-technical

knowledge lies mainly in the other seven levels in the hierarchy. Together the nine levels offer a structure the development of epistemologically sound theoretical and practical knowledge systems to support designing.

The use of meta- theoretical hierarchies as taxonomies of epistemologically different knowledge elements is not new. For example, Reich's (1994a) comprehensive review of the state of knowledge in the literature of AI in Design was developed alongside and with reference to his three-level meta-theoretical hierarchy (Reich, 1994b). The meta-theoretical hierarchy described here has its roots in the work of Reich (1994b, 1995), Popper (1976), Franz (1994), Ullman (1992), and Konda and associates (1992).

The specific meta-theoretical hierarchy presented in this paper is one of a family whose underlying concepts and analyses were developed by Love in the mid-1990s (see, for example, Love, 1996, Love, 1998a). The core structure was designed to enable different meta-theoretical hierarchies to be constructed to assist with the differentiation of interdependent theoretical representations, theories and concepts in a wide variety of situations across different domains of knowledge (see, for example, Love, 2001 (accepted), Love, 2001a, Love, 2000, Love, 2001b). The model was originally developed to help resolve several real practical problems in relation to:

- Bringing together the qualitative and quantitative aspects of knowledge that designers use into a single theoretical form.
- Facilitating the development of a single body of knowledge or discipline relating to designs and designing that crosses the disciplinary boundaries associated with the content knowledge that designers use.
- Developing a set of tools to facilitate the careful analysis of the existing body of literature about designing and designs: a body of literature that is conceptually and terminologically problematic.

The above problems are essentially practical rather than abstract, and because of this, the theoretical perspective on which the meta theoretical hierarchy concept was built was chosen intentionally to lie as close as possible to the dominant scientific tradition of thinking and research. The use of a hierarchical classificatory approach was chosen to enable the inclusion of qualitative issues whilst retaining the means to logically analyse the structure and dynamics of theoretical/knowledge elements as theory.

The core structure was designed to:

- Include qualitative factors and human values alongside quantitatively described physical phenomena
- Include human designing (as 'addressing the future') as a primary function of human activity

- Increase the granularity in parts of the hierarchy associated with qualitative issues
- Be relatively domain/discipline independent i.e. using hierarchy categories that apply across disciplines
- Take into account that insights from brain research are likely to significantly transform knowledge, understanding and theories in these areas, particularly in relation to human knowledge processing.
- Use an underlying theory that is as concrete as possible, i.e. close to traditional scientific/positivist paradigms consistent with fulfilling the aims of including qualitative factors without recourse to transmogrifying them as physical phenomena.

This meta-theoretical hierarchy is essentially a means of analysing the structure and dynamics of theories. In this role, in spite of its apparent scientific structure, it is also well suited to analysing phenomenological, hermeneutic and other postmodern approaches to knowledge generation.

A meta-theoretical hierarchy model structured for knowledge management for designers is laid out in Table 1 below.

Table 1: A meta-theoretical hierarchy model for strategic knowledge management

Level	Classification	Description
9	**Ontological issues relating to theories of knowledge, knowledge management and designing**	The ontological basis for building representations of knowledge, its management, design theories and the activity of designing. It is at this level that human values and fundamental assumptions of researchers, designers and others implicated in designing and knowledge management are included.
8	**Epistemological perspectives relating to theories of knowledge, knowledge management and designing**	The identification of different perspectives for the critical study of the nature, grounds, limits and criteria for validity and representation of knowledge and designing based on ontological foundations located in level 9.
7	**General theories about designing and knowledge management**	Theories that seek to describe *in toto* knowledge management and designing and their relationships to designed objects and contexts.

6	**Theories about the internal human processes of designing and collaboration between individuals**	Theories about the reasoning and cognising of individuals, about collaboration, and about socio-cultural effects on designers' outputs.
5	**Theories about design processes**	Theories about the underlying structure of activities and processes of designing and knowledge management based on domain, culture, artefact types, epistemological and other attributes, and criteria.
4	**Methods and techniques to support designers**	Theories about, and proposals for, methods and techniques to assist humans in using knowledge in designing to change their contexts, behaviour and internal functioning.
3	**Theories about mechanisms of choice**	Theories about the ways that choices are made between different elements described as abstractions.
2	**Theories about the behaviour of elements**	Theories about the behaviour of elements (described in theories and concepts) that may be incorporated into designed objects, processes and systems or other changes that impact on humans' futures.
1	**Theories about initial conception and labelling of reality**	This level focuses on humans' labelling of perceptions and conceptions. This is the first step in abstraction: the initial recognition and classification of experience that is the core element from which other theoretical abstractions emerge.

The nine levels of the meta-theoretical hierarchy above stretch from least abstract to most abstract. Level 1 focuses on the most concrete aspects of knowledge formulation, the naming, perception and conception of experiences, artefacts, objects, situations, behaviours etc.. Level 9 includes the most sophisticated reflective, philosophical aspects of human understanding and knowledge; the essences of the elements, values and forces that impact on human understanding and knowledge creation and management. In between are levels that differentiate knowledge and theory between: behaviours of objects (in Western cultures general viewed in scientific, quantitative ways), how humans cognise and interact with each other and with objects in terms of decision-making, how knowledge is formalized through theories and general theories and bodies of knowledge across disciplines, and how this mélange relates epistemologically to human values and fundamental constructs about existence.

4. Using the Meta-Theoretical Hierarchy in Managing Knowledge

The meta-theoretical hierarchy above applies to several dimensions of the management of strategic knowledge:

- It maps out the breadth of strategic knowledge issues in ways that include non-technical issues.
- It offers 'rich picture' analyses of individual concepts and theories. The hierarchy supports researchers in identifying the relationships between a particular theory, concept or knowledge element at one level of abstraction with theories and concepts at other levels.
- It offers the underlying basis for a theory/knowledge/rule structure for complex highly parallel knowledge management systems that more closely resemble human approaches to knowledge management activities.
- It helps researchers avoid category confusion. This is a potentially significant philosophical issue that has been raised earlier in section 2. in relation to the use of generic systems, object-based software and mathematical modeling. By nature these approaches to mapping or managing knowledge tend to convert all knowledge inputs into epistemologically similar form of theoretical objects differing only by their object attributes.
- It acts as a reminder that human knowledge depends on human values, social constructions, and on the creative internal human functioning involved in designing, planning and strategizing.

Two examples below indicate the broad range of possibilities of the use of the meta-theoretical hierarchy in knowledge management systems – especially computationally based knowledge management systems. The first describes its use in providing a structured overview of theories and concepts that relate to building computerized models for strategic knowledge management. The second describes how the meta-theoretical hierarchy offers a structural basis for complex automated systems of knowledge management that build on a fuller feature set of human functioning in relation to knowledge.

4.1. EXAMPLE1: A TAXONOMY OF THEORIES & CONCEPTS OF KNOWLEDGE, AND KNOWLEDGE MANAGEMENT

The meta-theoretical hierarchy offers a basis for classifying abstractions, theories and concepts used in the fields of knowledge, knowledge management and designing. Table 2 below sketches likely contents of each of the nine levels

in the hierarchy when using it in this role.

Table 2: A meta-theoretical hierarchical taxonomy of knowledge management theories

Level	Classification	Description
9	**Ontological issues relating to theories of knowledge, knowledge management and designing**	Ontological foundations for theories and research relating to about knowledge, knowledge management and strategic knowledge management. This level contains descriptions of, and justification for, different elements that underpin theory making. In positivist epistemologies these include the axiomatic or elemental concepts on which theories are constructed (e.g. a bit, chunk, thought, perception, object property, object). For post-positivist perspectives these foundations consist of the core elements of human values, worldviews, human attitudes: all those things that form the foundations to responses to the questions 'What is existence?" and "What is reality?"
8	**Epistemological perspectives relating to theories of knowledge, knowledge management and designing**	At this level are found the descriptions of, and justifications for, different positivist and other perspectives on theories about knowledge, knowledge management, strategic knowledge management and designing. This level focuses on the different forms of scientific, constructivist, constructionist, critical and other interpretive epistemological perspectives that underpin the relationship between theories and ontologies.
7	**General theories about knowledge, knowledge management, strategic knowledge management and designing**	Theories that seek to describe *in toto* knowledge, knowledge management, strategic knowledge management and designing and their relationships to designed objects and other contexts.
6	**Theories about the internal human processes of designing and collaboration between individuals**	Theories about the reasoning and cognising of individuals, about collaboration, and about socio-cultural effects on designers' outputs.
5	**Theories about design processes**	Theories about the underlying structure of activities and processes of designing and knowledge management based on domain, culture, artefact types, epistemological and other attributes, and criteria.
4	**Methods and techniques to support designers**	Theories about, and proposals for, methods and techniques to assist humans in using knowledge in designing to change their contexts, behaviour

		and internal functioning.
3	**Theories about mechanisms of choice**	Theories about the ways that choices are made between different elements described as abstractions.
2	**Theories about the behaviour of elements**	Theories about the behaviour of elements (described in theories and concepts) that may be incorporated into designed objects, processes and systems or other changes that impact on humans' futures.
1	**Theories about initial conception and labelling of reality**	This level focuses on humans' labelling of perceptions and conceptions. This is the first step in abstraction: the initial recognition and classification of experience that is the core element from which other theoretical abstractions emerge.

In the above hierarchy, theories about computerizing strategic knowledge management are mainly found in the lower levels in the hierarchy. This is similar to the distribution of theories in other technical disciplines. It differs, however, at level 1 where knowledge management research necessarily pays additional attention to the identification and conceptualization of patterns or 'objects' worthy of 'naming' or 'labeling'. This contrasts with many technical fields, for example, Engineering, where level 1 theory is less relevant, and only addressed in peripheral topic areas such as 'non-dimensional analysis'.

The use of the meta-theoretical hierarchy draws attention to ontological, epistemological, social, psychological and biological issues relating to how knowledge is collected, owned, managed and used. It points to an important role for hegemonic analysis and critical theory (level 8) in strategic knowledge management research. It offers unexpected benefits also. For example, using the hierarchy as a means of identifying less well-addressed areas reveals the ways that customers are involved in knowledge-creating financial processes because of the designing that they undertake on their own behalf for their own purposes. On the web, for instance, customers use strategic knowledge management systems (often built for other purposes) to 'design' their own lives. This is seen, for example, in customers using web-enabled mortgage/loan calculators to design their financial futures. In developing e-business knowledge management systems relating to business-to-customer (B2C) and business-to-business (B2B) interactions, an understanding of the ways that customers use facilities built for other purposes for their own alternate design processes can offer significant insights to those designing knowledge-based enabled web-enabled services and interfaces.

4.2. EXAMPLE 2: FOUNDATIONS OF A COMPUTATIONAL MODEL OF STRATEGIC KNOWLEDGE MANAGEMENT THAT INCLUDES HUMAN ISSUES

Knowledge is not value neutral. The ways knowledge is used strategically are shaped by priorities that individuals set, the perspectives they choose to view situations, and the underlying paradigms that they use as reference points for locating knowledge, its use and its management. These factors differentiate computational systems of knowledge management that emulate human functioning from computational systems defined either in terms of a single ontological/epistemological perspective, or that neglect the role of human values and perspectives.

Building a computational model of strategic knowledge management that includes an understanding of how humans create and use knowledge (as distinct from information or data) requires the inclusion of:

- How individuals 'chunk', identify and categorise knowledge elements, and how they label them
- A fuller understanding of the cognitive processes that individuals use – including all the somato-sensory aspects of affects and emotions
- The role of social interactions in defining how knowledge is created, shaped, managed and used
- How the ways knowledge is catalogued, managed searched for is influenced by ontological perspectives on existence (What is reality? What are the building blocks of reality? How are they shaped?), and epistemological perspectives relating theory to ontological assumptions.

The meta-theoretical hierarchy offers a structure to locate knowledge elements in an n-dimensional search space in which 9 dimensions are used to enable the association of knowledge element with others at different levels of the meta-theoretical hierarchy. This arrangement offers benefits though the use of the underlying axioms that define relationships between knowledge elements in the hierarchy (Love, 1998b, pp 142-152).

One axiom of this meta-theoretical hierarchical approach is that every theory element or object must necessarily have a relationship with at least one other theory element in each of the other levels That is, each theory element must be part of a chain with links at all the meta-theoretical levels. Usually, theoretical elements are connected with more than one element at other levels, and this results in cascades of interdependent theoretical relationships from any one element through the levels higher and lower than the one that it occupies.

The hierarchical nature of the model is defined so that in epistemological

terms, knowledge elements at any one level describe patterns of relationships between or about elements that are lower in the hierarchy. Additionally, the specific meanings of individual knowledge elements depend on higher elements for their theoretical foundations, i.e., the assumptions that shape these meanings. In knowledge terms, the attributes given to a concept or theory element, and the rules to which it conforms or determines, depend on the relative status given by the reader or author to abstractions at other levels in the hierarchy to which the original element is related.

The axioms and the hierarchy structure between them provide a basis for the development of conceptual and knowledge management tools to codify, manage, search and manipulate knowledge elements via the epistemologically hierarchical relationships that exist between them at the same and at different levels of abstraction. The multiple parallel, and often usefully redundant, relationship paths between elements are in addition to those normally elicited by knowledge capture mechanisms, They provide the basis for new tools that use these relationships alongside conventional rule-based relationships and controls. Each level in the meta-theoretical hierarchy also provides a boundary of object classes of theory/knowledge elements, and thus offers a further mechanism shaping the way that searches of content and rules of a knowledgebase can be conducted. The use of the hierarchy can be further extended because of its fundamentally reflexive nature by which the theory elements and meta theoretical structures of one hierarchy might well be the objects and object behaviours (theoretical abstractions at levels 2 and 3) of a more sophisticated or more abstract hierarchy. For building intelligent agents capable of assembling strategic knowledge-based responses to a query, the meta-theoretical hierarchy model offers a means for any theoretical element to be used as a criterion for searching using its epistemological relationships to theoretical elements above and below it in the hierarchy. This use of the attributes of knowledge elements relating to epistemological relationships is helpful because it automatically bounds the knowledge space within which searches are likely to be successful. In addition, the hierarchy forms the basis for a structure for modeling the mechanisms and user interfaces associated with searching, storing, modeling and managing and codifying captured knowledge data: a different issue from how the data and rules are structured and stored.

Finally, the proposals presented in this example also sketch out part of the basis for computationally automating knowledge management processes that include everyday issues in human knowledge (as opposed to highly distilled technical knowledge). In this sense, the meta-theoretical hierarchy approach aligns with the work of ontological researchers working on the development of

the Cyc knowledge management database being developed in the USA (Cycorp, 2001) and suggests a process for partial automation of this work.

5. Conclusions

This paper has outlined the use of Love's meta-theoretical hierarchy in developing knowledge management systems to support designers. The paper sketches out how a meta-theoretical hierarchy may provide the basis for developing conceptual toolsets for strategically managing knowledge, and gives examples of how it might be used in two areas of knowledge management. The first example describes the use of the meta-theoretical hierarchy in managing knowledge management theories; for structuring and clarifying theories, for avoiding category mistakes, and for avoiding the accidental and inappropriate conflation of knowledge/theory elements. The second example outlines how the meta-theoretical hierarchy can provide a structure for a computerized system of knowledge management that encourages the inclusion of, and reference to, qualitative areas of knowledge management that researchers have identified as being relatively neglected by traditional approaches.

6. References

Black, W. J. (1987) Van Nostrand Reinhold, Wokingham, UK.

Carrico, M. A., Girard, J. E. and Jones, J. P. (1989) *Building Knowledge Systems*, Intertext Publication, New York.

Chopra, K. (1998) *The Valuation of Biodiversity within Protected Areas: Alternative Approaches and a Case Study* (pdf file). Institute of Economic Growth, University Enclave, Delhi, Available: http://www.feem.it/gnee/pap-abs/chopra.pdf.

Crane, J. A. (1989) 'The Problem of Valuation in Risk-Cost-Benefit Assessment of Public Policies', In Byrne, E. F. and Pitt, J. C. (eds), *Technological Transformation: Contextual and Conceptual Implications*, Vol. 5 Kluwer Academic Publishers, Dordrecht, pp. 67-79.

Cycorp (2001),Cycorp.

Franz, J. M. (1994) 'A critical framework for methodological research in architecture', *Design Studies*, **15,** 443-447.

Konda, S., Monarch, I., Sargent, P. and Subrahmanian, E. (1992) 'Shared Memory in Design: A Unifying Theme for Research and Practice', *Research in Engineering Design*, **4,** 23-42.

Kozlowski, M. A. (1997) *Delphi research Identifies Culture as Key Hurdle to Knowledge Management* (html file). The Delphi Group, Boston MA, Available: www.delphigroup.com/pressreleases/1997-PR/11051197KMApplicationHurdl.htn.

Kozlowski, M. A. (1998) *'Do you know how much you know?' Delphi Group Analyst asks CKOs at KM Summit* (html file). The Delphi Group, Boston MA, Available: www.delphigroup.com/pressreleases/1998-PR/06091198KM2.html.

Kozlowski, M. A. (1999) *Delphi Group Research identifies leading business applications of Knowledge Management* (html file). The Delphi Group, Boston MA, Available: www.delphigroup.com/pressreleases/1999-PR/03291199KMBusApps.html.

Love, T. (1996) 'Social, environmental and ethical factors: their implications for design theory', In Groves, M. A. and Wong, S. (eds), *Design for People*, Edith Cowan University, Perth, pp. 199-206.

Love, T. (1998a) *Social, Environmental and Ethical Factors in Engineering Design Theory: a Post positivist Approach*, Praxis Education, Perth, Western Australia.

Love, T. (1998b). *Social, environmental and ethical factors in engineering design theory: a post positivist approach.* Unpublished PhD thesis, Mechanical and Materials Engineering, University of Western Australia, Perth.

Love, T. (2000) 'Philosophy of Design: a meta-theoretical structure for design theory', *Design Studies*, **21,** 293-313.

Love, T. (2001a) *Affective Information Systems: Contributions to IS from Design Research - We-B Research Seminar* (ppt files for seminar presentation of working paper). We-b Research Centre, ECU, Perth, WA

Love, T. (2001b) *Design Research & Management Information Systems: Symbiotic Factors* (Working paper). Edith Cowan University, Perth

Love, T. (2001 (accepted)) 'Constructing a coherent cross-disciplinary body of theory about designing and designs: some philosophical issues', *Design Studies*.

Popper, K. (1976) *Unended Quest*, Open Court, Illinois.

Poyhonen, M. (1998) *On Attribute Weighting in Value Trees* (pdf file A73). Systems Analysis Department, University of Technology, Helsinki, Espoo, Available: http://www.hut.fi/Units/SAL/Publications/pdf-files/rpoy98a.pdf.

Reich, Y. (1994a) 'Annotated bibliography on Research Methodology',

Artificial Intelligence in Engineering Design and Manufacturing, **8,** 355-366.
Reich, Y. (1994b) 'Layered models of research methodologies', *Artificial Intelligence in Engineering Design and Manufacturing,* **8,** 263-274.
Reich, Y. (1995) 'A Critical Review of General Design Theory', *Research in Engineering Design,* **7,** 1-18.
Ullman, D. G. (1992) 'A Taxonomy for Mechanical Design', *Research in Engineering Design,* **3,** 179-189.
Voogd, H. (1997) ' The changing role of evaluation methods in a changing planning environment', *European Planning Studies,* **5,** 257-266.
Zack, M. H. (1999) 'Managing Codified Knowledge', *Sloan Management Review,* **40,** 45-58.