THE MEANING OF TACIT KNOWLEDGE

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ABSTRACT

Tacit knowledge definitions tend to be extremely varied. Some argue that tacit knowledge is precisely that. Others feel that only time and effort prevent all tacit knowledge from eventually becoming articulated. For the purposes of our research "tacit knowledge", in practice at least, encompasses a medium ground, being comprised of articulable and inarticulable subsets. Along the lines of Weber (1997), we have formalised a meaning for this "tacit knowledge" and for comparison have completed a content analysis of the literature to determine what other researchers understand "tacit knowledge" to mean.

INTRODUCTION

Let us begin with a quote:

> ***Data*** consists of raw facts … ***Information*** is a collection of facts organised in such a way that they have additional value beyond the value of the facts themselves … ***Knowledge*** is the body of rules, guidelines, and procedures used to select, organise and manipulate data to make it suitable for a specific task...(Stair et. al. 1998, p.5 [italics added]).

This generalisation can be extended by noting that ***knowledge*** may be partitioned further into two categories, namely ***tacit knowledge*** and ***articulate knowledge***; the former, for example, being especially recognised by the Japanese (Takeuchi, 1998). It was Polanyi (1959) (in Greeno, 1987) who was instrumental in first

> … distinguish[ing] between explicit [or articulate] knowledge, "what is usually described as knowledge, as set out in written words or maps, or mathematical formulae," and Tacit knowledge, "such as we have of something we are in the act of doing" (p.12).

Tacit Knowledge versus Articulate Knowledge

Tacit knowledge is thus that component of knowledge that is widely held by individuals but not able to be readily expressed. It is expertise, skill, and 'know how', as opposed to codified knowledge. Alternatively:

> Tacit knowledge is the personal knowledge resident within the mind, behavior and perceptions of individuals. Tacit knowledge includes skills, experiences, insight, intuition and judgment. It is typically shared through discussion, stories, analogies and person-to-person interaction; therefore, it is difficult to capture or represent in explicit form. Because individuals continually add personal knowledge, which changes behavior and perceptions, tacit knowledge is by definition uncapped (Casonato and Harris, 1999).

Articulate knowledge is typically acquired through formal education, writings, books, rule sets, legal code to name but a few of its ways and means. Tacit knowledge on the other hand is often acquired through a more intimate relationship, say between a teacher and an apprentice. It is transferred more orally, more by way of example, more by sight. More generally, and this is particularly applicable in a modern organisation, tacit knowledge is acquired through shared experience in cooperative work.

A Working Definition of Tacit Knowledge

On the one hand, it is argued that ***some*** tacit knowledge can never actually be articulated (Leonard and Sensiper, 1998), or indeed ***all*** tacit knowledge (Burstein, 2001). On the other hand, economists arguing in reductionist terms consider that: "only cost considerations prevent residual forms of tacit knowledge [from being] codified" (Ancori, Bureth and Cohendet, 2000, p.281). Indeed, it is often accepted "that tacit knowledge (as distinct from intangible investment more generally) is non-codified, disembodied know how that is acquired in the informal take-up of learned behaviour and procedures" (Howells, 1995, p.2). Tacit knowledge also has its traces in Gärdenfors' Conceptual Spaces (Gärdenfors, 2000). Research by Aisbett and Gibbon (2001) identifies the "subconceptual layer" of Gärdenfors as being representable, for example, by neural nets. This suggests that if we equate the brain's subconscious with tacit knowledge, then we have an explanation of tacit knowledge processing as subconscious pattern matching in the human mind. Such pattern matching is not explicitly codified of course, until a conscious effort is made to articulate such tacit knowledge, to make it conscious, and to codify it.

Although the economist Hayek had first discussed the presence of inarticulable knowledge (Ebeling, 1999), it is Polanyi (1958) who is considered the father and discoverer of tacit knowledge, with his reference to ***subsidiary***

and ***focal*** awareness. More specifically Polanyi (1968) had actually contemplated a triad of: 1) subsidiary particulars, 2) a focal target, and 3) the knower who links the particulars to the focal target. The linking highlights the dependency of tacit knowledge on the ***context*** for the particular and the target, as the knower perceives it.

By ***focal*** awareness Polanyi referred to our using systems of meaning to interpret what we see, hear or read; whereas our ***subsidiary*** awareness arouses within us past experiences, which guide our ability to further understand what it is we are experiencing. In short:

> "… tacit knowledge is manifestly present ... not only when it exceeds the powers of articulation, but even when it exactly coincides with them, as it does when we have acquired it a moment before by listening to or reading a text" (Polanyi, 1968, p.92).

The last part of the quotation above relates to Polanyi's concept of 'indwelling', or assimilating outside influences within (Polanyi, 1967), so typical of the tacit acquisition process.

Tacit knowledge, depending on one's interpretation, may actually be, we speculate, any pattern matching process from sensory skills such as learning to ride a bicycle, through to tricks of the trade, the latter often articulated and passed on from the senior to the apprentice. Our use of tacit knowledge in this paper refers to:

> "those components of technology that are not codified into blueprints, manual patents and the like. In other words, tacit knowledge is intangible knowledge, such as rules of thumb, heuristics, and other "tricks of the trade"" (Arora, 1996, p.234).

For the ***practical*** purposes of our information systems research, tacit knowledge could be said to be the ***implicit articulable IT managerial knowledge*** that IT practitioners draw upon when conducting their 'management of themselves, others, and their careers', as Wagner and Sternberg (1991a; 1991b) would say. When such tacit knowledge is shared from mutual experience and culture it gains a dimension within an organisation. It thus requires an added dimension to the theory to take into account the nature of learning that is particularly applicable to ***knowledge evolution***.

Two Approaches to Definition

According to the Macquarie Dictionary, definition is:

> [Definition, ***n***. **1**. The act of defining or making definite or clear. **2**. The formal statement of the meaning or signification of a word, phrase, etc. (The Macquarie Dictionary, 1981)]

In defining tacit knowledge we have chosen to present two alternative approaches. The first approach applies formal content analysis of the literature to define tacit knowledge, based on what other authors, the research community, believe to be tacit knowledge. The second approach provides a formal framework or theory for defining tacit knowledge that is based on ***denotation***.

Following Weber (1977), definitions may be justified by both interpretation and representation: -

1) ***Interpretation***: by agreeing amongst us that the definitions effectively describe and provide a qualitative understanding of the reality and human value systems we are dealing with. If this is satisfied we can assert that the definitions are relevant to our value systems and beliefs. Note that "us" and "our" refer to the group of people entrusted with the understanding required.
2) ***Representation***: by formalisation in a mathematical theory that has sound and valid models. If representation is satisfied then from a strictly formal perspective, the definitions have a sound underlying theory.

The content analysis, ***interpretation***, and formal theory; ***representation***, presented in the two approaches, thus complement each other.

What is evident from both of these approaches is that tacit knowledge is heavily individualistic and based on self–experience, which leads ultimately to our greater understanding for situations we will confront in the future. The latter aspect of tacit knowledge ties in directly with Polanyi's epistemology, while the useful nature of tacit knowledge for improving our future understanding of situations ties in with Sternberg's epistemology where tacit knowledge is considered to be a management asset (Wagner and Sternberg, 1991a; 1991b).

Approach I: Interpretation - Qualitative Content Analysis of Tacit Knowledge in the Research Literature

In previous reported research, we have used formal content analysis to find, by consensus of the research community, a qualitative understanding of tacit knowledge. {Busch et al, 2001)

A common assertion in tacit knowledge research is that if knowledge is articulated in some way, then it is no longer tacit. While logically this may seem true at first, it is important to note that:

> …. in theory, tacit knowledge can be verbalised and taught (in which case we still refer to it as "tacit knowledge" even though strictly speaking it is no longer tacit) (Sternberg, 1995).

In that research, an examination of 68 recently published documents, the following appeared the most widely cited as explaining what tacit knowledge entails. The terms are as follows, in descending order of groundedness. The terms given are subjectively coded 'themes' that have been derived from the literature, rather than direct terms, as they exist per se. We provide only those codes that have a groundedness of greater than 2 instances in the literature here:

> Knowledge (80); Individuals (50); Organisational domain (46); Skill (35); Non-Codification (28); Non-verbal (27); Experience (26); Context specific (24); Intuition (20); Learned (16); Know how (15); Not formal (13); Action (12); Expertise (11); Culture (10); Contingency based (9); Environment (9); Externalisation (9); Knowing (9); Not easily communicated (9); Practical (9); Sub-consciousness (9); Understanding (9); Cognitive (8), Internalisation (8); Mental models (8); Not directly taught (8); Not easily transmitted (8); Process (8); Abilities (7); Apprenticeship (7); Low environmental support (7); Management (7); Practice (7); Society (7); Two dimensional (7); Behaviour (6); Beliefs (6); Conscious (6); Direct contact (6); Face to face transfer (6); Goal attainment (6); Inferences (6); Learning by doing (6); Maxims (6); Non-awareness (6); Pattern recognition (6); Perceptions (6); Procedural in nature (6); Routine (6); Subjectivity (6); Tasks (6); Technology (6); Values (6); Common sense (5); Decision making (5); Embodied (5); Implicit (5); Implied (5); Information (5); Judgement (5); No idea (5); Not easily codifiable (5); Sharing (5); Taken for granted (5); Unconscious (5); Everyday situations (4); Interaction (4); Job knowledge (4); Know more than we can tell (4); Not easily formalised (4); Not formal instruction (4); Others (4); Physical control (4); Riding a bicycle (4); Rule (4); Schema (4); Time (4); Touch sensitivity (4); Wisdom (4); Abstraction (3); Access constraints (3); Awareness (3); Communal (3); Competitive advantage (3); Embedded (3); Emotions (3); Experientially established cognitive structures (3); Focal awareness (3); Groups (3); Holism (3); Ideals (3); Importance of language (3); Information retrieval (3); Insight (3); Learning by using (3); Meaning (3); Mind (3); Motor skills (3); Observation (3); Oneself (3); Particular uses/particular situations (3); Performance (3); Practical intelligence (3); Procedures (3); Resistance to revelation (3); Rules of thumb (3); Selective comparison (3); Semantics (3); Sense perception (3); Transmission (3).

This list is not complete, and a significant number of codes remain that contain a groundedness of 1 and 2 instances in the literature (code total 1,310), which were considered too trivial for inclusion here. Note can nevertheless be made from the codes above that tacit knowledge is typically individualistic (50) (beliefs (6); oneself (3)), heavily organisationally based (46), it is directly related at least to skill (35) and it is context specific (24). Furthermore it tends to be practically (9) rather than theoretically oriented in nature (practice (7); learning by doing (6); learning by using (3); practical intelligence (3)), and given the nature of human competition, it is acquired in conditions of low environmental support (7), which leads to it's being used for competitive advantage (3). One other very important issue, often not realised with tacit knowledge is the need for understanding (9) (internalisation (8); others (4); awareness (3); meaning (3); oneself (3)) on the part of the receiver.

Sveiby (1997) for example, states that "knowledge cannot be described in words because it is mainly tacit … it is also dynamic and static", and furthermore, "information and knowledge should be seen as distinctly different. Information is entropic (chaotic); knowledge is nonentropic. The receiver of the information – not the sender – gives it meaning. Information as such is meaningless" (pp.38, 49). In other words, tacit knowledge is not knowledge if the receiver does not understand it. This may help explain why tacit knowledge is so culturally loaded (10) (environment (9); society (7); beliefs (6); values (6); ideals (3); importance of language (3)), and why others of, for example, NESB[1] people may not understand immediately what is taking place, even if they do happen to understand the syntax and semantics of English. Over time the tacit knowledge component, in addition to the already acquired syntax and semantics, aids in improved communication amongst people.

The content analysis has provided a means by which a balance or 'reality check' was able to be obtained, in addition to formalising what could be said to comprise tacit knowledge. The definitions provide a view of what many other authors have considered comprises tacit knowledge. The importance in particular of the individualistic nature of tacit knowledge serves, if nothing more, to establish the contextual nature of this knowledge and its reliance upon an individual's ***Weltanschauung***[2]. The disadvantage of attempting any such form of content analysis is that authors' definitions often tend to vary wildly and so finding any one 'true' definition can be difficult, if not impossible. Truth, like the contextual nature of tacit knowledge is finally a subjective assessment.

[1] Non-English Speaking Background.

[2] Philosophy of life or world outlook.

We therefore state, that there exist articulable tacit knowledge properties, and inarticulable tacit knowledge properties. Consider the articulable properties that we have selected to exemplify tacit knowledge:

$$\{a, \ldots, n\} \subseteq aTK$$

where {a … n} is the set of the following articulable tacit knowledge constructs:

{Abstract high level plans, Abstraction, Access constraints, All purpose algorithms, Analogies, Aphorisms, Artistic vision, Assumptions, Behaviour, Beliefs, Business knowledge, Common sense, Competitive advantage, Complex multi-conditional rules, Concepts, Constructs, Content, Contradiction, Convincing people, Crafts, Culture, Customer's attitudes, Customs, Data, Decision making, Descriptors, Discussion, Everyday situations, Examples can be articulated, Expectations, Externalisation, Face to face transfer, Goal attainment, Grammatical rules, Gut feel, Habits, Heuristics, Hunches, Ideals, Imitation, Impressions, Information, Information placed in meaningful context - eg. Message, Innovation, Interaction, Job knowledge, Judgement, Justified true belief, Know how, Knowledge base that enables us to face the everyday world, Knowledge of designs, Logical rules, Maxims, Meaning, Methods, Negotiation, Observation, Perceptions, Performance, Perspectives, Political correctness, Practical know how, Practice, Prescriptive knowledge, Principles, Private knowledge, Procedural in nature, Procedures, Process, Proverbs, Reproduction, Riding a bicycle, Ritual, Routine, Rule, Rules of thumb, Schema, Script/Scripted, Semantics, Shop lore, Stories, Subjectivity, Swimming, Task management, Tasks, Team coordination, Technique, Technology, Theories, Tradition, Trial and error, Tricks, Understanding, Understanding of categories, Values, Way things are done, Wisdom} $\subseteq$ aTK

In other words, the above subset forms tacit knowledge examples that are actually considered articulable, necessarily from a subjective point of view. Note once again that we have taken these terms in qualitative fashion from those researchers who have sought to define tacit knowledge to date.
Furthermore, from our qualitative 'database' of tacit knowledge, we are able to identify the following as specifically constituting examples of tacit knowledge that cannot, or rather typically do not, lend themselves to being articulated, what we shall refer to here as inarticulable tacit knowledge ITK:

$$\{a' \ldots n'\} \subseteq iTK$$

where {a' … n'} include the following inarticulable tacit constructs:

{Abilities, Accidental, Accomplishment, Action, Action oriented know how, Action slips, Ad hoc, Adaptation, After the fact, Analysis, Application, Attention, Automatic, Automatic knowledge, Awareness, Background knowledge, Between the lines, Body language, Charisma, Concentration, Coordination, create and enjoy challenges, Diagnostic closure, Emotions, Executive commitment, Exists, Experience, Expertise, Focal awareness, Force/tension required, Gaining promotion, Gaining respect, Getting one's feet wet, Hands on teaching, Have a feeling, Here and now, Hidden, High level goals, Holistic in nature, How to seek out, Idiosyncratic, Immutable, Implicit, Implied, Indeterminacy, Inferences, Inferred from actions/statements, Informating, Ingrained, Insight, Inspiration, Instinctive reaction, Intangibility, Intimacy, Intuition, Involuntary, Know more than we can tell, Know why, Knowing, Knowledge possessed by itself, Learning by doing, Learning the ropes, Lip service, Management, Managing relationships, Managing subordinates, Manual dexterity, Meaning requires tacit component, Mediation, Mental models, Meta-cognitive understanding, Motivation, Motor skills, Networking, No idea, Noiseless, Non awareness, Non focus on parts, Orientation, Out of the corner of the eye, Paradigms, Pattern recognition, Personality, Physical control, Place, Possessed, Power, Practical intelligence, Practice wisdom, Preciousness, Presuppositions, Principles, Product of process, Proximal knowledge, Psychomotor skills, Recognition, Recognition of musical note, Reflection in action, Reflection upon reflection, Relativity, Residual category, Rooted, Second hand, Second nature, See as' rather than see, Selective comparison, Semiconscious, Sense perception, Short term, Skill, Smell, Socialisation, Society, Spatial awareness, Spontaneity, Sub-consciousness, Thinking in practice, Tool, Touch sensitivity, Unanalysed, Unconscious, Vision, Vivid, Way things ought to be, Weltanschauung, Wholeness} $\subseteq$ iTK

These subsets are selected from Busch et al's (2001) formal content analysis. They are hereby presented as identified constituents, which demonstrate the extent of tacit knowledge about any system.

APPROACH II - FORMAL REPRESENTATION OF INFORMATION ABOUT TACIT KNOWLEDGE

It is apparent that there are many statements that describe what tacit knowledge is in terms of its constituents and components. The first approach above exemplifies the research community's attempts to convey information by making statements about tacit knowledge. We now take advantage of Weber's work that has enabled a link to denotational semantics and thus the development of a formal framework for making statements about tacit knowledge.

In what follows we use the term ***information structure*** to refer collectively to the structure in information system models and constructs.

Weber's (1997) work applying Bunge's (1979) ontology to information systems defines a basic set of constructs. These Weber proposed as necessary and sufficient for us to construct and ***represent*** the concepts in the reality we encounter. In short, these ontological constructs provide us a framework for representing the meaning of our ***conceptual reality***. This meaning, to emphasise, is based on and is relative to the Bunge ontology as interpreted by Weber and Wand.

We now extend the meaning of a system, as it exists in reality, by adding definitions that make explicit the underlying assumptions of our formalisation of knowledge. In essence, we add the dimension of the human mind by which information and then knowledge is realised. Knowledge thus embraces intent, purpose, values and beliefs formed within the human mind by experience and whatever other mechanisms there might be. Knowledge therefore is more than the concepts in an immediate encountered reality. Furthermore, though we have not explored it in this paper, the underlying philosophy of knowledge should extend to an epistemology so as to embrace learning.

In terms of the semiotic ladder (Stamper, 1991), the extension goes beyond conventional semantics to embrace pragmatics and belief systems, the higher semiotic levels, by including notions of commitment, intelligent behaviour and wisdom, which are quintessentially of the human mind, and subjective.

Representation and Denotation

Representation is at the heart of Weber's work. Representability is central also to the denotational semantics of programming languages. The link between representing the information systems structure of a conceptual reality and denotational semantics proves to be important. Previous work by Dampney (1998) showed that Weber's static and dynamic models[3] could be formalised using category theory constructs that turn out to be used also in programming language denotational semantics. Since then Jacob's (1999) monograph on categorical logic and type theory, which focuses on fibration, a means proposed by Colomb, Dampney and Johnson (2001) for composing information structures, provides substantiating evidence linking the composition of information structures, (c.f. Weber's composition model) and computation structures.

Representability requires that an information system σ and changes in the information system $[\sigma \rightarrow \sigma]$ ***both*** be representable in a ***Sets*** category. That both σ and $[\sigma \rightarrow \sigma]$ be representable in the same mathematical domain requires a constraint on the changes as expressed by the operator "$\rightarrow$".

The constraint is that the mapping to the ***Sets*** category satisfies ***denotation*** as formalized by ***denotation semantics*** (e.g. van Leeuwen, 1990). Thus a slightly stronger condition than ***representable***, and than Weber's formalization in sets and relations implies, is required. This constraint is satisfied if the category satisfies a property called ***cartesian closure.*** We defer further discussion of this issue in this context as we change context below to statements about knowledge systems, for which different operators apply, but which are still formalized as a category satisfying cartesian closure and the requirements of denotational semantics.

This enables us to express ***statements*** about an information system in a formal theory and consequently provide mathematically sound and valid definition.

An Exercise in Formalization

We are now in a position to develop a theory within which (our understanding of) knowledge can be ***formally*** described and to take into account the dimension of the human mind.

We begin formally by declaring the existence of data (D), information (I), knowledge (K), tacit knowledge (TK), and articulable tacit knowledge (aTK). The term aTK some may feel more comfortable labelling ***implicit knowledge***, and for completeness we also identify inarticulable tacit knowledge (iTK) as truly tacit and not able to be passed on through person-to-person interaction.

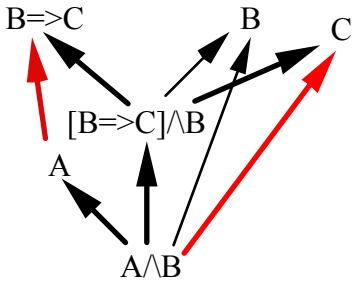
This requires, from a formal denotational semantic perspective, several assumptions about how knowledge may be represented in ***Sets*** so as to be subject to analysis. We say that there exist sets of whatever constitutes or characterises these various elements of knowledge and that there is a partial order, "$\subseteq$", on the sets which

[3] The representation model (static), the state-tracking model (dynamic), and the compositional model.

enables us to say that knowledge objects ***contain*** other knowledge objects. Mathematically, a partial order defines a lattice (complete partial ordering (CPO)). Lattices have proved to be an effective means of representation in formal concept analysis used by knowledge analysts, in computational theory (denotational semantics) and in many other areas.
In a style suggested by denotational semantics, we begin by identifying the objects with which we may formulate tacit knowledge in a domain:

$$\exists D, \exists K, \exists I, \exists TK, \exists aTK, \exists iTK$$

together with the two combinators appropriate to describing knowledge – "$\wedge$" (conjunction - also called "meet", "intersection"), and "$\vee$" (disjunction - also called "join", "union"). The combinators enable us to combine any two objects, say A and B, to form new objects $A \wedge B$ and $A \vee B$. These objects are governed according to a partial ordering "$\subseteq$" which in our case could be called "containment". So for example we can say that $A \wedge B \subseteq C$.
It would be useful if we have a means for expressing ***implication*** over sets. Overloading our symbolism for the moment - suppose B represents some population that satisfies some condition ***B***, similarly for C, and that {B=>C] represents the population that satisfies the condition that if ***B*** is satisfied then ***C*** is satisfied. Not necessarily all of C. We can express this as $([B=>C] \wedge B) \subseteq C$
It turns out that satisfying denotation requires that we introduce a new operator "=>"[4], which we now identify as ***implication,*** and which satisfies $([B=>C] \wedge B) \subseteq C$. This enables the domain to be Cartesian closed, that is, denotable.
The ***denotation constraint*** is satisfied if for every partial order $(A \wedge B) \subseteq C$ there is a partial order $A \subseteq [B=>C]$ and vice versa as illustrated by the diagram. [The arrow represents a partial order "$\subseteq$".].
This correspondence proves useful.



We can now propose definitions concerning the information structure of knowledge, which are derived from assertions made by various experts. These definitions will at least be sound and valid in the formal sense.

Definition: The Tacit Components of Knowledge

There is little argument in stating that ***articulable*** and ***inarticulable*** tacit knowledge are contained within tacit knowledge, thus:

$$aTK \subseteq TK \text{ and } iTK \subseteq TK$$

Furthermore we say that (i) aTK and iTK form disjoint subsets of TK, and (ii) aTK and iTK do not necessarily form complete subsets of TK. Tacit knowledge in its entirety, necessarily includes both inarticulable and articulable knowledge, thus:

$$(aTK \vee iTK) \subseteq TK$$

Furthermore, from previous argument, we define tacit knowledge as comprising a subset of knowledge, thus:

$$TK \subseteq K$$

Definition: Beyond Knowledge - Choice and Intelligent Behaviour

[4] Often denoted by the symbol "$\supset$". This operator plays the same role as "$\rightarrow$" used earlier.

We extend this representation of knowledge to include Intelligent Behaviour, Choice, Values, Commitment and Wisdom within our formalisation.
As Tuomi (1999/2000) suggests:

> … when the human mind uses this knowledge to choose among alternatives, behavior becomes intelligent (p.105).

We can restate this assertion as ***Knowledge (K) combined with*** (∧) ***Choice (Ch) is contained within (⊆) Intelligent Behaviour*** (IB) and represent it formally by

$$(K \wedge Ch) \subseteq IB \quad (1)$$

From the denotation constraint we have:

$$K \subseteq [Ch \Rightarrow IB] \quad (2)$$

and, to check consistency, evaluate so that from (1) and (2)

$$(K \wedge Ch) \subseteq ([Ch \Rightarrow IB] \wedge Ch) \subseteq IB$$

We can now interpret the formal expression $K \subseteq [Ch \Rightarrow IB]$ as

> "(Within our minds) knowledge (K) is ***contained within*** (⊆) the implication process [Ch => IB] of Choice (Ch) over alternatives to gain Intelligent Behaviour."

Definition: Intelligent Behaviour with Values and Commitment Leads to Wisdom.

Tuomi (1999/2000) further asserts:

> … when values [V] and commitment [C] guide intelligent behaviour [IB], behaviour may be said to be based on wisdom [W] (p. 105).

Restated, this says ***that Intelligent Behaviour with Values and Commitment is contained within Wisdom.*** Representing it formally and subscripting to designate the assertion:

$$IB \wedge V \wedge C \subseteq W_{(Tuomi).} \text{ or equivalently } IB \subseteq [V \wedge C \Rightarrow W_{(Tuomi).}]$$

We see that $\{IB \wedge V \wedge C\} \subseteq ([V \wedge C \Rightarrow W_{(Tuomi).}] \wedge V \wedge C) \subseteq W_{(Tuomi).}$

In a deeper interpretation, Sternberg (2000) notes that wisdom relies on altruistic principles, as in:

> … wisdom is defined as the application of tacit knowledge as mediated by values toward the goal of achieving a common good through a balance among multiple interests – (a) intrapersonal, (b) interpersonal, and (c) extrapersonal – in order to achieve a balance among responses to: (a) environmental contexts, (b) shaping existing environmental contexts, and (c) selecting new environmental contexts, over both (a) short – and (b) long terms … [where] … common good refers to what is good in common for all, not just for those with whom one identifies (pp.253, 254).

From this interpretation we formally represent wisdom thus:

$$V \wedge C \wedge IB \wedge Al \wedge TK \subseteq W_{(Sternberg)}; \text{ equivalently}$$

$$V \subseteq [C \wedge IB \wedge Al \wedge TK \Rightarrow W_{(Sternberg)};] \text{ where Al refers to Altruism}$$

From $\{IB \wedge V \wedge C\} \subseteq W_{(Tuomi).}$ above we have , $W_{(Sternberg)} \subseteq W_{(Tuomi).}$

$$\text{because } V \wedge C \wedge IB \wedge Al \wedge TK \subseteq V \wedge C \wedge IB \}$$

This brings into question whether Al∧TK is superfluous, which places Sternberg's interpretation in question, or whether Al∧TK is required, thus making Tuomi's assertion too broad. A resolution is that the notion of Wisdom is different in the minds of the two authors. One would expect Wisdom relative to altruism (Al) and tacit knowledge (TK) to be more focused.

Definition: Data, Information and Knowledge.

We address the concepts of data, information and knowledge, which have been covered at length by many authors. Many of these authors emphasis the lack of interconnectedness inherent in ***data***, the contextual nature

of ***information*** and the individual belief systems that heavily bias a person's interpretation of ***knowledge***. Zack (1999) presents a useful definition that sums up succinctly these three types of knowledge. It is for this reason that we use it here:

> Data represent observations or facts out of context that are, therefore, not directly meaningful. Information results from placing data within some meaningful context, often in the form of a message. Knowledge is that which we come to believe and value on the basis of the meaningfully organised accumulation of information (messages) through experience, communication, or inference (Bobrow et al. in Zack, 1999). Knowledge can be viewed both as a thing to be stored and manipulated and as a process of simultaneously knowing and acting - that is, applying expertise (Blackler, 1995; Dretske, 1981; Lave, 1988 in Zack, 1999).

If we take the above definitions as a starting point, then we may say that information is derived from data. It is the ***useful*** combination of data with context that provides us with information, the emphasis being placed on ***useful***. The ***FRISCO*** report's (Falkenberg et al, 1998) definition of knowledge as "a relatively stable and sufficiently consistent set of ***conceptions*** possessed by single ***human actors***" (p.66), whereas "the term **data** denotes any set of ***representations of knowledge***, expressed in a ***language***." In other words, data are meaningful symbolic constructs (expressed in a language), that can be qualified as "knowledge bearing" (p.66); whereas information "is the ***knowledge*** increment brought about by a ***receiving action*** in a ***message transfer***, i.e. it is the difference between ***conceptions*** interpreted from a received ***message*** and the ***knowledge*** of the ***receiving action*** …. An important aspect of information is how a receiver uses it" (p.68).

What appears in this instance to be unique about the term ***tacit knowledge*** is that if we take the definitions of knowledge and information given above, then tacit knowledge is actually a ***combination*** of the two. It is a prerequisite of tacit knowledge that it be understood by the receiver (***information***) or make ***sense*** to the receiver, yet tacit knowledge comprises a set of conceptions or interpretations by human actors (***knowledge***) or ***meaning*** as interpreted by the receiver.

We can thus formalise the concept of context ($\exists$ Co) and data ($\exists$ D) being contained within information (I) by: -

$$[Co \wedge D] \subseteq I$$

Context we suggest is close to or equivalent in meaning to Weber's (1997) ***Environment***.

Now, as defined above, articulable tacit knowledge and inarticulable tacit knowledge are contained within tacit knowledge.

$$\{aTK \vee iTK\} \subseteq TK.$$

Presuming that (in)articulable sense and (in)articulable meaning are disjoint subsets of sense and meaning respectively, we may express this concept in the following manner:

$$\exists\ aSe, \exists\ aMe, \exists\ iSe, \exists\ iMe$$
$$\{aSe \vee iSe\} \subseteq Se$$
$$\{aMe \vee iMe\} \subseteq Me$$

where Se = sense, Me = meaning, aSe = articulable sense, aMe = articulable meaning, iSe = inarticulable Sense, iMe = inarticulable Meaning

Presuming that articulable sense and articulable meaning comprise articulable tacit knowledge and inarticulable sense and inarticulable meaning also add to the total definition of tacit knowledge, a more complete definition may be seen as the following:

$$(I \wedge Se \wedge Me) \subseteq K$$

This may be interpreted as "sense and meaning need to be combined with information to have knowledge" and as " Information is contained in Knowledge".

Furthermore $\{(aSe \wedge aMe), (iSe \wedge iMe), (iSe \wedge aMe), (aSe \wedge iMe)\} \subseteq K$
and we now speculatively identify

$$(iSe \wedge iMe) \subseteq iTK;$$

$\{(aSe \wedge iMe) \vee (iSe \wedge aMe)\} \subseteq aTK$; and
$(aSe \wedge aMe) \not\subset$ □ □.

to suggest that the ability to articulate both the sense and meaning of information is required for explicit knowledge.
The above definitions are a consistent denotable representation in a formal theory relating the various constituents and associates of data, tacit knowledge, information, knowledge and wisdom. Perhaps our major contribution has been to recognise that the elements of knowledge inter-relate within a lattice of containments, suggesting therefore that the elements of knowledge are both inter-dependent and form themselves into overlapping hierarchies.

Properties as Constituents or Characterizations of Tacit Knowledge

In the argument presented in the formalisation, we deferred definition of the elements, if any, of what ***denotes***, that is constitutes or characterizes, tacit knowledge. ***Properties*** are a candidate as they are elemental in both the Chisholm (1996) and the Bunge ontologies. One may say that 'shop talk', 'work experience', 'skills' and so forth constitute knowledge of properties of systems. The properties may be of the various types identified by Weber (1997) from general, particular, intrinsic, mutual, emergent, and hereditary.
We ***denote*** tacit knowledge (TK) perceived within the human mind η of H[5] as (a subset, more strictly a sub-object lattice, $\mathbb{P}_i$ of) properties within $\mathbb{P}$ of a system σ of □[6]. Thus:

Denote_TK: (□ → □ → $\wp(\mathbb{P})$) where $\wp$ is the powerset symbol and $\wp(\mathbb{P})$ forms a lattice]

Thus the tacit knowledge TK(σ,η) by a human mind η of a system σ is about properties p_j singly or associated by conjunction $\vee_j p_j$) and disjunction ($\wedge_j p_j$). Thus TK(η,σ) maps to a sublattice $\mathbb{P}_i$ of properties. This means that some properties contain more elemental properties, and this we argue is in keeping with the way we think and reason about our reality.
Denotation introduces implication and the ability to express a richer set of propositions over the properties. The properties will include constraints as needed to satisfy the ontology of the domain.
The properties must finally be attributed and the population of the system satisfying the attributed property determined. How well properties are attributed is a separate issue and this will inherently cause a level of uncertainty in transference of human knowledge. Such issues are beyond the scope of this paper.
The propositions about properties may now be regarded as statements about the system for knowledge analysis purposes.

CONCLUSION

We have examined a way to formalise tacit knowledge along the lines proposed by Weber (1997) for systems theory in general. As a balance to formalisation we also present some results from a content analysis of the tacit knowledge literature, which reveals themes that best interpret this special type of knowledge. Tacit knowledge, at least in practice, encompasses a component that lends itself to eventual articulation.
The formalization has been applied to infer a number of conclusions from more basic conjectures derived from assertions in the literature:

- Without sense, meaning and context properties are just recorded data. With context data becomes information. Adding sense and meaning with the human mind provides the means for understanding. By unknown processes, the evidence from experience is that sense and meaning, evolves within our minds, first inarticulable and tacit, then expanding to become articulable and explicit.
- Knowledge is combined with other intelligence to define wisdom. Wisdom involves knowledge, but within a human value system that enables intelligent behaviour and choice. The cultural context, within which tacit knowledge is acquired, therefore bears consideration, as does the competitive nature of the knowledge, which indicates why tacit knowledge is not so easily, or rather readily, transferred.

Whether or not these conclusions withstand closer scrutiny remains to be seen. But we now assert that the formalization has at least provided a means for closer scrutiny.

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[5] η of H is a human mind η from amongst all human minds. Similarly for σ of Σ, where σ is a system and Σ is all systems.

[6] See previous footnote.

Finally at the core of this paper is the conjecture that information space and computational space are governed by the same essential structure. Knowledge adds the human dimension that may ultimately be unfathomable, at least by us.

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