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Textual representations and knowledge support-systems in research intensive networks

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> The 'lifeworld' is everyday lived experience. The 'transcendental' of academic and scholarly knowledge stands in contradistinction to the commonsense knowing of the lifeworld, which by comparison is relatively unconscious and un-reflexive (Cope and Kalantzis, Chapter 5, 'Books and journal articles').

Serious consideration of this contradistinction between 'the lifeworld' and the more focused and harder work of science, as described in the previous chapter, poses some daunting intellectual and practical challenges. We aim to explore some of these challenges in this chapter. In so doing, we will cross over a multitude of perspectives and boundaries, many of which are discussed at length throughout this book. In doing this, we are interested in unpacking some of the theoretical inter-relationships between lifeworlds and science, and between constructivism and realism.

But first we ask—can these particular cross-paradigmatic perspectives be reasonably represented and reconciled in textual form? We think that attempts to do so are worthy of the greatest effort and that the reason for doing this is self-evident. Ideas are refined and improved through the process of writing. But beyond this, creation of textual representations of knowledge is of fundamental importance to the effective functioning of research intensive networks.

To support the increased efficacy and efficiency of research intensive networks and their impact in the world, we claim there is a need to expand the context of knowledge systems associated with research intensive networks. This idea for us involves the development of a public knowledge imperative. We suggest that textual representations expressed as knowledge claims can no longer be hidden away from the eyes of public scrutiny when there are important matters of public interest either implicitly or explicitly at stake. The recent catastrophe in the Gulf of Mexico provides an example of how particular types of knowledge, for example, procedures associated with offshore oil rigs, can rise up to become of the highest public priority almost overnight. To neglect the potency of such knowledge through a lack of public scrutiny can have devastating consequences, as the whole world has found out.

In this chapter we set out to provide a rationale as to why we think a public knowledge imperative is so important. To give expression to this imperative, we think there is a need for a new type of institutional and regulatory framework to protect and enhance the role of public knowledge. We call this framework a public knowledge space. It is public by virtue of the fact that it relies on semantic technologies and web-publishing principles. But more importantly, in order to understand the multiple functions of a public knowledge space, we suggest it is first necessary to develop a detailed ontology of knowledge itself. Our ontology outlined in this chapter is broadly based because we emphasise the value of experience and lifeworlds as much as we do the importance of rigorous critiquing and transparent review. By extension, our views are slightly orthogonal to prevailing perspectives of the semantic web.

In many ways, the underpinning of our notion of a public knowledge space is in alignment with the argument developed by Magee in chapters 11 and 12 of this book. Magee suggests it is possible to create a framework for commensurability which 'embraces correspondence, coherentist and consensual notions of truth'. Further, Magee's prominent referencing of the German sociologist and philosopher Jürgen Habermas and Habermas's interest in a 'public sphere' resonate strongly with what we develop in this chapter. It is interesting that we arrive at very similar conclusions but through quite a divergent intellectual pathway.

Introduction

Scholarly research is the primary driving force behind humanity's ever-increasing knowledge of the world. The utility of knowledge claims depends on how they are developed, refined and tested in the real world. The value of a claim is increased most through social processes of scholarly research involving cycles of knowledge sharing that includes individual creativity and inter-subjective criticism. We assert in this chapter that such scholarly research involves processes that occur within a hierarchically complex social system involving individual people, research teams, components at a research domain level, and the world in general, including consumers of research outputs. What makes these systems complex is that the patterns of behaviour across these varying levels of hierarchy are truly emergent in that they cannot be predicted. Thus, the impact of engaging in scholarly research work then is unpredictable.

Part of the reason for this lack of predictability we suggest is because all work is deeply grounded at the level of the lifeworld. All human beings bring their experience of the world to the context associated with their actions and to some extent we can never predict how people respond to any type of stimuli. This we suggest later in the chapter is fundamental to our understanding of knowledge itself. However, at a generalised level, we do suggest that scholarly work begins at the personal level with sense making, observation, creative thinking and self-criticism; and that this is entailed by commitments to the critiquing of preliminary ideas against existing knowledge, empirical data and more observations. This is followed by the individual's articulation and expression of knowledge claims. Such individual work is often conducted within a higher level social environment of collaboration with other people. Personal or small group expression of a knowledge claim is normally followed by inter-subjective activities within a research team, including further observation, data capture, analysis, group-orientated criticism and testing before a consensus about a collaboration is articulated and expressed. Through time, this creative work is then formalised at a discipline level through a publication process involving editorially managed peer reviews that may lead to reconsideration and revision by the authors prior to editorial acceptance and publication. Following publication of relevant research, interested communities in the broader world may further test, criticise, reshape and refine the knowledge claims through subsequent cycles of personal sense making, observation and publication.

From the establishment of scientific societies and the first journals in the Scientific Revolution in the 1660s until recently this process was relatively tangible, involving contacts and exchanges between participants that were either face-to-face or conducted via physical correspondence, leading up to the final printing and publication of the scholarly work (Fjallbrant 1997; Harkness 2007). The only technologies (other than observational instruments) involved in the process of building knowledge were those of writing (typing), duplication (printing) and the physical transport of paper manuscripts and documents between participants. Printing was a major revolution in its own right that made the Scientific Revolution possible (Eisenstein 1979, 1983; Fjallbrant 1997; Hall 2006b). For a time, printing made it possible for many peers to read and criticise the same version of a document. However, beyond this historical revolution, beginning with the exponential developments of computers in the 1950s and the internet in the 1970s, new technologies supporting scholarly research and communication are becoming more and more sophisticated and interconnected (ARL 2009; Lederberg 1991; Mackenzie Owen 2005; Maron and Kirby Smith 2008; Mukherjee 2009). These now are extending the capacity of human cognition for research in what Hall (2006b) claims is a revolution in our abilities to process codified knowledge (see also Carr and Harnad 2009; Dror and Harnad 2008).

In Chapter 4, 'What does the digital do to knowledge making?', Cope and Kalantzis describe six areas of current or imminent change that parallel Hall's views about a 'knowledge processing revolution'. These are discussed in detail under the descriptions of 'the mechanics of rendering'; the rise of a 'new navigation order'; the trend towards 'multimodal environments' and 'ubiquitous recording'; the 'change in sources and directions of knowledge flows'; and what Cope and Kalantzis describe as 'polylingual potentials' of the new digital media.

We think Cope and Kalantzis's descriptions offer a unique and significant insight into the nature of the changes emerging with the rise of digital media. However, we aim to reframe part of their and Magee's analyses by drawing on an extended theoretical filter. We do this by highlighting that research knowledge is developed, reviewed and disseminated in a hierarchy of subsystems comprising individual people, research teams and professional domains and the wider societal level. These subsystems involve the personal, social and intellectual interactions between people as well as the interactions mediated via technologies and the use of different types of *schemas* and standards.

We define a schema as the semantic and organisational structure of a cognitive process. Thus, schemas can be tacit, implicit and explicit. For example, we experience the tacit nature of schemas when working in cross-cultural contexts that are unfamiliar, where the ability to understand language and to accurately attribute meaning is far from certain. Tacit schemas are just that—they are deeply connected to the lifeworlds of actors. They cannot be made explicit and thus cannot be articulated within documents or database structures. By contrast, the semantics and structures diffusely embedded within documents, for example, can implicitly encode a schema that is representative of a person's personal knowledge of a particular domain. Such schemas are implicit to the extent that these schemas are not explicitly represented. However, given time, they can be made explicit and this is what distinguishes implicit schemas from tacit schemas.

There is a growing recognition that schemas associated with unstructured and semi-structured ways of thinking and expression need to be made explicit and published. This is because there is significant utility associated with the use of the internet and related technological systems to manage content exchanges.

For such benefits to be maximised, information systems need to be made interoperable by conforming to agreed standards. To reach negotiated agreements about such standards, reviews are undertaken by industry bodies which define, and then describe, the standard in question. These negotiated agreements are published as schemas. Such schemas 'express shared vocabularies and allow machines to carry out rules made by people' (Sperberg-McQueen and Thompson 2000–2007). The advantage of the process just described is that it allows an industry-standards body to agree on a schema which is sympathetic to the needs of that industry and declares it to be a standard for that industry.

The interactions that occur between the different subsystems involved in the creation of scientific and scholarly knowledge outlined above are reliant on the use of schemas ranging from tacit to explicit and formalised standards. Therefore, we think that these schemas and standards form part of what we call a 'knowledge support-system'. These support-systems are socio-technical in nature in that their functioning is reliant on networks of people, the mediation of person-to-person interactions through the use of technology, and individual people's interaction with computers and machines.

What makes these knowledge support-systems in the current era fundamentally different from the historical world of print is that the exchanges of bits and bytes of coded information can now occur more or less at light speed—and that these exchanges can be enacted simultaneously between the varying levels of hierarchy (for example, between individuals and research teams; individuals and teams and a research domain level; or between individuals, teams and research domain level and national or international standards body). Also, at least some components of the cognitive processing function are increasingly being assisted and automated or semi-automated by technology.

In our chapter we are interested in how people collectively harness and use these emerging knowledge support-systems to develop solutions to research problems. We consider these socio-technical activities as vital to the effective functioning of a 'research enterprise'. In using the term 'research enterprise', we are referring to both the internal and the extended networks that contribute to scholarly research globally. For example, it could refer to academic research institutions such as universities or other knowledge intensive organisations, or even commercial and semi-commercial research publishing enterprises where there is a high degree of reliance on research to support evidence-informed decision making.

The development and application of the knowledge support-systems described above is growing so rapidly that it is difficult for many to comprehend fully how these changes are affecting the socio-technical nature of the 'research enterprise' itself. For example, people in many different disciplines now routinely use knowledge support-systems to help them create and evaluate research knowledge. As part of these activities, these people are designing and implementing support-systems to process data and information in novel ways. In so doing, we claim a proliferation of subsystems is contributing to significant conceptual and terminological confusion when data is exchanged across system or discipline boundaries. When data crosses such boundaries, the differences in world views tacitly embedded within the social and professional languages used as part of the genre of these domains becomes evident. Therefore as the benefits of online data exchange grow, the need for conceptual and terminological clarity increases. Thus, in our chapter, we expose in some detail many of the challenges described by Cope and Kalantzis in Chapter 4, 'What does the digital do to knowledge making?', when they highlight the complexity of topics such as the emergence of a 'new navigation order' or the 'new dynamics of difference'.

A major barrier to the effective functioning of research enterprises is that of interoperability—a topic described in Chapter 14, 'Interoperability and the exchange of humanly usable digital content'. This problem emerges naturally because components of any system developed by stakeholders within a research enterprise may rely on different schemas and standards to support the exchange of data, information and knowledge. We think that consideration of the challenges associated with interoperability provides a concrete example of what Cope and Kalantzis calls the 'new dynamics of difference'.

Within this broad conception of the nature of the socio-technical research enterprise, we claim it will prove necessary to develop a deep epistemological and structural understanding of how research enterprises conceive, generate and use knowledge. We further claim that a semi-formal ontology is required to support enhanced communication across disciplinary boundaries. We aim to address some of the underlying epistemological and ontological confusion that we believe constrains the effective functioning of the modern day research enterprise.

Our central concern in writing this chapter is to show why we think the effective functioning of modern day research enterprises will increasingly rely on the emergence of an institutional framework we have previously referred to as a public knowledge space. We think these knowledge spaces are likely to emerge where multiple stakeholders, including government, are required to collaborate to solve problems. Central to addressing real-world problems is the willingness and ability of stakeholders to collaborate to create shared context. This ability can be facilitated by publishing and harmonising the different schemas and standards that are essential for online information sharing and monitoring.

We discuss how a public knowledge space can provide a range of services including providing pathways to access historical knowledge assets and related contexts. The need for this type of public infrastructure is likely to increase as the complexity of our knowledge-orientated society increases. A number of emergent projects are discussed.

Finally, the many challenges outlined are exacerbated by the fact that even professional knowledge managers—an emergent professional domain that could well do much to mediate paradigmatic differences—cannot agree on what it is they are supposed to be managing (Land 2009; Stenmark 2002; Wilson 2002).

To address this foundation problem, we begin our chapter by introducing a theory and ontology of knowledge derived from Karl Popper's evolutionary epistemology. We think this theory and ontology is necessary to explain the various forms of knowledge that emerge within a research enterprise. Popper's epistemology is combined with a theory of hierarchically complex systems to help understand the multiple layers of complexities within the research enterprise. We highlight that this application of a synthesis of theories has utility because it helps focus on interactions within and between the different levels of organisation—of individual researcher (and his or her lifeworld), research team, research community, research administration and worldwide.

Towards an ontology of knowledge

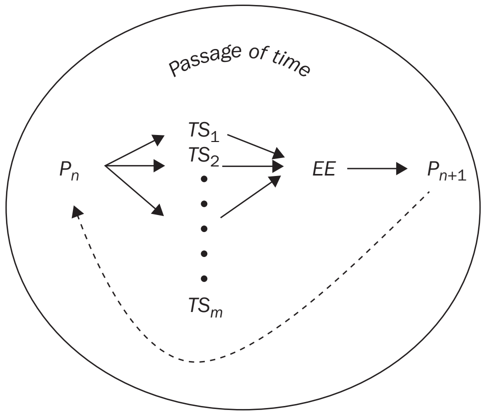
In this section we aim to outline an 'ontology of knowledge'. At base level here, we are interested in unpacking the theoretical questions and inter-relationships that arise when exploring the boundaries between lifeworlds and science; and between constructivism and realism. We do this first by discussing the notion that knowledge is an emergent property of evolutionary systems. We then describe the means by which different types of knowledge emerge through time within research enterprises. Finally, we refer to other types of cyclical models associated with the acquisition and growth of knowledge.

Knowledge as an emergent property of evolutionary systems

What do we mean by 'knowledge'? In knowledge management there are almost as many definitions of knowledge as there are practitioners, to say nothing of arguments about relationships between data, information and knowledge (e.g. Land 2009; Stenmark 2002). Here we adopt Karl R. Popper's (1972) concept that 'knowledge is solutions to problems'—or at least claims towards solutions. We choose to adopt this approach because it is grounded in an idea called an 'evolutionary epistemology' ('EE'). Donald T. Campbell (1974) first coined this term. However, Campbell credits Popper with its origination and with expressing its fundamental perspective in *Logik der Forschung* (1935). Both Campbell (1959, 1960, 1991) and Popper argued that knowledge emerges in living things as they adapt to the world. In his most complete explanation, Popper (1972, pp. 241–45) referred to this as his 'general theory of evolution'.

In this theory, outlined in Figure 6.1, P_n is a 'problem situation' the living entity faces and TS_m represents a range of 'tentative solutions', 'tentative hypotheses' or 'tentative theories' the living entity may propose or act on. *EE* ('error elimination') represents a process by which tentative solutions are tested or criticised to selectively remove solutions or claims that don't work in practice. Popper and Campbell are slightly different in their perspectives of EE in that Popper sees the selective forces of reality eliminating the failures, whereas Campbell sees selection leaving behind those tentative solutions that didn't fail. In either case, P_{n+1} represents the now changed problem situation remaining after a solution has been incorporated. As the entity iterates and reiterates the process (the arrow indicating iteration is added), it will construct increasingly accurate representations of and responses to external reality. These interconnected ideas formed the basis of Popper's (1972) 'general theory of evolution' and the 'growth of knowledge' that takes place in living entities. This idea of an evolutionary epistemology encompasses

Figure 6.1 **Popper's 'general theory of evolution'**



From Hall 2005, after Popper 1972, p. 243

what we mean when we say that *knowledge is an emergent property of an evolutionary system*. The arrows in Figure 6.1 indicate that these iterations through time are sequential processes and may involve self-observation. Some may suggest that such system attributes can result in a viciously circular and self-reenforced closed system (e.g., Luhmann 1995a, 1995b). But this is not the case, because the evolutionary system is open along the time axis (Hall and Nousala 2010). We suggest this latter point might be seen as slightly innocuous, but it could have significant ramifications for future research directions. For example, we think it opens up creative possibilities within the context of Cope and Kalantzis's juxtaposition of the realm of the lifeword against the harder work of science. It might also have the potential to create a pathway to be able to hold in balance constructivist, including radical constructivist, and realist perspectives. Thus we conclude the place of time within our ontology of knowledge is an exceptionally important one.

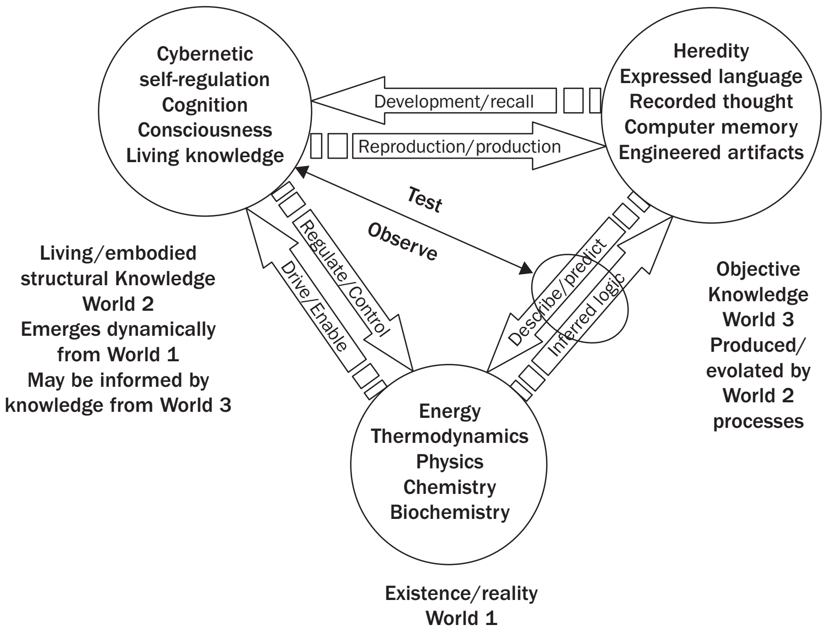
To fully comprehend what might be possible and what might become available through Popper's notion of an evolutionary epistemology it is necessary to consider additionally that Popper thought that knowledge grows through iterated interactions of three ontological domains or 'worlds' (Popper 1972). We contend this articulation of an ontology of knowledge is crucial in order to understand and explain the different types of knowledge that evolve through time.

Our ontology development therefore begins with defining these three distinct but interacting ontological domains or 'worlds' (Popper 1972, p. 107, etc., 1978, as extended by Hall 2005, 2006a). 'World 1' (W1) is 'the world of physical objects or of physical states', including the uninterpreted dynamics of everything physical. 'World 2' (W2) is the 'the world of states of consciousness, or of mental states, or perhaps of behavioural dispositions to act', which we extend to encompass the 'living' world of cybernetics, cognition and knowledge in the broad sense. Popper includes '*subjective' knowledge* (the subject's personal knowledge), which is an individual or subject's inherent propensity or disposition to 'behave or react' (1972, p. 108) in certain ways in particular circumstances in W2. This approximates Polanyi's (1958, 1966) personal and 'tacit' knowledge and we would suggest is inclusive of certain aspects of the lifeworld discussed in the previous chapter. 'World 3' (W3) includes all kinds of persistently encoded knowledge (e.g., the logical contents of written documents, electronically encoded information, sequences of nucleotides in a DNA molecule, etc.; Popper 1972, pp. 73–74). 'Knowledge in the objective sense is *knowledge without a knower*; it is *knowledge without a knowing subject*' (Popper 1972, p. 109). Codified knowledge is 'objective' because its logical content can exist in W3 logically encoded in the physical structure of a W1 container that can exist separately from the 'knowing subject', and can be decoded in W2 with similar subjective meanings by different subjects.

A fundamental question is: How does knowledge emerge when there are three ontological domains involved? Popper differed significantly from the logical positivists in that he argued no objective truth could be proved—only that certain claims could be shown to be in error through tests or criticisms of the claims as they impact reality (W1). He argued that knowledge claims may be aggregated and transformed, progressing from raw sense data registering impacts of the physical world on a living entity (for example, experience or observations of events), to well-tested and proven solutions for the major problems of life (Popper 1999). A theory referring to W1 can be constructed by people in W2 and (optionally) be expressed and shared in the form of W3 content. Through iterated cycles of hypothesising solutions, and testing and criticising them to eliminate errors, knowledge claims asserted in W2 or W3 can approach correspondence with W1's reality, as Popper (1972) explained in his 'general theory of evolution' (Figure 6.1).

Popper's ideas of the three worlds can be grossly misunderstood if one tries to interpret W3 from the viewpoint of Platonic idealism (Balaguer 2009), strict monism (Popper 1994; Schaffer 2009) or dualism (Robinson 2009). However, in Popper's interactionist concept (Popper 1994; see also Robb and Heil 2009 for interactionism), and as we use it here, the three worlds are constantly interacting, as shown in Figure 6.2. For example,

Figure 6.2 Knowledge in the three worlds ontology



the dynamics of W1 drives life and its cyclical activities in W2, and these in turn contribute to the control of the physical dynamics of W1 through cybernetic regulatory processes. W2 processes in living entities can encode knowledge about W1 into objective knowledge that can persist in W3 over time and space. Or the inferred knowledge about W1 can be decoded from W3 and interpreted and acted on in W2, where it then serves to describe and predict dynamics in W1 (W1 and W2 do not interact directly, but only via cybernetic dynamics in W2).

Thus, we think that the interactions between these three worlds are as important as the epistemic distinctions between them. It is these interactions that differentiate Popper's approach from Plato's static approach or monistic or dualist approaches and that lies at the heart of our understanding of abstract objects that are textual representations of knowledge in W3.

The emergence of different types of knowledge through time

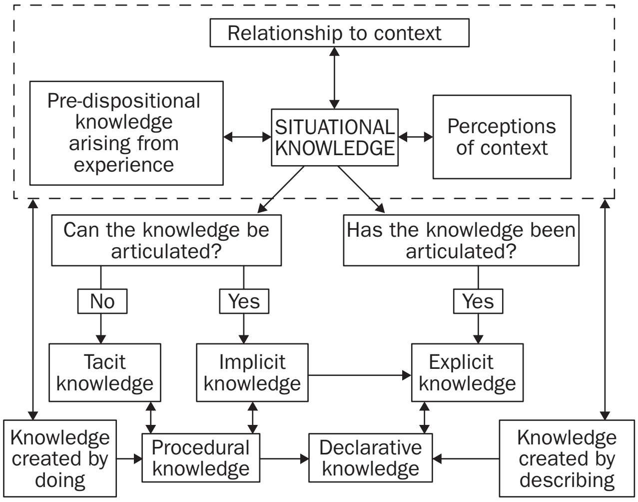
We have introduced the three-world ontology as above specifically because we claim it provides a foundation on which to understand the emergence of different types of knowledge through time. The reason we think the three world ontology is an important component of this theoretical framework is that it is the continuous interaction between the three ontological domains that give rise to the different types of knowledge we now describe. In the appendix to this chapter we provide a detailed summary of our ontology of knowledge as it relates to a research enterprise. We have documented this because it provides an understanding of our claim that different types of knowledge are continuously transformed into other types of knowledge. Later in our chapter we explain why we think this has important ramifications for knowledge support-systems within research enterprises and the functioning of a public knowledge space.

We start our description of knowledge by referencing Michael Polanyi (1958, 1966). Polanyi hypothesised that 'personal knowledge' encompasses several types of knowledge, and specifically includes what Popper (1972) described as 'dispositional' or 'subjective' knowledge. Dispositional knowledge is embodied in people's unconscious propensities to act in certain ways (as 'natural talent', habits and skills), while subjective knowledge lives in people's minds and together these contribute to personal knowledge in W2. The un-interpreted physical–chemical and dynamic structure of a person's brain exists in W1. However, the cybernetic control of that structure, whether it is physiological and reflexive or under the control of conscious decisions and the memory of history that together constitute the mind's knowledge, lives in W2 (Hall 2005, 2006a; Hall, Dalmaris and Nousala 2005; Popper 1978). Aspects of this personal knowledge can be encoded in W3 in inert and objectively persistent formats (as 'explicit' knowledge). Where the existence of this explicit knowledge is known only to the individual, we include this within 'personal knowledge'.

Personal knowledge emerges from cycles of natural selection and individual 'sense making'—encompassing activities in W2 that organise sensory impressions (data) of W1. Part of sense making may involve decoding W3 content and extracting and reformulating these materials to extend living knowledge—possibly to support immediate action and/or to create new content in W3 to support W2 memory or social processes of sense making and action.

In Figure 6.3 we adapt Nickols' (2000) terminology to highlight that personal knowledge is always contextualised. Knowledge initially emerges or is constructed as 'situational knowledge' in living entities—generally in response to situations and problems of existence. 'Tacit knowledge' (W2) is unconscious or inherent in a person and cannot be readily articulated. 'Implicit knowledge' also resides in W2, but is consciously available to the

Figure 6.3 **The contextual nature of personal knowledge**



Adapted from Nickols 2000

person and can be articulated and may be codified for storage in W3. Tacit knowledge can become 'tacit procedural knowledge' if it becomes embodied in unconscious personal routines. Nelson and Winter (1982) argue that some competitive differences between (organisational) systems can be attributed to relatively stable capabilities expressed in the dynamic structures of these systems. These 'heritable' organisational capabilities include such things as undocumented 'routinization' of knowledge intensive processes at the organisational level, development of specific jargons, and the layout of plant and equipment. Nelson and Winter specifically called this 'tacit organisational knowledge' after Polanyi (1966). We think this contributes to cybernetic regulatory and control mechanisms (in W2) at the level of organisational knowledge systems and suggest this makes the knowledge of a research team, group, establishment or discipline something more than the sum of the personal knowledge of the networks' individual human members.

Personal knowledge may be shared with other people via conversation and articulation. Unless it has been shared and understood, tacit or implicit knowledge important to a research team or domain becomes 'lost knowledge' when links to it are broken (e.g., when people holding relevant personal knowledge leave that domain or network).

When knowledge is codified in an objectively persistent format (W3) it becomes 'explicit knowledge'. Explicit knowledge is 'objective' in

Popper's sense because it has been codified into or onto a persistent substrate, for example as sequences of letter marks on paper or polarisation domains on a magnetic surface. The logical and semantic content of the knowledge exists in W3. The atoms and molecules of the physically encoded form of that content exist in W1, but its meaning can only be made operational (Corning 2001) by a person's W2 processes to decode and act on the knowledge. Examples of explicit knowledge within a research enterprise include all documents, graphics, spreadsheet files, databases, emails, video clips, wikis and blogs, etc.

Even where important knowledge exists explicitly, access to that content may still rely on the personal knowledge of only one or two people (or no one). Thus, a research network may retain explicit knowledge generated by its members even after they leave, but in many cases the personal knowledge of other people, including tacit knowledge, is still required to access and apply it (Cowan, David and Foray 2000; Nousala et al. 2005; Tsoukas 2005). Where explicit knowledge is on paper, when personal knowledge about its existence and location is not available to a research network or is not available when and where it is needed, then such knowledge becomes 'orphaned explicit knowledge' and might as well not exist at all. Where explicit knowledge has been preserved in electronic formats, search capabilities in a technological support-system can minimise this kind of orphaning.

'Procedural knowledge' can often be both tacit and implicit and is created through learning by 'doing'. Procedural knowledge that is implicit in nature can be articulated to become 'declarative knowledge' and is created by describing things. 'Articulation' means putting ideas into words that may then be encoded into W3. We think there is some greyness and uncertainty about how to understand the ontological nature of articulated or declarative knowledge and when these types of knowledge are understood as explicit or objective. Some suggest that speech vanishes as it is articulated and leaves only subjective mental trace in the minds of those who hear it (Ong, 1982). But with the increasing ubiquity of mechanical recording devices this creates the potential to place recorded speech in W3. Thus, when recording of speech does occur, speech is fully explicit and objective.

'Common knowledge' is content that has been widely shared or is readily discoverable when needed using familiar retrieval methods. Personal tacit knowledge may be shared to become 'common tacit knowledge' (Nousala 2006; Nousala, Hall and John 2007). For example, apprenticeships, 'grapevines', 'rumour mills' and undocumented routines—'that's the way we do things here'—all provide examples of how 'personal knowledge' can be transferred and made 'common' without being made explicit. Similarly, explicit knowledge that becomes widely known or easily retrievable is termed 'common-explicit knowledge'. Consideration has been given to using the term 'shared' in these contexts instead of 'common', but sharing refers to a process and does not indicate how widespread the shared content might be. Only when the knowledge is widespread or easily discovered and accessed, and thus able to survive the absence of key individuals who know it, does the knowledge truly become available to members of a research network or enterprise rather than just a few individuals. Network protocols that limit access to particular files and documents or business practices that impede tacit sharing reduce the accessibility of knowledge, and hence the ability for it to become common rather than lost or orphaned.

'Formal knowledge' refers to 'authorised common knowledge'. Formal knowledge is that subset of common knowledge in W2 or W3 that has been socially critiqued and approved in an organisational context. Through the process of critiquing and reaching negotiated agreements, authorisation is given to use knowledge in appropriate contexts. Examples of formal knowledge include:

- negotiated schemas and industry based standards
- content of an industry training or university accredited training program
- knowledge transferred via apprenticeship programs
- instruction manuals, policies, procedures, engineering documentation, lessons-learned documents, research publications and so on, as formalised via release and publication workflows, acceptance by an organisational committee or a industry working party
- formally established business processes and workflows
- documented routines and processes, including plant and equipment layout, and so on, where people have authorised the implementation of chosen routines and processes.

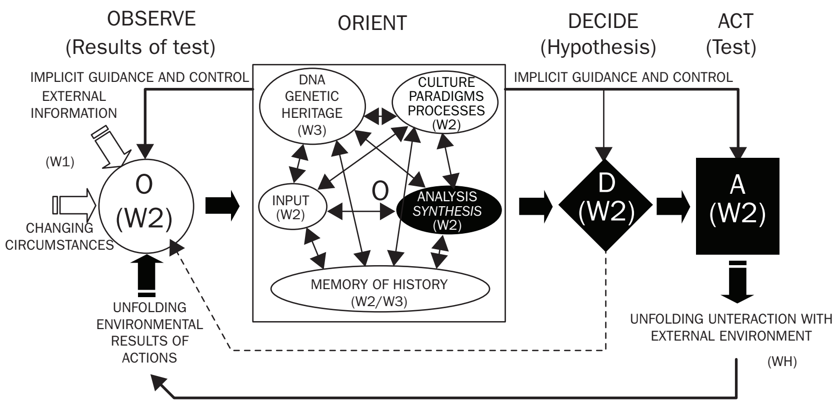
Formal knowledge can be both tacit and explicit. For example, 'formal tacit knowledge' might refer to processes that are well-defined routines with these routines guiding how things are done in ways that are well known but not explicitly documented (after Nelson and Winter 1982). In contrast, 'formal explicit knowledge' refers to routines or policies that are developed as a result of research and are published in an objectively persistent format. Formal documents:

encompasses many categories of documents, including letters, notes, book reviews, conference papers, journal articles, responses and academic books. The common feature is that they have been subjected to formal review prior to publication, and hence carry some form of imprimatur recognized within the relevant scholarly community (Clarke and Kingsley 2008).

Other cyclical models associated with the acquisition and growth of knowledge

As represented at its most fundamental level by Popper's (1972) evolutionary epistemology (see Figure 6.1), the dynamics of knowledge acquisition and application is cyclical. Other cycles similar to Popper's have also been proposed, for example, SECI (Nonaka 1994; Nonaka and Takeuchi 1995), single and double loop learning (reviewed by Blackman, Connelly and Henderson 2004) or the knowledge life cycle (Firestone and McElroy 2003a). Because of its similarities to Popper's representation of the evolutionary theory of knowledge and the severe testing it has received in real-world conflicts (Mutch 2006), we find Boyd's (1976–1996) observe–orient–decide–act (OODA) cycle (Angerman 2004; Grant and Kooter 2004; Hall 2003, 2005, 2006a; Martin, Philp and Hall 2009; Philp and Martin 2009; Richards 2008) (see Figure 6.4) is suited to the discussion here.

Figure 6.4 **John Boyd's OODA loop concept**



From Hall 2005 (after Boyd 1976–1996); Richards 2008

'Observe' and 'orient' involve the cybernetic processing of information in W2 (as shown in Figure 6.4) to collect and then contextualise observations of the world. In the generation of research knowledge, external information feeding into the cybernetic processing of observation and orientation includes knowledge extracted from the research literature. Then, in 'decide', decisions are made about what action to take—where 'decision' can involve anything from an instant gut response by an individual (W2) to deciding the results from the inter-subjective criticism of formal hypotheses (W3). Finally, the entity 'acts' to test its understanding and prior learning by observing results of action in the physical world. A new cycle begins with observing the results of prior action.

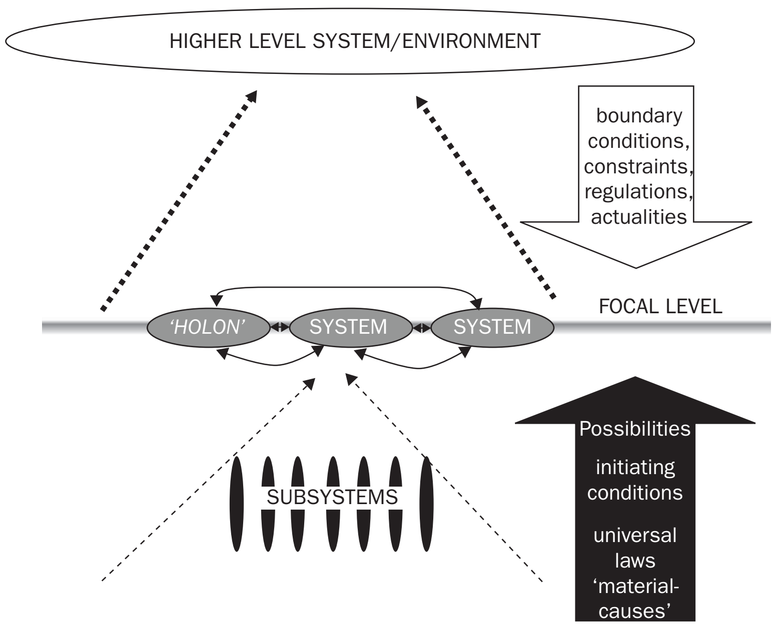
The theory of hierarchically complex systems

We have previously defined several knowledge related concepts and types of knowledge. We now add another dimension to this ontology by considering the functions of knowledge in the hierarchically complex systems of today's research enterprises.

It is easy for us to recognise and see complex system entities at our own human focal level or lower levels of organisation as through a magnifying glass or microscope (e.g., where most of us would know how to interpret what we see). On the other hand it is much more difficult for us to discriminate and 'see' complex entities at larger scales and higher levels of focus than our own, for example, entities such as the biological species we belong to (*Homo sapiens*), our solar system, or the Milky Way galaxy including our solar system (Chaisson 2001; Gould 2002; Hall 2005, 2006a; Salthe 1985, 2004). It takes the equivalent of looking through the 'wrong' end of a telescope and considerable mental effort and practice for us to recognise and focus on the boundaries of higher level systems that include us as components. However, many high-level systems including humans as components (e.g., knowledge-system networks) are bounded by the equivalent of a living cell's semi-permeable membrane that we can learn to recognise as 'permeable boundaries'. For example, members may be recruited on the basis of qualifications, there might be an allocation of passwords to allow authorised access to research data and research resources, and there might be some restrictions about communication of research findings etc). Following Simon (1962) such boundaries are normally reflected by a higher level of knowledge sharing interactions between people forming a system versus similar interactions with those outside the system. These considerations are clarified by hierarchy theory.

The theory of hierarchically complex dynamic systems derives from concepts of complexity (Simon 1962, 1973, 2002), control and causation (Corning 2001; Pattee 1973, 2000), and scalar levels of organisation and emergence (Hall 2006a; Salthe 1985, 1993, 2004). The dynamics of control and causation in a system are entropically driven by the dissipation of free energy in the transport of energy from a high potential source to a low potential sink (Prigogine 1955, 1981). 'Systems' are comprised of causally connected parts. In a 'complex system', where many parts interact non-linearly in ways such that even given the properties of the parts and the laws of their interactions, the properties of the whole are not easily predicted (Simon 1962). 'Hierarchically complex systems' are those where individual parts that interact to form a designated system at one 'level of focus' can be seen to be composed of several to many interacting components at a more detailed, 'lower', level of focus (Simon 1962, 1973); see Figure 6.5. Every entity that is a complex system can be seen to have a triadic existence (Koestler 1967, 1978; Salthe 1993): (1) as a component of and within a higher level system (e.g., a person working within a firm), (2) the existence of the

Figure 6.5 **The systems triad in hierarchy of complex dynamic systems**



Hall, Dalmaris and Nousala 2005 (after Salthe 1985) system itself (the person) at the focal level, called a 'holon', which in turn is comprised of (3), the collection of lower level systems serving as its components (the living cells comprising the person's body).

In general, by comparison to a specific holon or 'focal system' of interest that can be discerned at a given level of organisation, dynamic activities within the much smaller lower level components subsystems will be generally so much faster that they will appear to be in equilibrium—in effect defining the laws of interaction among the systems visible at the focal level and thus determining what it is possible for the holon to do. The dynamics of the much larger super-system, which includes the focal system as a subsystem, will be so much slower that they appear to provide a constant environment for the focal system—thus establishing constraints and boundary conditions on what the holon can do (Salthe 1985, 1993; Simon 1973, 2002). Constraints applying downward control may be negative (inhibitory) or positive (facilitative). The dynamic structure of a focal system (the specific states, interactions and trajectories of the components comprising the system) at a point in time establishes conditions that provide a downward control over the dynamic possibilities available to the subsystems comprising the focal system (Pattee 1973, 2000). The structures providing that control can be considered to embody 'control information' (Corning 2001; Pattee 2000).

Where the potential gradient in the energy flux between the source and sink across a given focal system is large enough (e.g., because the higher level super-system is 'inefficient') processes may emerge to form an additional dissipative system establishing an intermediate level of organisation in the complex systems hierarchy between the higher level system and the focal level (Salthe 2004).

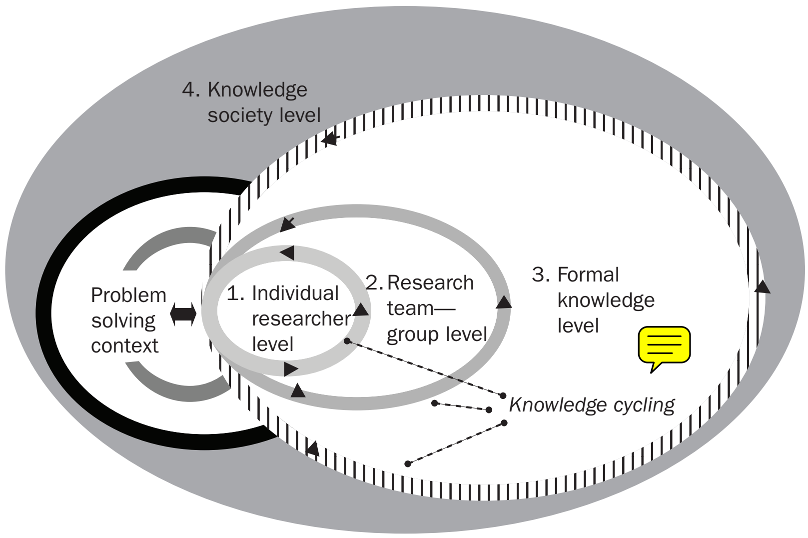
These matters have relevance to the ontology of knowledge as this relates to research knowledge systems. For example, in large research enterprises, the formal processes surrounding applications for research funding are an example of one level of focus within the hierarchical complex system of academic research. At lower focal level individual researchers or research teams jostle to secure as much flexibility and adaptive capacity as possible, in order to respond to dynamics of these lower levels of hierarchy. The tension between these two levels of hierarchy, for example, has significant impact on the dynamics of the emergence and formalisation of knowledge. Downward causation, resulting in significant system constraints at lower levels of hierarchy, can prevent or facilitate the emergence of new knowledge claims. Going forward, one of the key skills will be to determine how and when system constraints should be applied (or relaxed) and on what basis.

Research knowledge and the dynamics of hierarchically complex systems

Modern-day research enterprises work to increase the formal knowledge available to a knowledge society (Lederberg 1991) and to solve pressing problems. We claim that the growth of knowledge in a knowledge society takes place in a hierarchically complex system comprised of at least four interacting levels of cyclical knowledge building. In what follows, we expand our ontology to discuss some of the processes through which research knowledge emerges and grows through time. We are particularly interested to highlight the dynamics through which research knowledge claims are constructed and evaluated and to show how the nature of knowledge that emerge from these varying levels of knowledge cycling. In outlining parts of our discussions we also refer to aspects of Popper's general theory of evolution (see Figure 6.1) and Boyd's OODA loop process (see Figure 6.4).

We will now proceed to examine the dynamics of the four levels of knowledge cycling in particular systems as shown in Figure 6.6 more closely.

Figure 6.6 **The hierarchical levels of knowledge cycling in a research enterprise**



Individual researcher level (personal knowledge)

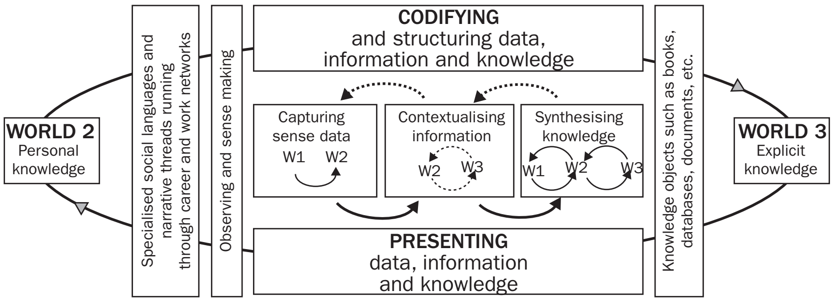
Scholarly research begins at the individual researcher level and involves sense making and associated cognitive activities of individual researchers. Individual researchers tend to follow a generic research cycle similar to the OODA cycle discussed above. They act by:

- observing (*O*) problems in the world (P_n), and the context within which the problem is manifest (problem solving context)
- orienting (*O*) to the observations through their awareness of prior explicit knowledge contained in the 'body of formal knowledge' (BoFK) as mediated by their innate cognitive capacities and constrained by cultural paradigms and processes (both corresponding to observation and orientation in the OODA cycle)
- formulating ideas and articulating claims or 'tentative theories' (*TT*—cf. decide in OODA cycle)
- eliminating errors (*EE*—cf. act in OODA) through criticising and testing them against the world
- observing the results (beginning the iteration of a new cognitive cycle at the researcher level).

While this process appears to be well structured and logical, significant amounts of tacit and implicit cognitive processing can be involved. That is, individuals may not be able to articulate what it is they do, why they make specific types of decisions or what types of schemas they apply in their work. We define a schema as the semantic and organisational structure of a cognitive process and thus at the individual researcher level schemas are mostly tacit and implicit in nature.

Figure 6.7 outlines the transformation of personal knowledge into explicit knowledge that occurs at the individual researcher level. Iterative interactions occur involving observing W1; mental processes, sense making, social languages and narrative exchanges in W2; and the coding and decoding of knowledge between W2 and W3. Part of the overall sense-making process may involve codifying empirical data and information into explicit knowledge objects (W3) as informed by cognitive processing in W2. An extension to existing research knowledge occurs when new knowledge claims are tested against W1 and the results are criticised in W2 against prior knowledge claims that exist in W3. It is the constant and cyclical interactions between these worlds that enable knowledge to be constructed tested, critiqued and refined. Through time, different versions of objective artefacts are produced.

Figure 6.7 **General process for turning personal into explicit knowledge**



After Vines, Hall and Naismith 2007

Popper (1994, p. 13) makes an interesting statement:

> As for subjective knowledge [W2], much of it is simply taken over from objective knowledge [W3]. We learn a great deal from books, and in universities. But the opposite does not hold: although objective knowledge is man-made, it is rarely made by taking over subjective knowledge. It happens very rarely that a man first forms a conviction on the basis of personal experience, publishes it, and gets it objectively accepted as one of the things which we say 'it is known that…'.

What usually happens is that the knowledge claim is articulated and often written down in draft form for intersubjective criticism and testing long before it is accepted and approved for formal publication in a journal or book.

The exchange and sharing of personal knowledge often involves interactions that extend into team or group level interactions when a research claim or tentative theory is first being constructed. It is through these extended networks that personal knowledge begins to be articulated and tested in practice. One of the most important media through which such processes occurs is natural language conversation itself. There is, however, a risk that such personal knowledge sharing may have detrimental impacts because each person unavoidably constructs an understanding of the world within a personal frame of reference (Kuhn 1962, 1983). In effect, individual knowledge processing schemas as summarised in Figure 6.7 can be innate and tacit—corresponding to the culture, paradigms and processes of Boyd's OODA loop concept (Figure 6.4)—as well as implicit.

There are significant impediments to the transformation of personal knowledge into explicit knowledge. For example, solutions often emerge in a social environment, where personal knowledge can provide a tacit or implicit compass to guide action. Equally, attempting to use personal knowledge to create explicit knowledge so that such knowledge can be applied in other contexts by other people can also be problematic, because emergent knowledge might be highly context sensitive. Also, for various reasons, researchers may not want to explicitly advertise their expertise (Ardichvili 2008; Bock et al. 2005), because they may fear this might diminish their own particular position, they may not welcome critiquing of their professional expertise that could arise if they make their expertise explicit, or they simply may not wish to be bothered by people asking for help. On top of this, even where people are willing to share, there may still be limitations to sharing because of the principle of bounded rationality (Else 2004; Hall et al. 2007; Nousala 2006; Nousala et al. 2005, 2009; Simon 1979; Snowden 2002). That is, people cannot share all that they know, and sharing invariably results in some loss of knowledge. Workers also cannot write down everything they may be willing to share (Snowden 2002), although once codified, knowledge may be accessed and distributed more rapidly and widely than speech.

Research team or larger group level (common knowledge)

Today most research is done in a social environment of informal or formal collaboration. The second, higher level cycle shown in Figure 6.6 involves collaboration within a research team or larger group. This process may begin with:

- the sharing of articulated theories (Popper's *TT*) verbally or via draft papers, followed by
- collective orientation to the shared ideas and BoFK, followed by
- inter-subjective error elimination (*EE*), and concluding with
- collective criticism (c.f. 'act' in OODA) of the *TT*, leading to the authoring of an explicit knowledge claim or claims.

The development of higher levels of collaboration brings with it the challenge of enabling explicit knowledge artefacts to become more accessible, thereby gradually transforming explicit knowledge into common explicit knowledge. Online databases, enterprise web portals and document management systems with electronic workflows and search mechanisms (Hall et al. 2008) all help transform explicit knowledge into common knowledge. The challenge is to provide appropriate technologies, network architectures and process workflows to make this transformation easy and to limit the use of internal security controls that reduce the discoverability and accessibility of explicit knowledge as common knowledge.

Within a knowledge-system network, the shift from individual to collaborative decision making can never be assumed. There is a need to cultivate a level of shared context and language in order to support collaborative opportunities and directions. It is in understanding and managing the boundaries between personal knowledge and more communitarian understandings of knowledge where the complexities of the discipline of knowledge management arise. One of the purposes of the role of knowledge management and indeed of science education itself is to help individuals develop and expand their personal knowledge, and to facilitate rational knowledge sharing. We do not suggest this journey towards rational knowledge sharing is easy, because strong emotional responses can be unearthed in any journey that involves researching the unfamiliar.

Formal knowledge level

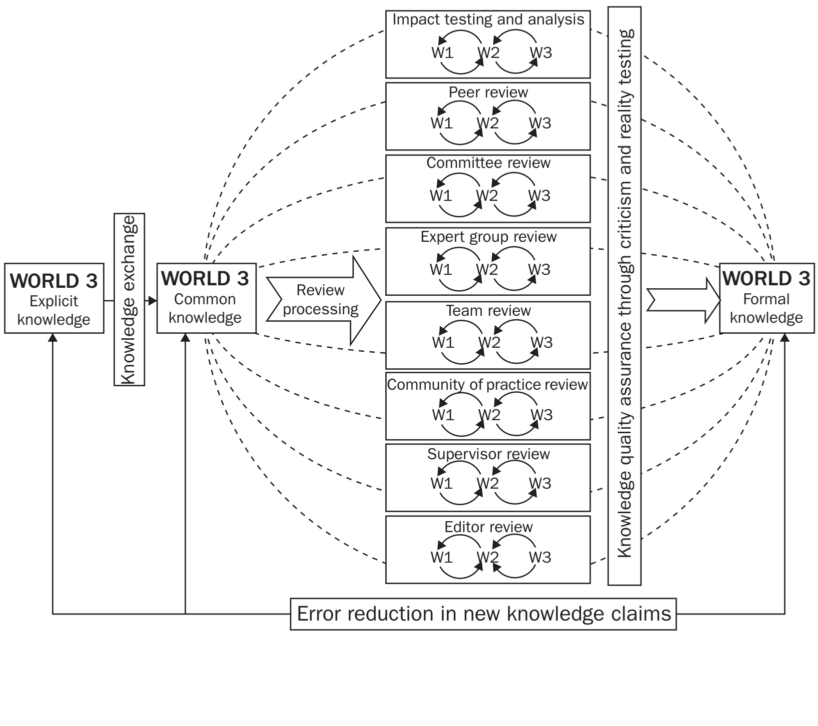
The third, higher level involves the development of formal knowledge. Within the research enterprise this can include formal publishing processes. In simplified form, at this level the knowledge cycle involves:

- submission of a paper by a researcher or group of collaborators to a publisher or authentication body
- initiation of a peer-review process by an editor working at the organisational level that involves observing and orienting to the paper and selecting appropriate reviewers for it
- individual peer reviewers at the researcher level each observing and orienting to the paper and in some cases testing the knowledge claims, criticising them and returning their explicit criticisms to the publisher or authentication organisation
- the editor at the organisational level either committing the paper to formal publication as an addition to the BoFK or returning it to the author(s) as a rejection or with a request for changes or improvement—which then initiates further cycles at the investigator and collaborator layers.

Within the research enterprise itself, the creation of formal knowledge can also involve various internal social processes of critiquing such as those that occur through supervision, community of practice reviews, committee structures and the like (Figure 6.8). We contend that this review of common knowledge is a knowledge quality-assurance process (Vines and Naismith 2002). Through such review processes, understandings and agreements are reached about the degree to which knowledge claims can be used to solve real-world problems (Firestone and McElroy 2003a, 2003b). Such agreements can be struck in a range of different contexts, including, for example, through staff supervision, formal research projects, formal committee structures or the journal publishing peer-review mechanism.

Part of any negotiation of 'agreements' involves dealing with the varying belief paradigms held by multiple stakeholders. What is needed is not a process of reaching 'shared or consensual truths' about a research domain's knowledge base, nor should decisions be made on the traditional hierarchical expression of power. Rather, the review process (and the role of the reviewer in the process) is to test knowledge claims against the real world (W1) and ensure that decisions reflect agreed views about what will

Figure 6.8 **Social construction and formalisation of knowledge**



deal with real problems—until something else more pragmatically beneficial emerges (Firestone and McElroy 2003a). Ideally, reviewers, editors or those authorised to approve formal knowledge claims, such as technical committee chairpersons, should learn to make their observations taking into account multiple perspectives, to have their own underlying assumptions continuously tested (Firestone and McElroy 2003b), and to share this learning throughout any knowledge-system network.

Knowledge society level (acting on formal knowledge)

The highest layer of knowledge cycling occurs at the level of the knowledge society. The research enterprise incrementally contributes to better solutions to problems (P_n) by adding to a formalised BoFK. After formal publication of new or improved findings, these may well continue to be observed, oriented and criticised by an academy and may result in further cycles of research on new problems revealed by answers to the original problem (Popper's P_2). New research questions are posed, beginning again with individual investigators and research teams.

We claim later in this paper that new institutional mechanisms might well be required to support the acquisition and growth of knowledge at a knowledge society level. Preliminary ideas about such matters are introduced under the topic 'public knowledge space'.

The socio-technical aspects of schema interactions within research enterprises

As Cope and Kalantzis highlight, the knowledge practices embedded within the traditional paper journal and book publishing industries have emerged over the past five centuries. These knowledge processes involved simple exchange of text and recursive construction of textual knowledge. For example, tangible artefacts such as letters, draft manuscripts and publications were exchanged iteratively between authors, publishers and printers. The only technologies involved in the process of communicating knowledge were those of writing, typing and printing, and the ponderously slow physical transport of paper between participants.

However, with the advent of computers in the past several decades, digital technologies supporting scholarly work emerged and are becoming ever more sophisticated and interconnected, to the extent that these now form part of a research 'knowledge support-system'. These support-systems are being developed in such ways so as to enable larger and larger volumes of data and information to be exchanged and transformed virtually instantaneously via through online transactions. For example, up until the last decade or so, typesetting a paper from an author's manuscript required hours of work by people with specialised skills in a publishing house. Today, by clicking an Adobe PDF button in an Adobe Acrobat add-in to MS Word, an author can turn her MS Word manuscript into a typeset quality PDF e-print in seconds.

As the volume of data and information exchanges increase, a need emerges to structure data and information. This need arises from the benefits associate with the automated and semi-automated exchange of such data and information between different systems. When this need emerges, it is often only then that the extent of variation in the schemas held at different levels of focus (individual, team, organisational) comes into full view. At the individual level schemas are mostly often tacit and implicit in nature and form part of any individual's lifeworld. However, as the need for collaboration and coordination of research work increases, the need for what we call community-schemas emerges. These community-schemas emerge as explicit knowledge artefacts and as a form of common explicit knowledge. That is, they are usually published in formal ways, for example, through structured forms, data dictionaries or taxonomies. These explicit schemas are designed to facilitate a degree of mediation between the schemas tacitly and implicitly held by individuals and schemas relevant to the needs of a wider community of stakeholders within the research enterprise. In this way there is an ability to creatively harness the diversity and distributed nature of human cognition across the multiple levels of focus discussed in this section.

Where there is a need for the research enterprise to exchange data and information beyond its own boundaries to the wider world, a need for more formalised schemas declared as industry standards becomes more pressing. Such standards might be expressed as a formal specification in the form of an ontology, an industry or organisational specific XML standard, document type definitions (DTDs) or data dictionaries that the research enterprise needs to adopt or comply with. Such knowledge representations are emerging from a wide range of research domains including health and community services.

What makes these knowledge support-systems fundamentally different from the historical world of print is that the exchanges of bits and bytes of coded information can now occur more or less at light speed—and that these exchanges can be enacted simultaneously across varying levels of hierarchy (for example, those relevant to individuals, research teams, formal knowledge domains and a knowledge society). While this might be the case, we suggest that such support-systems are being developed and applied so rapidly that insufficient attention is being paid to the problems of conceptual and terminological confusion at different levels of organisation. There are two sources of such confusion. First, a wide range of personnel from different research domains are designing and enacting standards and schemas that reflect their own narrowly focused professional or social languages. Thus when exchanging information across professional boundaries the schemas used to support data and information exchange can often be incommensurable with other schemas. Second, and perhaps more importantly, insufficient attention is being paid to the challenges associated with harmonising variant schemas that emerge at different levels of hierarchy in the modern research enterprise (see Figure 6.6).

Implications for managing research enterprises in a knowledge society

The historical concern associated with 'open science'

In the final part of this chapter we want to draw out what we regard are the implications of our analysis thus far—particularly with respect to the future design of knowledge support-systems. Concerns are already being expressed as to whether the types of support-systems described in this paper are contributing to the continued strengthening of 'open science' for example:

> Provision of enhanced technical means of accessing distributed research resources is neither a necessary nor a sufficient condition for achieving open scientific collaboration… Collaboration technologies—both infrastructures and specific application tools and instruments—may be used to facilitate the work of distributed members of 'closed clubs,'… that work with proprietary data and materials, guarding their findings as trade secrets until they obtain the legal protections granted by intellectual property rights. Nor do researchers' tools as such define the organizational character of collaboration. This is evident from the fact that many academic

> researchers who fully and frequently disclose their findings, and collaborate freely with colleagues on an informal, non-contractual basis, nonetheless employ proprietary software and patented instruments, and publish in commercial scientific journals that charge high subscription fees (David, den Besten and Schroeder 2009, p. 2).

In the historical world of print-based journal publishing, many of the principles of open science emanated from tensions in the relationships between research and intellectual property. Boyle, for example, draws on significant historical analyses from Jefferson to the present day in order to tease out many of the complexities and intricacies of such matters: 'The general rule of law is that the noblest of human productions—knowledge, truths ascertained conceptions and ideas—become after voluntary communications to others, free as the air to common use' (2008, p. xv).

Within this broad context of common use, Merton ([1942] 1973) suggested a normative structure of science required commitments to ensure the advancement of reliable knowledge. He summarised these commitments using the acronym CUDOS. The production of reliable knowledge is reliant on the principle that research is a collective pursuit—thus the norm of (C)ommunalism. The norm of (U)niversalism entails that anyone can participate in the research process, thus the research field remains open to all competent persons. Commitments by (D)isinterested agents are required to ensure that findings are not skewed by the personal interests of researchers. The quality of knowledge is dependent on the (O)riginality of research contributions. A spirit of (S)cepticism and scrutiny is required to ensure claims are appropriately critiqued—thus safeguarding the quality of knowledge.

Merton was writing before the conception of the internet and semantic technologies. So, a relevant question is to ask whether a normative structure to science and the concern for the creation of 'reliable knowledge' still has currency in relation to the modern era, especially one where socio-technical systems are being deployed to support research activities. David, den Bestern and Schroeder think so, but that there might be a need to reconceptualise those norms to take into account the e of e-science:

> Questions concerning the actual extent of 'openness' of research processes identified with contemporary e-science, therefore ought to address at least two main sets of issues pertaining to the conduct of 'open science'. The first set concerns the terms on which individuals

> may enter and leave research projects. […] The second set of questions concerns the norms and rules governing disclosure of data and information about research methods and results (2009, p. 7–8).

Part of the rationale underpinning this chapter is that we think the natural sciences and biology (B. McKelvey 1997, 2002a, 2002b; W. McKelvey 2003) offers a useful theoretical framework within which to consider contemporary e-research systems—and, specifically, socio-technical support-systems. The question of whether the widespread adoption of such systems is undermining the normative structure of research and commitments to open research as outlined by Merton ([1942] 1973) is a serious one. We contend that what is at stake is the 'reliability and diversity of research knowledge' itself. Thus, we claim, there is a public interest at stake.

Public knowledge space

If the reliability, diversity and integrity of research claims are to be safeguarded over time, ideally, we propose that such claims should be developed within the context of a new type of institutional space. The Director of the e-Scholarship Research Centre (eSRC) at the University of Melbourne in Australia, Gavan McCarthy, has called this space a 'public knowledge space'. We will elaborate on this topic briefly under three broad headings: examples of emergent public knowledge spaces; supporting the introduction of contextual information management practices; and harmonising variant schemas and standards.

Public knowledge and the notion of a public knowledge space

One of the central claims of our chapter is that socio-technical aspects of how knowledge emerges may well require commitments to public knowledge itself. The objective is to safeguard as much as possible the ongoing reliability of knowledge claim evaluations. To highlight this point, we now discuss three examples of initiatives that have the potential to evolve into what we are calling public knowledge spaces.

In 2002 the University of Melbourne's eSRC supported the establishment of the Agreements, Treaties and Negotiated Settlements (ATNS) with Indigenous Peoples in Settler States project. Early on the eSRC assisted this project to develop a public website that 'links together current information, historical detail and published material relating to agreements made between Indigenous people and others in Australia and overseas' (University of Melbourne 2007).

But the project was not just about making information resources public. The function of the site and the nature of the ATNS project have continued to evolve since its inception in 2002:

> The project's significance lies in its potential contribution to the social and economic fabric of remote and rural communities through enhanced planning and management of the implementation of agreements between Indigenous and local peoples and their government and Industry Partners in a range of jurisdictions. This new research proposal focuses existing expertise upon the investigation of four areas—legal, economic, governance and social/cultural sustainability—that we have identified as central research issues for examining agreement implementation and outcomes. More specifically, the project will investigate novel conceptual and practical issues related to agreements, including: Identification of Parties to an Agreement; Effective Legal Models for Implementation Economic Development; Governance; Communication Structures; Community Governance and Social Sustainability; and Biodiversity and Cultural Rights (University of Melbourne 2007).

We contend that the ATNS website represents an emergent public knowledge space, in that it services a wider function than just a website. The publishing of information that allows for the linking of current information with historical detail has helped catalyse and extend research and development activities. Indeed, the ATNS project has now drawn in ongoing commitments by various stakeholders, including the Australian Commonwealth government and corporates such as the Minerals Council of Australia and Rio Tinto Pty Ltd. A public knowledge space is being generated because a shared context is being generated to create effective links between research and policy formation and the ability to generate real-world impacts such as the reduction of poverty:

> In 2009/2010 a new ARC Linkage Project will commence entitled Poverty in the Midst of Plenty: Economic Empowerment, Wealth Creation and Institutional Reform for Sustainable Indigenous and Local Communities. The new research team comprises, Prof Marcia Langton, Assoc Prof Maureen Tehan, Prof Lee Godden,

> Assoc Prof Miranda Stewart (all from the University of Melbourne), Prof Ciaran O'Faircheallaigh (Griffith University), Dr John Taylor (Australian National University) and Dr Lisa Strelein (AIATSIS). The industry partners for the new project are the Office of Indigenous Policy Coordination, Rio Tinto Ltd, Woodside Energy Ltd, Santos Ltd and Marnda Mia Central Negotiating Committee Pty Ltd. The new project aims to study the institutional, legal and policy reforms required to reduce indigenous people's poverty and to promote economic development for sustainable indigenous communities (University of Melbourne 2007).

In a different way, a second eSRC project has laid a foundation for the expression of a different type of public knowledge. In 2009 the eSRC commenced an Australian Research Council funded project in partnership with the University of Melbourne's Department of Social Work including a consortia consisting of the Australian Catholic University and several 'out of home care' providers in the state of Victoria. A critical component of the project was the creation of a public website within twelve months of the project commencing. This website provides a space where the history of the 'out of home care' sector in Victoria is made available to the general public. Pathways' *Historical Resources for People Who Have Experienced Out of Home 'Care' in Victoria* was launched publicly in December:

> Pathways is a resource for people who as children were in out-of-home 'care' in Victoria, including people known as 'care' leavers, Forgotten Australians, foster children, wards of the state, adopted children, Homies, child migrants, and members of the Stolen Generations. Some of these experiences overlap—for example, child migrants and the Stolen Generations usually grew up in Homes in Australia and many children were made wards of the state as well as being fostered or adopted. Only a small proportion of all these categories of children were legally orphans and for a time the term 'orphans of the living' was common—they had parents but were not able to be cared for by them for a variety of reasons.
>
> Pathways brings together historical resources relating to institutional 'care' in Victoria from its beginnings in the 1840s through to the present. You can use Pathways to find information, including documents and images, about institutions; organisations that managed children's institutions; policies; public figures, and legislation (Pathways 2009).

The Pathways project therefore is also creating a shared context for people who as children were in out-of-home care in Victoria. It is providing an opportunity for multiple stakeholders to create a public knowledge space to affect better linkages between research, policy and social work practice.

The potential utility of this embryonic idea of a 'public knowledge space' and its ability to facilitate effective linkages between research, policy and practice is significant. For example, in a recent report commissioned by the Victorian Government in Australia, it has been highlighted that the notion of a public knowledge space may well have a place in reducing the burden of uncoordinated regulatory interventions such as quality standards:

> What is now possible is the emergence of a new type of public knowledge space, similar to the Agreements, Treaties and Negotiated Settlements project referenced earlier in this document. A primary focus of this type of knowledge space is the continuous and relentless elimination of burden associated with collecting unnecessary data and information (Vines, McCarthy and Jones 2009).

Thus, we think there is potential to reduce the burden of government regulatory interventions if greater emphasis is placed on the idea that such interventions are expressions of 'public knowledge claims'. The notion of a public knowledge space, within this particular context, could do much to ensure that the reliability of such claims is continuously tested. For example, a public knowledge space might involve commitments to publish information that explicitly identifies relationship links with different instruments of regulation including:

- the acts of parliaments referenced within quality standards
- other types of published resources such as practice guidelines that form part of the basis of legislative intent or regulatory intervention such as the promulgation of quality standards
- detailed explanations of the role of corporate bodies involved in the conception, implementation and administration of quality standards and associated regulatory functions, including the changes to these over time
- the continued evolution through time of the evidence-base that forms the basis of any regulatory intervention such as the publishing of quality standard specifications
- publishing such information, to ensure there is public scrutiny of the effectiveness and reliability of the knowledge claims embedded across the different instruments of regulation just described.

In framing the notion of public knowledge in the way that we are doing here, we suggest this could do much to ensure that research challenges are continuously framed within the context of an emergent public interest. We emphasise that this notion of a public interest can be defined as widely or narrowly as the context might require. Therefore, these ideas have application where there is a public knowledge imperative within private sector, industry sector or scholarly community networks. A public knowledge agenda can do much to mediate cross-paradigmatic perspectives in order to solve pressing problems.

To support the advancement of these types of public knowledge commitments, we now extend our discussion by describing two overarching objectives that could do much to help secure the accessibility, diversity and reliability of public knowledge. These include 'enabling the introduction of contextual information management practices' and 'the role of knowledge brokering in harmonising variant schemas and standards'.

Public knowledge and contextual information management practices

When we suggest that a public knowledge space would provide a vehicle through which contextual information management practices could be supported, we are explicitly referring to three interacting challenges:

- the processes of documenting the context of research
- time persistence
- the exchange and interoperability of contextual information management.

We discuss these now in turn.

First, context. What does it actually mean to document context in a way that the records of a research enterprise can be situated in an information framework that will enable these records to be understood not just by the people intimately associated with their creation but by others who have an interest or need? For over a decade, this has been a fundamental challenge of the global archival community and has led to standards for archival description and management that include specific mention of context and its information components (ISAAR 2004). In Australia these standards have been used to map the socio-technical complexity of Australian science (McCarthy and Evans 2007).

By mapping the socio-technical complexity it is meant that there is a focus on mapping the relationship between information and archival resources created through time and the context within which such resources are created. The origins of this type of approach derive from the domain of archives management (Dryden 2007).

Documenting context is an evolving area of archival practice and this is a good time to start using a different term to cover this area. Context control seems to serve the purpose, and could tentatively be defined as:

> the process of establishing the preferred form of the name of a records creator, describing the records creator and the functions and activities that produced the records, and showing the relationships among records-creators, and between records-creators and records, for use in archival descriptions.

Second, time persistence. To be consistent with an evolutionary epistemology outlined in this chapter, we think a public knowledge space should include the publishing of research resources in a way that is consistent with the principles of contextual information management described above. The principle of persistence ensures evolutionary changes through time can be monitored and recorded systematically. Thus, part of the function of a public knowledge space should be concerned with how these spaces allow for—indeed captures—the evidence of evolution of these spaces through time. Such an approach is an essential characteristic of understanding the emergence of knowledge within an evolutionary framework.

Third, the exchange of contextual information. The People Australia project (2008) provides an example of the sorts of interoperability functionality a public knowledge space can facilitate. In late 2008 the National Library of Australia and the eSRC, using the data collected over an eight-year period in the Australian Women's register (Australian Women's Register 2009), exchanged rich and highly structured information using the Encoded Archival Context (EAC 2009) XML schema and the Open Archive Initiative—Protocol for Metadata Harvesting (OAIPMH undated). The boundary objects or points of interconnection were not publications or archival collections but context entities—information about historic people. Although still in testing and development, the success of the People Australia trials indicate it is possible to interconnect separate information systems in an open knowledge environment in a systematic and resilient manner. Thus the practice of contextual information management can be applied to support the interoperability of data and information exchange between different focal levels within a research enterprise. A vision of this type of approach is outlined in Vines, McCarthy and Jones (2009, pp. 25–33).

Interestingly these ideas and developments have parallels in the Netherlands. Wisse (2001) has outlined a foundation for a decade of conceptual thinking that has in effect tried to revolutionise how information systems are conceived and how they are constructed. He suggests that the systematic management and use of contextual information draws on relational theory, network theory as well as object and aspect orientated approaches. In Holland this conceptual work has led to the creation of 'Forum Standaardisatie' by the Dutch Minister of Economic Affairs in 2006 (Open Standaarden 2006). The intent of this initiative was to improve information interoperability not just between government agencies but also between government and citizens and companies. The Dutch experience highlights that if basic information registers do not sufficiently support semantic interoperability, the reuse of data (or knowledge) is compromised. Interoperability and reuse of data facilitate service improvement and reduce the administrative burden of government regulatory interventions.

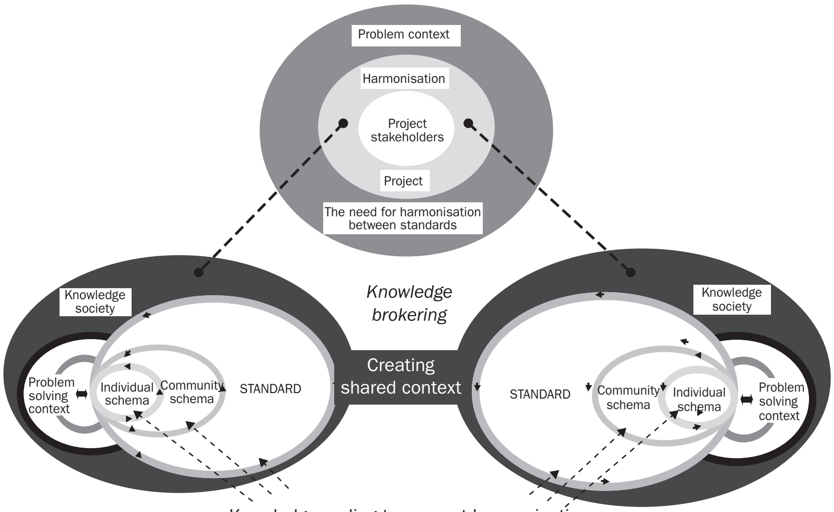
Public knowledge and the role of knowledge brokering

We have previously highlighted that the widespread adoption of socio-technical support-systems is potentially having an unintended consequence of undermining the normative structure of research commitments as proposed by Merton ([1942] 1973). We think the notion of a public knowledge space could do much to address this problem. But, in thinking through the ways in which this can be done, we also claim it is necessary to take into account the synthesis of theoretical perspectives presented in this chapter including Popper's (1972) evolutionary epistemology and hierarchically complex systems (Corning 2001; Hall 2006a; Pattee 1973, 2000; Salthe 1985, 1993, 2004; Simon 1962, 1973, 2002).

The use of explicit schemas and standards that form part of a research enterprise's knowledge support-system is reflective of a normative approach to research: schemas and standards help establish practice norms. The problem with normative approaches to practice is that standards can easily become reified or excessively fixed. Thus, standards can provide a means of exerting centralised control over highly distributed activities.

In contrast, we claim it is necessary to support the continuous evolution of the variant schemas and standards that emerge at different levels of hierarchy. We have represented this challenge in diagrammatic form in Figure 6.9. In this diagram we represent the harmonisation of standards across two different research communities. To illustrate what this figure

Figure 6.9 **Socio-technical aspects of harmonising standards across different research communities**



means, we now refer to a particular example. One research community might be those with interests in understanding the outcomes for patients who are discharged from public hospitals. A second community might be those with interests in how best to reduce homelessness rates in the general population. A shared problem context might emerge in that research could identify potential benefits if hospital discharge units were able to refer at risk patients to those who provide homelessness services. The achievement of effective solutions would require the development of shared understandings between those involved in research, policy and practice. In order to achieve this, a type of knowledge brokering is required. This is likely to involve the integration of the case management schemas that pertain to hospital discharge units and those that provide homelessness services. Thus, in the process of facilitating more effective referral pathways, particularly e-referral pathways, between these different communities, there is a need to harmonise the variant schemas associated with each stakeholder group.

The topic of knowledge brokering is currently being given greater attention, particularly in its application to bridge the gaps between research, practice and policy (Bammer, Michaux and Sanson 2010). In contributing to this debate, we claim that the relationship between knowledge brokering and the idea of a public knowledge space has great utility. We suggest that the purpose of a public knowledge space is to create a shared context for problem definition and problem solving.

Our central claim is that in addressing the challenges of data and information sharing (interoperability), provision must be made to allow for significant amounts of tacit, implicit and explicit knowledge sharing and cycling. Knowledge brokering involves lifeworlds meeting science and the hard edge of evidence-based practice (realism) being continuously tested and modified as a result of feedback based on practitioners' personal knowledge and experience about what works in the world. We think that commitments to a public knowledge space could do much to mediate these often incommensurable positions.

Conclusions

The central concern in writing this chapter has been to show why we think the effective functioning of modern day research enterprises will become reliant on the emergence of a new type of institutional framework. We have called this framework a public knowledge space. In presenting this argument, we have attempted to highlight that the rationale for this public knowledge space may not be immediately apparent. This is because we suggest that there is widespread lack of agreement about the nature of public knowledge itself.

In unpacking this challenge, we first felt it necessary to address a foundation question about the very nature of knowledge itself. In doing this, we have been interested in unpacking some of the theoretical questions and inter-relationships that arise when exploring the boundaries between lifeworlds and science; and between constructivism and realism. We have done this by introducing a theory and ontology of knowledge derived from Karl Popper's evolutionary epistemology. We have combined Popper's epistemology with a theory of hierarchically complex systems to highlight that knowledge is an emergent property of complex systems and that it can emerge at any level of context—for example, at the individual level, the research team level, or at larger levels of complexity (termed the super-system level). We highlight that the dynamics of these super-systems which include the focal subsystems (such as a research team) are much slower. Thus they can exert significant constraints on any given subsystem. These constraints can be both negative (inhibitory) or positive (facilitative).

We claim that the synthesis of these different perspectives is required in order to understand the opportunities and constraints associated with the use of what we call ‘knowledge support-systems’. Such support-systems are emerging within large complex research enterprises. They are socio-technical systems in nature in that they are reliant on networks of people, the mediation of person-to-person interactions through the use of technology and individual people’s interaction with computers and machines. We claim that the design of any knowledge support-system must take into account the different types of schemas and standards that emerge at varying levels of hierarchy within any given research system. These schemas can be tacit, implicit or explicit. As we explain, there is increasing utility in being able to publish schemas in an explicit way, because of the benefits arising from being able to exchange content between multiple (electronic) information systems. But, in attending to these matters, we highlight that an increase in semantic technologies is giving rise to what Cope and Kalantzis have outlined in Chapter 4, ‘What does the digital do to knowledge making?’, as an emergence of a ‘new navigation order’ and ‘new dynamics of difference’. Such dynamics include the means by which textual representations of knowledge in the form of schemas and standards are harmonised to help solve practical and real-world problems.

These are not small matters. They go to the heart of the future and effective functioning of a wide range of public–private service systems including, for example, the health and community service sectors. We have highlighted also in our introduction how the recent catastrophe in the Gulf of Mexico provides an example of the ways in which particular types of knowledge can rise up to become of the highest public priority almost overnight. To neglect the potency of such knowledge through a lack of public scrutiny can have devastating consequences as the whole world has found out.

Thus we conclude by outlining what we consider to be some of the key characteristics of a public knowledge space. We suggest that this notion can be defined as widely or narrowly as the context might require. Thus the principles have application within private sector organisations, industry representation bodies and within scholarly communities themselves. It is the potential function these institutional mechanisms offer that could prove to be decisively important. We claim such mechanisms will facilitate open access to important knowledge assets through time, thus allowing persistent access to such assets through time. We further suggest that they will include reference to the historical context of the emergence of these knowledge assets and their publication. If this is to be successfully achieved, we have shown why we think a public knowledge space would aim to facilitate the emergence of a 'shared context' among its various stakeholder groups in order to solve pressing problems in more efficient ways. Our ideas extend to the idea of harmonising variant schemas and standards as we have described in this chapter.

Many of these ideas are orthogonal to current and prevailing thinking about the future of the semantic web.

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Appendix: a preliminary ontology for research knowledge support

Worlds—ontologically separate domains relating to nature of knowledge and existence (Hall after Popper)	
	world 1 (W1)—W of physical and chemical dynamics, uninterpreted (mindless) existence of everything
	world 2 (W2)—W of cybernetic, cognitive and living phenomena; tacit, implicit and articulated knowledge
	world 3 (W3)—W of knowledge as physically codified into persistent objects and artefacts
Action relationships that facilitate interactions between worlds	
	encode or decode—(W2 to W3; W3 to W2) Knowledge is built into an inert and persistent object that living things can interact with at different times and places from the original encoding to decode the contained knowledge. Encoding moves knowledge from W2 to W3. Decoding moves knowledge from W3 to W2. Decoded knowledge is not necessarily immediately expressed in terms of development, behavior or action.

Appendix: a preliminary ontology for research knowledge support (*Cont'd*)

		embody—Knowledge is built into the dynamic structure of a W2 system. This corresponds more or less to Polanyi's tacit knowledge. The knowledge may not be expressed until required—we may not know what we know until we need to know it. (Note: there is a hint of W1 in this, as the embodiment of knowledge will affect the propensities of the physical structure to respond dynamically in certain ways.)
		enact—'to act out'. The application of knowledge via actions on W1.
Evolution—incremental accumulation of information in a system through time as a consequence of internal and external interactions (after Salthe 1993)		
Information—in (W2) a significant arrangement in the structure of a system that could have been different without any different expenditure of energy (after Salthe 1993) or a difference that makes a difference (Bateson 1972)		
Knowledge (broad sense)—in (W2) or (W3), information towards solving problems of life (after Popper)		
	degree of testing	
		idea—(W2) unexpressed thought that something might be so (or possible)
		claim—(W2 or W3) articulated claim to know
		tentative theory (Popper) or *hypothesis*—(W3) explicit expression of a claim open to testing
		tested K—(W3) claim that has been criticised or tested against observation of predicted effects
		reviewed K—(W3) claim or hypothesis that has been formally exposed to inter-subjective criticism
		authorised or *published K*—(W3) claim that has been accepted and published via a formal editorial process
		integrated or *working K*—(W2) knowledge that has become tacitly embodied in thinking or in working routines
	sense of dispersion or spread of an idea, claim or knowledge as an object, etc. held by	
		individual, *personal* or *subjective* (Popper) K—(W2) knowledge of the world held by a single individual
		common K—(W2 or W3) knowledge that is widely shared or easily discoverable by familiar retrieval methods
		team, *group* or *community K*—knowledge that is common to members of a team, group or community
		disciplinary K—knowledge that is common within a research discipline
		world K—knowledge that is common across the global research enterprise

Appendix: a preliminary ontology for research knowledge support (*Cont'd*)

	degree of expression	
		tacit—K held unconsciously by a living individual (W2)
		implicit—K that is consciously accessible to the individual but not articulated (W2)
		articulated—K that is expressed in words or speech (only) (W2) (Note: speech vanishes in the instant it is articulated. Its only record is in the W2 perceptions and memories of those who hear it.)
		explicit, *codified* or *objective* (Popper)—K expressed in an objectively persistent form that conveys the similar meanings when decoded at another time or by other individuals (W3)
		enacted, *integrated* or *embodied*—K internalised and embodied in the dynamic structure of a system (again tacit—W2)
		organic K—structurally determined propensities or dispositions to act in certain ways—knowledge that is tacit at a higher level of structure—see enacted, integrated or embodied (W2)
		procedural K—the organic K is explicitly defined and understood (W3 or W2)
	context	
		situational K—K formed by an entity in the context a particular situation
		procedural K (Nickols)—K created by doing
		declarative K (Nickols)—K created by describing (but see articulated, codified)
		lost or *orphaned K*—K that once existed but can now no longer be found, accessed or acted on because its links to situations and problems no longer exist
	types of knowledge by structural level of organisation	
		body of formal knowledge (BoFK)—the world repository of formalised knowledge available to the knowledge society (W3)
		cultural K—K embodied in the scientific and academic world in general (W2 and W3)
		organisational K—K controlling the functioning of higher level social, technical or socio-technical systems (e.g., university, scientific society, publisher) (W2 and W3)
		organismic or *tacit* (Polanyi) or *dispositional* (Popper) K—(W2) structural K controlling the functioning of individual organisms or people (e.g., as based on wiring of the nervous system—see tacit K)
		artifactual—explicit K expressed in technological artifacts, e.g., stored computer program (W3)

Appendix: a preliminary ontology for research knowledge support (*Cont'd*)

	cellular K—deeply organic forms of K passed on through cell lines controlling the development of cells and multicellular entities
	epigenetic K (heredity)—form of heredity based on the dynamic structure of cells (W2) and asexually reproducing multicellular organisms
	genetic K (heredity)—hereditary information encoded in DNA molecules (W3)
Hierarchy—a relationship in which each element is categorised into successive ranks or grades with each level contained within or governed by the one above	
	H theory—theory that identifies and maps the hierarchical structural organisation of the world
	natural or *scalar H*—representation of the world as composed of hierarchically organised levels of structure such that entities at a selected level of organisation can be seen as structural components contained within a higher level and that contains an assembly of several to many distinguishable entities at successively lower levels, down to the lowest level of organisation where entities can be distinguished
	specification H—a hierarchical classification, as in a taxonomic tree
	command or *governance H*—higher level entities control entities at lower levels in the hierarchy
Level of organisation—any particular level in a scalar hierarchy where an entity can be distinguished as a component of and within a higher level and can be seen to consist of components of a lower level of organisation	
	holon—a distinguishable entity at any level of organisation forming a component of an entity at the next higher level and containing within it several to many component entities at the next lower level
	focal level—a level of organisation designated for analysis
System—persistent assemblage of dynamically interacting components causally interacting with the world	
	S entity—set of components defined as belonging to a system or set of components more regularly interacting with one another than with elements in the rest of the world
	complex S—S comprising 'a large number of parts that interact in a nonsimple way' (Simon 1962)
	hierarchical S—S 'composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem' (Simon 1962)
	social S—S comprising interacting living entities or people
	technological S—S comprising interacting logical or material artefacts

Appendix: a preliminary ontology for research knowledge support (*Cont'd*)

		socio-technical S—S comprising people and technology
		network—the graph of causal or information connections among components of a S
Research—consciously controlled or disciplined activities focused on extending knowledge of the world		
	research organisations at different levels of hierarchical organisation	
		knowledge society (Lederberg or Mukherjee) or *academia*—world interested in the results of disciplined R and formalised knowledge
		global R enterprise—the sum of all institutions directly concerned with carrying out R
		R domain—a broad area of common R interest
		R enterprise—a particular enterprise or large scale organisation devoted to R, specifically including people and their research knowledge support technologies
		R network—an extended group of investigators linked via direct person to person communications
		R group or *team*—individuals or co-investigators interacting around a particular research project
		R collaborators—individuals involved in authoring specific works
		individual researcher or *investigator*—a single individual involved in conducting R
	components of research enterprises	
		R knowledge support technologies—technological systems supporting the creation, management and communication of knowledge by humans (Note: concept specifically excludes data collection instruments (e.g., microscopes, telescopes, cyclotrons). E-science databases and data reduction systems (e.g., storage and pre-processing of terabytes of physical, astronomic and genomic data) represent a borderline.)
		Research establishment—system of people involved in R—investigators, technicians, administrators and other support personnel
		R paradigm—disciplinary matrix of shared vocabularies, exemplars and world views (Kuhn) that guides the enterprise's R activities and facilitates cognitive interactions among the enterprise's members
Schema—the semantic structure or dynamic organisation of cognitive processes, whether in the individual, mediated by technology or embodied at a higher level in the socio-technical research enterprise		
		incommensurable S—where there is a lack of direct equivalence between objects and functions between two different schemas (two paradigms may also be incommensurable)

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Note: All URLs valid on 12 September 2010.

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