

# **Toward Pragmatic Dimensions of Knowledge Reuse and Learning on the Web**

**Paola Di Maio**

(DMEM: Faculty of Design Manufacture Engineering Management  
University of Strathclyde, UK  
paola.dimaio@strath.ac.uk)

**Abstract:** Web based technologies have been promising to boost the Knowledge Management practice, by exploring the potential of knowledge Reuse and Learning. In assessing state of the art of this area of research, and in attempting to locate the boundaries for knowledge transformation and 'emergence', a pragmatic dimension surfaces. This paper contributes a novel perspective on knowledge reuse in the light of a 'pragmatic web' context, and prompts a line of inquiry in the exploration of this novel interdisciplinary domain of study and practice.

**Keywords:** Knowledge Reuse, Semantic Web, Systems and Software

**Categories:** M.3, M.8, H.1.1, L.1.0, L.1.1, L.1.3, L.2.3, L.2.4

## **1 Introduction, Scope, Intended Contribution**

The state of the art of 'Knowledge Reuse and Learning' can be captured at least in part by tracking its chronological evolution, which goes back over twenty years. [Smith, Duffy, 2001]. Much transformation and changes are happening thanks to current advances in web technologies, despite chaotic growth unfolding in real time across several overlapping and loosely specified paradigms, such as 'web 2.0' versus 'web 3.0', for example. While changes happen thanks to technological innovation, essentially they transform and impact the fabric of organisations and society at large. This position paper introduces the rationale for aligning traditional 'knowledge reuse' (KR) practices as studied in classical Knowledge Management (KM), to the latest paradigm of web research, here identified as 'pragmatic web'. The scope of this research to date is exploratory and aimed at identifying knowledge reuse and learning in practice, and taking into account a wider interdisciplinary context, the boundaries of which are yet to be defined. To the author's knowledge at the time of writing, it is the first time that knowledge reuse and learning are studied in relation to the pragmatic web framework. The identification of new pragmatic web boundaries of knowledge reuse, and the formulation of corresponding hypotheses aim to be the main contribution of this paper. Expected outcomes of this research are improved understanding of knowledge reuse dynamics and their impact in open networked knowledge exchanged environments, to guide the development of suitable practices, tools and systems.

## 1.1 Paper Organisation

This paper is organised roughly into four main sections as follows: section 2 provides a summary of literature review and a problem statement, section 3 discusses KR in relation to evolving web paradigms, section 4 discusses KR research open questions in the light of Pragmatic Web research, presenting and justifying the rationale for a non linear, chaotic and interdisciplinary approach to addressing the complexity of open KR questions.

## 2 Literature review

The emphasis of information management practice in recent decades, has shifted from revolving around data management (DM) to knowledge management (KM), whereby knowledge results from the combination of data, information, skills, know how, experience, intelligence, ability, and includes more subjective factors such as insights, intuition and ambitions of individuals and resources that are the foundation of knowledge networks. [Nonaka, 1995].

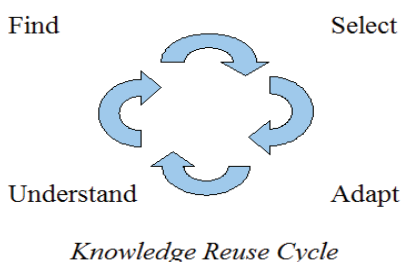


Figure 1: Adapted from Dusink and Katwijk

A typical 'knowledge management lifecycle' breaks down the KM process into activity sets, for example discovery, organisation, sharing and application (use, reuse). Modelling such KM activities as discrete functions however is arbitrary, as in reality they are interdependent, blend together and often take place simultaneously. Knowledge 'Reuse' (KR) which within the classical knowledge management lifecycle is considered a 'phase' [Tao et al., 2005], actually is an underlying function of most other KM activities, and should be modelled as such. Loosely adapted from the software domain [Dusink and Katwijk, 1995], the notion of 'reuse' can be defined as the systematic application of existing artifacts, or the physical incorporation of existing artifacts, during the process of building a new system, whereby artifacts are identified as pieces of formalized knowledge that can contribute to an engineering process, such as designs, transformation rules, as well as e.g. descriptions of how to detect abstract data types. A typical Knowledge Reuse cycle consists of steps such as find, select, understand, adapt/adopt (Figure 1). Although 'tacit' knowledge is also a contributing factor to KR [Harsh, 2008], for the purpose of this research we focus on knowledge reuse that takes place mainly through 'explicit' knowledge, and that as

such is codified via explicit 'knowledge representation' formalisms and artifacts. In a Theory of Knowledge Reuse, Lynn [Lynn, 2001] characterizes four distinct typologies of situations: shared work producers, who produce knowledge they later reuse; shared work practitioners, who reuse each other's knowledge contributions; expertise-seeking novices; and secondary knowledge miners bringing to light the importance of distinguishing 'context' to all aspects of KR. More recently, Carlile [Carlile, 2003] considers reuse part of a 'knowledge transformation' process, which bears even more direct implications to the pragmatic view of the web. Knowledge Reuse is viewed by Carlile as a cycle, he also proposes an 'integrated framework' incorporating syntactic, semantic, pragmatic dimensions of knowledge transformation as a strategic and tactical approach to knowledge integration across disciplinary boundaries.

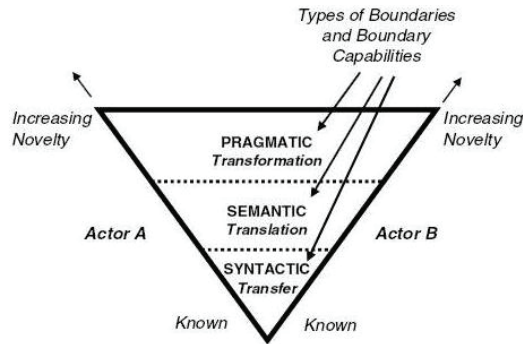


Figure 2: Knowledge transformation, Carlile 2003

Research into the pragmatic dimensions of knowledge reuse has already started, and constitutes one of the points of departure for the work ahead. Particularly important is the notion of 'context'. An analysis of context awareness and context codification [Chai and Nebus, 2006], identifies different dimensions for context, and corresponding mechanisms for overcoming such barriers are suggested by the same authors. The separation of 'semantic' and 'conceptual' layers for knowledge and its representation is already an established concept in the domain of operational simulations [Tolk, 2003]. Knowledge Transformers as a connecting link between learning and creativity were identified by Sim and Duffy [Sim and Duffy, 2004]. Future research may be desirable in understanding the role of knowledge transformer to the practice of knowledge reuse.

Knowledge Transformers	Description of how knowledge is transformed
Abstraction/ Detailing	Abstraction generates a new version of the knowledge with less detail than the original through the use of representation of abstract concepts or operators. Detailing is the opposite, in which the new knowledge is generated with more details.
Association/ Disassociation	Association determines a dependency between given entities or descriptions based on some logical, causal or statistical relationships. The opposite is disassociation, which asserts a lack of dependency.
Derivations (Reformulation)/ Randomisation	Derivations are transformations that derive one knowledge from another piece of knowledge (based on some dependency between them). Randomisation transforms one knowledge segment into another by making random changes.
Explanation/ Discovery	Explanation derives additional knowledge based on domain knowledge. Discovery derives new knowledge without an underlying domain knowledge.
Group Rationalisation (or Clustering)/ Decomposition	Group rationalisation involves the grouping of past designs according to their similarities when considering particular perspective(s) or criteria. Decomposition removes the groupings.
Generalisation/ Specialisation	Generalisation generates a description that characterises all of the concept based on a conjunction of all the specialisations of that concept. Typically, the underlying inference is inductive. Specialisation increases the specificity of the description.
Similarity comparison/ Dissimilarity comparison	Similarity comparison derives new knowledge about a design on the basis of similarity between the design and similar past design(s). The similarity comparison is based on analogical inference. The opposite is dissimilarity comparison, which derives the new knowledge on the basis of lack of similarity between the two or more past designs.

Figure 3: Knowledge Transformers, Sim and Duffy, 2004

## 2.1 Problem Statement

Despite increasing quantities of valuable ‘knowledge’ being produced everyday in all fields of research and practice, the ability of systems and personnel to manage and apply existing knowledge to decision making and problem solving, is not easily qualified nor quantified, and limited one the one hand by the physical, psychological and cognitive capacity (of human and machine), on the other hand by the configuration of the information systems and social and organisational infrastructures in place which directly or indirectly regulate the knowledge flows. The proliferation of talks, papers, studies, findings, surveys, theses, paradigms on knowledge reuse notwithstanding, limited measures are in place to assess its more ‘pragmatic’ aspects for example a) how knowledge is reused in practice, b) the effect of knowledge reuse on the organisational environment, c) the impact of research on the actual practice, d) the impact of knowledge reuse on the transformation of organisations and society at large. The answers to such questions are likely to require investigation methods adequate to their complexity of the domain. A preliminary analysis of literature review points to a state of the art in knowledge reuse and learning riddled with paradoxes and challenges, partly summarised as follows:

1. Essentially a multidisciplinary question, the more generalised aspects of knowledge reuse practice require a multidisciplinary framework that can address KR requirements from an integrated perspective, while the more specific aspects of knowledge reuse are still heavily domain dependent.
2. Increased proliferation of knowledge results in increased reuse challenges, whereby the reuse capability must imply the ability to filter applicable knowledge and apply it contextually. Semantic web technologies under development address this challenge only in part. Pragmatic web practices are expected to support knowledge in context, and operational and process aspects of knowledge reuse.

3. Limited instruments and tools exist to measure the impact of KR research on productivity and on the overall evolution of organisational processes and structures

## **2.2 KR and Learning and Organisational Transformation**

KM research and practice to date, offer only partial insights into the relationship between knowledge reuse and productivity, and ongoing patterns of organisational transformation. Even more limited insights exist with respect to the organisational transformations triggered by chaotic and distributed (networked) knowledge exchange environments, which are characterized by increased and virtually unbounded knowledge exchange patterns. In this context, the role of 'open' and 'web based' information environments, which are at the base of exponential knowledge exchange patterns, is becoming central to the notion of knowledge reuse. Among some of the factors that warrant this line of enquiry are:

- a) the increased adoption of distributed and networked organisational models [Borgatti, 2003]
- b) the emergence of the 'extended enterprise', whereby organisations externalise part of their production processes (product or services) which become shared across the supply chain

## **3 Knowledge Reuse and Web Paradigms**

New technologies, in particular web based technologies, open up new prospects for knowledge management, especially reuse and learning: virtual environments, characterized by the lack of time/space boundaries, dissolve the physical barriers to knowledge transfer, therefore supposedly facilitating pervasive knowledge access, reuse and transformation. In practice however other challenges come into being :

- while physical barriers to knowledge access may be reduced by the pervasiveness of the web, cognitive barriers still exist, and potentially become greater as the amount and degree of reliability of knowledge increases. It is expected that knowledge exchanges through web based social knowledge networks should address cognitive barriers with suitable propaedeutics (knowledge necessary for learning).
- the inherent nature of web based technologies, and the chaotic and virtually unbounded environments such as the web, constrain further the 'usability', hence the 'utility' of knowledge published on the web by increasing the complex challenge of sorting and retrieving meaningful, accurate and up to date data which is relevant to our queries, and to keep up and filter 'intelligence' from the vast amount of data that is being produced.

Additional obstacles to effective knowledge reuse may be partly due to inherent limitations of existing technologies and technology development patterns, and partly by non technical factors, such as organisational and social structures.

### **3.1 The Semantic Web**

In order to address these, and other challenges, the 'semantic web' was invented [Berners-Lee, Hendler, Lassila, 2001]. Semantic web technologies have been in development for over a decade, with the aim to support and leverage the logical relations that underlie knowledge represented in non structured form. The semantic web technology corpus, which includes knowledge, techniques and tools, is devised directly or indirectly with the intent to maximise knowledge reuse. It consist essentially of artifacts, such as vocabularies explicitly coded to represent relations, properties, hierarchies and classes, represented and exposed in such a way that they aim to be accessible and reusable. Formalised vocabularies are in fact considered the equivalent of 'simple ontologies'. Ontologies, in various degrees of formalization, can be used to support knowledge management functions [Mizoguchi et al]. Semantic web frameworks in support of Knowledge Reuse have been explored to some extent [Stojanovic and Handschuh, 2002]. But 'semantic knowledge management' to date is still purely notional. Current 'semantic web' standards issued by the governing consortium W3C are prescribed in the form of RDF, OWL which are respectively the recommended formats for vocabularies and ontologies, and SPARQL the corresponding query language. These recommendations represent 'attempts' to standardize novel approaches to semantic web, although they may not be the only way of supporting semantic capabilities on the web. Semantic technologies have been in development for some years, yet limited measurements of advances in terms of their impact on knowledge reuse are available, as much of the current efforts are devoted to overcome core infrastructural challenges ('plumbing'). This further supports and justifies the investigation into how pragmatic dimension contribute to the development of web based technologies in relation to KR. The more the semantic web takes shape, the more the lack of adequate instruments to capture and represent social and human dimensions, and practical context, become evident. The role and impact of human factors in the development of the semantic web, are still largely out of the scope of current SW research, prompting central questions that are often overlooked in technical debates.

### **3.2 The Pragmatic Web**

A 'pragmatic web' (PW) approach appears to prioritise a different set of challenges and an entirely new perspective, in comparison to the current semantic web (SW) research. Although at 'physical' level there is only one web (that we know of) - the open 'network of networks' that links computers via http and uses IP protocols and hypertext (HTML) - the 'pragmatic web' approach, as described in literature, [Schoop, De Moor, Dietz, 2008] focuses on the intent to explicitly research, support, interpret and model 'context' to knowledge on the web. Technically, and with some limitations, 'contextual' information can be represented on web with current SW artifacts and techniques [Tazari, 2003] and [Guha, McCool, Fikes, 2004]. Pragmatically, however, challenges to knowledge reuse, and relevant contextual dependencies, are not merely technical, but belong to the realm of social and organisational systems design and management, and extend well into the boundaries of what is designated as 'policy' management. Although it is impossible to pinpoint exactly where the semantic and pragmatic web overlap and where they actually differ,

in the sense that semantic web research is increasingly adopting a stronger 'user centric' approach, the focus of the PW as envisaged so far seems to emphasise:

1. placing the human-human interaction, together with its social and behavioural complexity at the heart of web based systems design and development
2. the exploration of alternative frameworks and assumptions that can more adequately capture such complexities, and that are not restricted to RDF/OWL as they are known today.

The distinction between syntactic, semantic and pragmatic 'dimensions' initially part of the linguistic and communication theory, credited to Charles Morris [Morris, 1946]. Morris defined pragmatics as "dealing with the origins, uses, and effects of signs within the total behaviour of the interpreters of signs"; semantics as "the relations between signs and the objects they signify", narrowing semiotic study to the strict literal meaning of signs and propositions. Syntactic "concerns the formal relations between signs themselves, further narrowing semiotic study to the logical and grammatical rules that govern sign use." Morris based much of his work on earlier studies of semiotics by Charles Pierce, and the 'social behaviourism' of Dewey and Mead. When considering the web as a virtually unbounded and chaotic information environment, structure and meaning acquire relevance mainly thanks to 'context', which is defined as the dynamic combination of factors and conditions that surround and affect an object or an event. On this premise, the pragmatic dimension is critical to information communication in that it allows the understanding and modelling of 'behaviours' and human 'experience', which in turn affect systems functionality and design. The complementarity of the 'pragmatic approach' to the 'semantic web' is consolidating around a small and diverse community of interest, with the intent to develop environments and infrastructures designed primarily to support the automation of human-human web based knowledge exchange, with particular emphasis on rule based reasoning and intelligent applications based on natural language. While much of the 'semantic web' is still under construction, the pragmatic web is pointing to a further shift toward adaptive and context sensitive real time communication environment capable of supporting intelligent and dynamic applications.

#### **4 Open Questions in Knowledge Reuse, role of a Pragmatic Web**

Web mediated human to human interaction is one of the purposes of pragmatic web research. Human to human interaction has so far been envisaged as essential to knowledge reuse. In a study carried out at NASA Jet Propulsion Laboratory, [Majchrzak, 2001] all six case analyses of reuse for innovation, primarily rely on human-to-human contact for learning to occur - to find the right individuals with the right solutions, to query the individuals to assess the applicability and limitation of the solution, and to physically manipulate the solutions to personally assess their appropriateness. The importance of 'social knowledge networks' in KR in the context of architecture/engineering/construction industry has already been studied to some extent [Demian and Fruchter, 2006]. One of the important issues emerging from

research is that ‘internal’ knowledge – knowledge existing within a role or within an organisation – is usually complementary and necessary to make use of to ‘external’ knowledge – knowledge stored in some repository:

“ [...] The term knowledge in context has been used by Finger (1998) in a similar sense. She notes that designers must seek out previous designs in the context of a design problem. Design is a process of constructing a theory of the artifact, not merely constructing a manufacturable description. This artifact theory is a contextual theory that provides knowledge for describing and analyzing an artifact and for explaining and predicting the nature of the artefact”.

Since the web is the largest knowledge repository ever existed, to create support for knowledge reuse in practice, taking into account the social knowledge networks dynamics already under study, points to new requirements to guide the development of web technologies and infrastructures. A preliminary conclusion from analysis of existing work in this area points to the need for artifacts capable of extending the capability of the web from an instrument to disseminate and expose data and information, to an instrument capable of disseminating knowledge, know how, and intelligence that are applicable to the evolution and advancement of society at large. Additionally, a gap is identified between theoretical research and in practice. (Skinner, 2007).

**Stages/Standards of Knowledge Utilization**

Stage	Category	Description
1	Reception	Receiving information/information <sup>a</sup> is within reach
2	Cognition	Read, digest, and understand information
3	Discussion	Altering frames of reference to the new information
4	Reference	Information influences action/adoption of information
5	Adoption	Influences outcomes and results/effort to favour information
6	Implementation	Adopted information becomes practice
7	Impact	Tangible benefits of information

*Note.* Summarized from Knott and Wildavsky (1980).

<sup>a</sup>The term “information” could be substituted by project, program, intervention, innovation, practice, policy, research, knowledge, document, evaluation, etc.

*Figure 4: Seven Standards of Utilization (Knott & Wildavsky, 1980)*

Open questions in Knowledge Reuse research to date include actual measurement of KM practices, and the impact and implication of networked Knowledge Reuse and Learning onto Organisational structures.

Starting from the seven Standards of Utilization Model (fig above) in our work we aim to measure Impact into more granular parameters, an initial outline of additional granularity below below:

1	Productivity	Efficiency of resources
2	Quality/experience	Experience (user, producer)
3	Model/Process Evolution	Process/model
4	Organisational Evolution	Organisational structure and dynamics
5	Contribution to Public Knowledge	Knowledge in the public domain
6	Contribution to Organisational Memory	Knowledge in the organisation

*Figure 5: Breaking down Impact/tangible benefits of Knowledge Reuse into further factors*

#### 4.1 Emerging Hypotheses

It is part of the underlying overall hypothesis supported by this paper that exploration of pragmatic aspects of the semantic web could lead to results applicable in the knowledge reuse and learning research and practice. The main motive for this paper and its underlying investigation is that KR remains limited and largely not understood nor justified, despite vast amounts resources being devoted to KR and semantic web technologies research and technologies. In the course of literature review, and in the attempt to understand the problem, and to better define the research question and corresponding method of inquiry, the following hypotheses emerge:

- 1) the practice of maximisation of KR, as a factor of knowledge exchange currently depends on the ability of individuals and organisations to accept the shift toward open and participatory paradigms, such as social networking. The benefits versus the risks of incorporating emergent organisational paradigms into traditional organisational structures remains to be weighted and tested.
- 2) the development of semantic web technologies, tools, platforms, environment and standards must be guided by the requirements of knowledge reuse in practice, which in turn must be guided by measurements of benefit parameters at different levels of granularity.
- 3) suitable multidisciplinary methods of enquiry must be developed for emergent dimensions of KR to be studied and applied

#### 4.2 An Interdisciplinary Approach to Complexity in Knowledge Reuse

Knowledge reuse can be viewed from different disciplinary perspectives, for example:

- a) A set of principles that can guide design [Duffy and Duffy, 1996]
- b) A desirable quality of any KM activity [Majchrzak, 2001]
- c) An essential component of learning processes [various]
- d) As a criteria to evaluate one quality factor of KM activities and tools [various]

Taking the above into account, knowledge reuse in distributed networked organisations which operate at least in part on the web, acquires exponential dimensions and becomes far more complex than originally thought of. On the one hand we observe more frequent and more rapid human to human interactions, where the knowledge flows virtually unbounded, and follows chaotic self directed patterns, on the other hand organisational structures, hierarchies, bureaucracies, protocols, rules

constrain such self directed knowledge flows, and more importantly regulate and influence the way this virtually unbounded knowledge flow is actually used, applied and internalised by the organisation. Most challenging, and interestingly, it's the study of the impact of 'networked' knowledge reuse on the transformation of organisational and social structures themselves (fig 6, Implications of Knowledge Reuse). In order for research to meaningfully investigate the depth and impact of knowledge reuse in complex information systems environments, a suitably multidimensional conceptual framework should be devised, a preliminary analysis of which is sketched below in section 4.3.

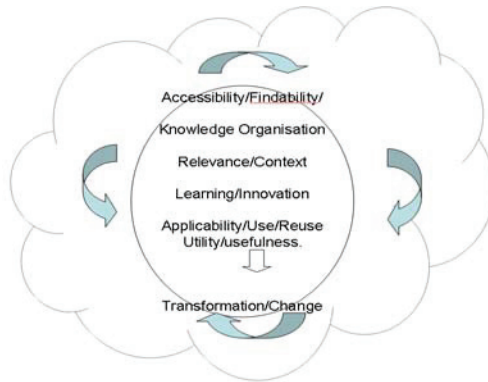
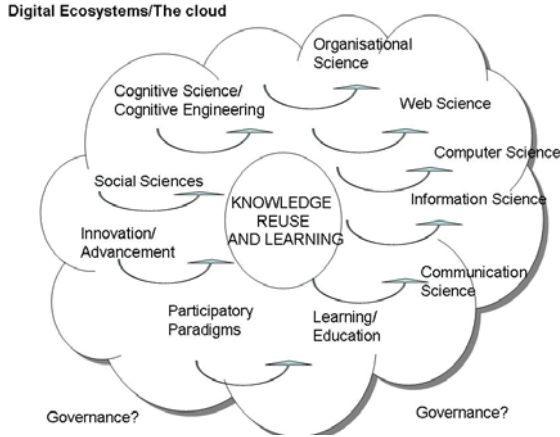


Figure 6: Implications of Knowledge Reuse

### 4.3 Crossing Domain Boundaries

The state of the art in Knowledge Exchange is characterized by a chaotic landscape of sometimes conflicting disciplines, a lot of theoretical research with limited practical applications, and limited instruments to assess the impact of research to understand and solve “real world“ issues. Evolutionary patterns of knowledge in design teams have already been investigated [Wu and Duffy, 2002], our work in this space extends previous model to the study of ‘knowledge reuse dynamics in practice’ with particular interest in co-evolution and reuse in networked enabled environments, and with a view to bridging the gap between theory and practice. Analysing the co-evolution factors and dynamics of knowledge reuse and organisational transformation starts drifting towards *complex systems sciences*, calling for sound yet extensible multidisciplinary methodological approaches and adequate frameworks for investigation and practice. A model for indertdisciplinary investigation which is inspiring our progress is provided by Tomiyama et al [Tomiyama et al., 2007] in Complexity of Multi-Disciplinary Design, which looks for crossdisciplinary solutions to cross disciplinary problems. The first research question there is whether inter-intra- multi- trans- or cross- disciplinary approach, or any combination thereof, is best suited to the problem ( currently still an open question). A preliminary outline of an integral domain approach in knowledge reuse is sketched in figure below.



*Figure 7: Knowledge Reuse in the Cloud*

In addition to the research areas identified above (see Image 7) other emerging domains that add a perspective to KR and that should be taken into account into a knowledge framework are:

- **Neuroscience/Brain Informatics:** The paper ‘The Fallacy of KR’ advocates that neuroscience provides the key to understand the mechanism of KR, and introduces the notion of knowledge mobilization and knowledge sustainability [Bennet and Bennet, 2008]
- **Digital Ecosystems** ‘Knowledge as Ecosystem’ considers knowledge exchange and reuse as a natural synergy taking place given favourable environmental conditions.
- **Knowledge Hubs and Knowledge Clusters:** The flow of knowledge can be helped by appropriate organisational configuration, however the flow dynamics need to be mapped and considered at organisational and system structures. The emergence of Knowledge Hubs and Knowledge Clusters should be studied [Evers, 2008]
- **Social Network Analysis:** The next frontier for knowledge reuse is the study of ‘Knowledge Networks Analysis’, whereby thanks to the support of suitable informatics tools, it is possible to analyze large volume knowledge exchange data and patterns, and how they occur in social networks. [various]

#### 4.4 Conclusions and Future Work

The web is the most pervasive, extensive and rapidly growing knowledge base ever existed. Its potential for optimising Knowledge Reuse is unlimited, but it is dependent on the availability of technologies capable of supporting KR needs in very fast changing worlds. Semantic Web capabilities (tools, platforms) must be developed taking into account applied usage and the rapid patterns of transformation that are taking place in all domains thanks to web based interactions. Last but not least, technologies should be developed to provide intended benefits for participating individuals, organisations and for the advancement of society at large. By analysing current literature, state of the art research in related fields and domain alignment to

provide an integrated perspective, this paper positions Knowledge Reuse in Practice in the context of the an evolving Web, given its complexity and multidisciplinary. As our research borders with the realm of complex systems science, non linear and at times chaotic methodological pattern of inquiry are hopefully justified.

## References

- [Berners-Lee, Lassila, Hendler, 2001] Berners-Lee, T., Hendler, J.A., Lassila, O.: The Semantic Web, *Scientific American*, 284(5):34-43, May 2001
- [Bennet and Bennet 2008] Bennet A., Bennet, D.: The fallacy of knowledge reuse: Building sustainable knowledge. Appeared in the Special Issue on Knowledge Based Development, *Journal of Knowledge Management (Knowledge Cities)* 2008.
- [Borgatti, 2003] Borgatti, S. P., Pacey C.: The Network Paradigm in Organizational Research: A Review and Typology, Foster Department of Organization Studies, 2003
- [Carlile, 2003] Carlile, P.R., Reberich, E.S.: Into the Black Box: The Knowledge Transformation Cycle, Sloan School of Management, MIT
- [Carlile, 2004] Carlile, P.: Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries. Into the Black Box: The Knowledge Transformation Cycle, 2004
- [Chai and Nebus, 2006] Chai, K.H., Nebus J.: Knowledge Reuse Across Borders: The Influence of Context, Awareness and Codifiability. On Knowledge Reuse Effectiveness, 2006
- [Demian and Fruchter, 2006] Demian P., Fruchter, R.: An ethnographic study of design knowledge reuse in the architecture, engineering and construction industry. *Research in Engineering Design*, 16(4), pp. 184-195, 2006
- [Duffy and Duffy 1996] Duffy, A., and Duffy, S. "Learning for Design Reuse." *Artificial Intelligence in Engineering Design, Analysis and Manufacturing*, 139-142, 1996
- [Dusink, 1995] Dusink, L., van Katwijk, J.: Reuse Dimensions. The ACM SIGSOFT Symposium On Software Reusability (SSR'05), Pp.137-149, April 1995
- [Dusink and Katwijk 1995] Dusink, L., van Katwijk, J.: Reuse Dimensions <http://portal.acm.org/citation.cfm?id=211828>
- [Evers, 2008] Evers, H.-D.: Knowledge hubs and knowledge clusters: Designing a knowledge architecture for development. ZEF Working paper Series, 2008
- [Guha, McCool, Fikes, 2004] Guha, R. McCool, R., Fikes, R.: Contexts for the semantic web. *International Semantic Web Conference*, volume 3298 of Lecture Notes in Computer Science <http://tap.stanford.edu/contexts.pdf> (2004)
- [Harsh, 2008] Harsh, O.K.: Reusable Data, Information, Knowledge And Management Techniques. *Journal of Knowledge Management Practice*, Vol. 9, No. 3, University of New England, Australia, September 2008

- [Lynn, 2001] Lynn, M.: Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success. *Journal of Management Information Systems*, 2001
- [Majchrzak, 2001] Majchrzak A., Neece, O.E., Cooper, L.P.: Knowledge Reuse for Innovation – The Missing Focus In Knowledge Management, 2001
- [Mizoguchi et al, ongoing] <http://www.ei.sanken.osaka-u.ac.jp/projects/reuse-ontologies.html>
- [Morris, 1946] Morris, C.: *Signs, Language, and Behaviour*, 1946
- [Nonaka, 1995] Nonaka, I.: *The Knowledge-Creating Company*
- [Schoop, De Moor, Dietz, 2008] Schoop, M., De Moor A., Dietz J.: *Pragmatic Web Manifesto*. *Communications of the ACM*, 2008
- [Sim and Duffy 2004] Sim, D.K., Duffy A.H.B.: Knowledge Transformers: A link between learning and creativity. AID02 Workshop University of Strathclyde, 2004
- [Skinner, 2007] Skinner, K.: Developing a Tool to Measure Knowledge Exchange Outcomes. University of Waterloo, Ontario *The Canadian Journal of Program Evaluation*, 2007
- [Smith, Duffy 2001] Smith, J.S., Duffy, A.H.B.: Re-Using Knowledge - Why, What and Where. 13th Int. Conference on Engineering Design (ICED 01), 21-23 August 2001, Glasgow
- [Stojanovic and Handshuh, 2002] Stojanovic, N., Handshuh, S.: A Framework for Knowledge Management on the Semantic Web. AIFB Institute University of Karlsruhe Englerstrasse 11 D-76131 Karlsruhe Germany, (2002)
- [Tao et al. 2005] Tao F., Millard, D., Woukeu A., Davis H.: Semantic Grid based e-Learning using the Knowledge Life Cycle. Hugh Davis University of Southampton, 2005
- [Tazari, 2003] Tazari M.-R.: A Context-Oriented RDF Database. Computer Graphics Center, Dept. Mobile Information Visualization, 2003
- [Tolk, 2003] Tolk, A.: Beyond Technical Interoperability - Introducing a Reference Model for Measures of Merit for Coalition Interoperability. Proceedings of the Command and Control Research and Technology Symposium (CCRTS), CCRP Press, 2003
- [Tomiya et al. 2007] Tomiyama, T., D'Amelio, V., Urbanic, J., ElMaraghy, W.: Complexity of Multi-Disciplinary Design (2)1, Elsevier 2007
- [Wu and Duffy 2002] Wu, Z., Duffy, A.: Mutual Knowledge Evolution in Team Design. University of Strathclyde, UK 2002