Acquisition of ArticulableTacit Knowledge

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Abstract. The knowledge economy is recognizing tacit knowledge as a resource even more valuable than their codified knowledge stocks. However, while much discussion is contained in the organizational and managerial literature, there are few technological solutions to assist its capture. In this paper we first consider the nature of tacit knowledge, the difficulties associated with its acquisition and the codification process. We then offer our technology-supported approaches, one from the knowledge acquisition community and the other from the knowledge management/information systems community. We compare these two approaches with each other and other related work from these fields.

1. Introduction to Knowledge

Organisations to date have been generally successful at creating and maintaining their codified knowledge stocks, but the tacit component is a phenomenon that is only just now starting to receive serious attention. It has for example been shown [2], that whilst codified knowledge has always permitted managerial decisions to be *planned*, it was the tacit knowledge component that was often called upon in emergency situations to provide decisions in a fast changing situation. As an aside, the structures of organisations [19] themselves may also affect transfer [15].

Tacit knowledge (TK) in itself is clearly the opposite of codified knowledge. Codified knowledge exists in print or electronic form and tends to be available to some degree either freely or for sale, or perhaps in the form of patent and classified documentation. What we often refer to as codified knowledge is however not necessarily knowledge, but information. In other words it does not become knowledge until the receiver understands what it is they are receiving. Technically speaking tacit knowledge on the other hand *is* knowledge, not data or information, insofar as the term tends to be used to describe knowledge that is far more heavily based on personal understanding or experience.

Strictly speaking tacit knowledge cannot be codified, rather what passes for tacit knowledge is actually the implicit knowledge that we as individuals all make use of to greater or lesser degrees of success. What is meant by implicit knowledge is that component that is not necessarily written anywhere, but we *tacitly* understand that using such knowledge is likely to lead to greater personal success. Stated another way, tacit knowledge is “knowledge that usually is not openly expressed or taught … by our use of tacit in the present context we do not wish to imply that this knowledge

is inaccessible to conscious awareness, unspeakable, or unteachable, but merely that it is not taught directly to most of us" [35 :436, 439]. Or as Baumard [1] differentiates, "on the one hand it is implicit knowledge, that is something we might know, but we do not wish to express. On the other hand, it is tacit knowledge, that is something that we know but cannot express" (:2).

An important factor in any knowledge discussion is that of its 'stickiness'. Stickiness refers to the way in which knowledge adheres to particular individuals or contexts. Codified knowledge tends to be far less sticky than tacit knowledge, to which end tacit knowledge almost always requires human contact for transfer.

We see knowledge as being a manifestation of skills and means expressed by humans, making use of both data and information. Sveiby [34] states that "knowledge cannot be described in words because it is mainly tacit … it is also dynamic and static", 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" (:38, 49). Although we realise that data is the most basic representation of information and that organised information requires a component of knowledge, if we take this reasoning one step further, we may envisage a knowledge hierarchy as illustrated in Figure 1. What begins as TK (Stage 1) (components of which may never be articulated), ultimately becomes separated from that which is able to be articulated (Stage 2), and eventually is so (Stage 3). In due course knowledge becomes categorised (Stage 4) and thereafter codified into rule sets (stage 5). The definitive examples of codification include mathematical, chemical or other scientific formulae. Finally, but not absolutely, the formulae are based on the axioms of the mathematics, which cannot be both complete and consistent [9], and on the decision that the interpretation of the axioms is valid in the domain in which they are being applied. Codification rests ultimately on continuing agreement to decisions previously made – no absolute or complete articulation is therefore ever possible.

Sternberg [33] notes that TK "is acquired [in the face of] low environmental support", meaning we do not receive much help as individuals in acquiring this knowledge. If the knowledge is difficult to acquire it is also difficult to transfer. Certainly a major proportion of tacit knowledge research is focused on attempting to make tacit knowledge explicit, a process that Nonaka, Takeuchi and Umemoto [22] refer to as externalisation. Broadly speaking however, tacit knowledge is gained either through (a.) personal experience over time and perhaps place or (b.) by serving in an apprenticeship fashion with someone who is senior and able to pass the knowledge on to the 'trainee' [10]. The important point to note is that tacit knowledge cannot by its very nature be passed in written format, as at this stage the knowledge is no longer tacit, but explicit. In contrast, Articulate Knowledge is acquired through formal education, writings, books, rule sets, legal code to name but a few examples.

It is important to realise that a proportion of tacit knowledge can never actually be articulated, for "much of it is not introspectable or verbally articulable (relevant examples of the latter would include our tacit knowledge of grammatical or logical rules, or even of most social conventions)" [23 :603]. Social conventions such as etiquette sets or what constitutes a proof, become codified over time as a practical matter, because the parties involved accept, agree or submit to the conventions, rules,

laws (or the means of arriving at them) as the case may be. Such examples are all very contextual and ultimately tacit of course.

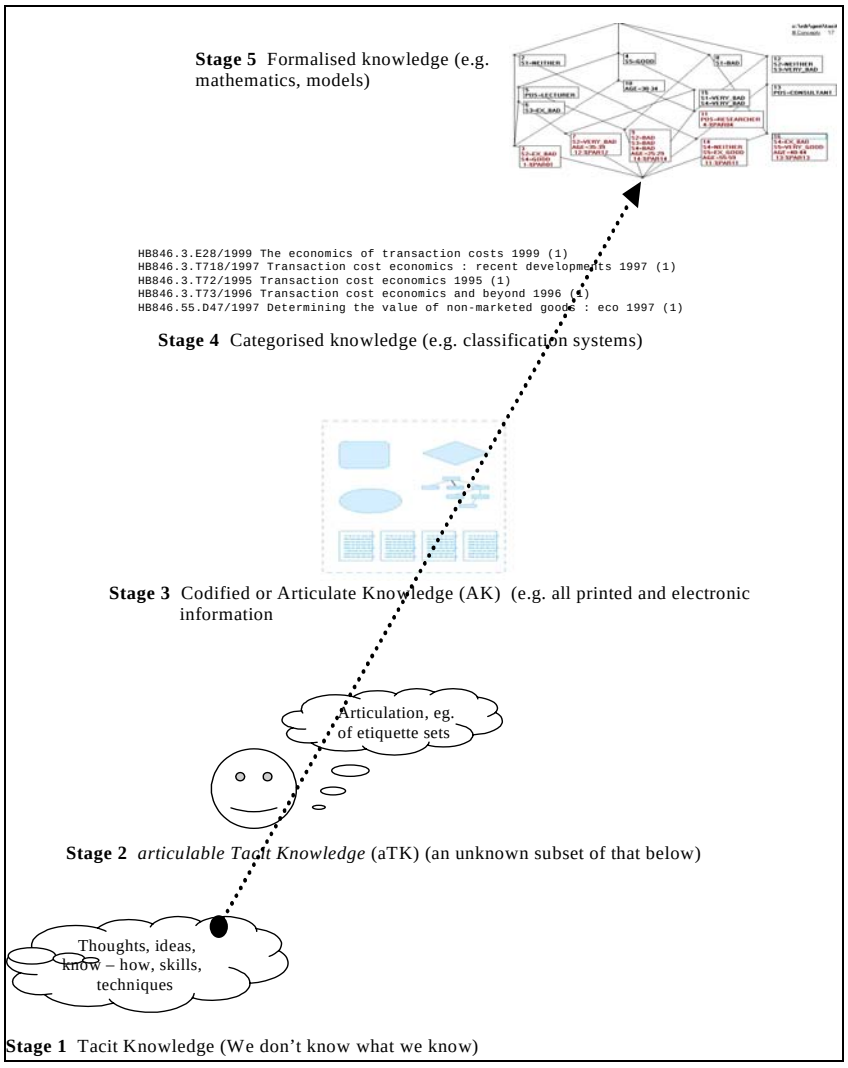

Figure 1: The knowledge hierarchy

MacKay [18] had, as early as 1974 alluded to the differences between articulable and inarticulable tacit knowing:

1) The "tacit" aspect of knowledge, as Polanyi himself has pointed out, is what we have in common with lower animals, presumably all of their "knowing" is tacit.

2) Therefore, we must distinguish between what *we* can say we know, and what a suitably equipped *observer* could say we know; between what *we cannot* put into words, and what *cannot be* put into words.

3) It is scientifically inappropriate to regard knowledge we can express in words as paradigmatic, and tacit knowledge as a peculiar special case. What we need from the outset is a methodology that can cope with tacit knowledge, taking verbalisable knowledge as a special case (:94)

Certainly such instances tie in with Polanyi's concepts of tacit knowledge being related to "know[ing] more than we can tell", or "knowledge that cannot be articulated", however we realise now that only a subset, even if a large subset, of tacit knowledge is truly not articulable. And that this subset is typically representing physical skill sets which simply do not lend themselves to codification, but can only be transferred through the 'indwelling' of the individual learning the new skill for themselves.

2. The tacit knowledge conversion process

While it has been shown "…….. that *new* tacit knowledge is generated as former tacit knowledge becomes codified" [29 :104], if we examine this process more closely, we feel in actual fact the transition to codified knowledge is not so sudden. What begins as an initial process of socialisation as pointed out by Nonaka [22], characteristic of experts showing novices 'the ropes', turns into a gradual codification process. A graphical interpretation of this principle is provided in fig. 2.

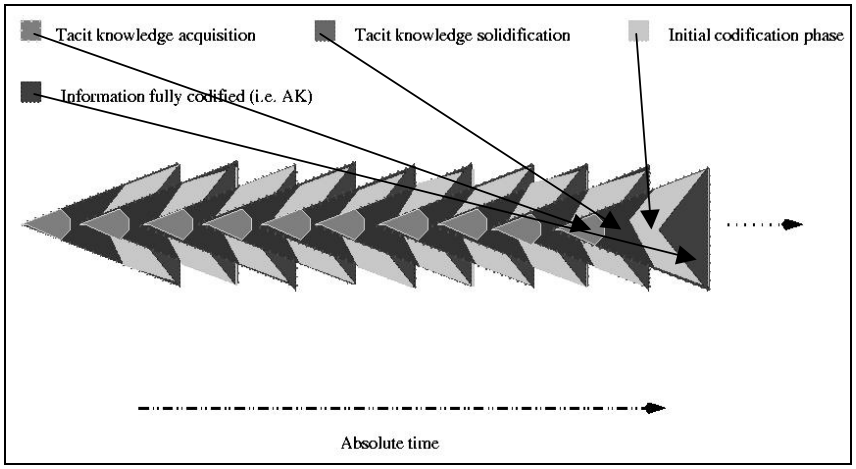

Figure 2: The tacit knowledge codification cycle

As shown in Figure 2, before the full codification phase takes place tacit knowledge is initially formalised by systems typically in 'unspoken rules', that nevertheless exist within the organisational sphere. We may term these 'etiquette sets'. Over time even etiquette becomes codified. We find codified examples of such rule sets in almost every society which dictate how behaviour should be conducted in all manner of situations (often social), from dining behaviour to what may be deemed acceptable relationships between the sexes. The partial codification phase characterises an environment where notes are available but not in any 'official capacity'. Examples would include 'research in progress', 'draft documents', material which is 'not to be quoted' and so on. Such material is far from being tacit, however fully codified it is not. Full codification is widespread, and includes all manner of printed and electronic material.

Let us bear in mind several other points. First of all tacit knowledge transference between individuals is often thought to take place whereby this knowledge becomes codified over time as for example in figure 2. We see this process as cyclical rather than strictly sequential as depicted in the figure by phases overlapping and at times occurring concurrently. In other words although tacit knowledge becomes chronologically codified, the transference from one individual to another does not take place equally. Senior people generally tend to teach junior people tacit knowledge, or experts tend to teach novices. A novice may however be senior and the expert junior, especially in the sciences and technology where young people may be more up to date technologically.

Eraut [8] provides an interesting insight into tacit knowledge elicitation problems chiefly those of bias likely within the respondents to any testing approach:

1. our series of encounters with another person are unlikely to provide a typical sample of his or her behaviour: the reasons and circumstances for the meetings will largely determine the nature of those encounters, and our own presence is also likely to affect what happens;
2. we are most likely to remember events within those encounters that demand our attention, i.e., those that are most 'memorable' rather than those which are most common;
3. preconceptions, created by earlier encounters, affect both parties' behaviour on later occasions, so the sample is not constructed from genuinely independent events;
4. people develop personal constructs [12], or ways of construing their environment, as a result of their life experiences; and these affect their understanding of, and hence behaviour towards, those whom they meet (:121 – 122).

Nonetheless even given such criticisms, few alternative approaches remain for attempting to explicate and in some way measure this pervasive but all too often underestimated source of intelligence, other than that proposed by Sternberg's Yale University research group. The work we present in section 4.2 builds on this work and will be discussed again there.

3. Primary reasons for undertaking tacit knowledge based research

Despite the difficulties associated with the measurement and/or capture of this elusive resource, there a numerous reasons for undertaking tacit knowledge related research particularly from an organisation and improved workplace performance perspective.

From the workplace point of view, a study of tacit knowledge is usually but not necessarily concerned with the area that has come to be known as Knowledge Management (KM). The capturing of tacit knowledge has been noted as being fundamental to such management. Indeed it was noted that "through 2001, more than 50 percent of the effort to implement knowledge management will be spent on cultural change and motivating knowledge sharing (0.8 probability)", which Casonato and Harris [5] had envisaged as including the more effective utilisation of tacit knowledge.

Tuomi [35] in relation to the Information Technology environment has summed up the importance of tacit knowledge management:

> If the design principles and methodology cannot address the tacit component, it cannot tell us where and how much we should invest in the explication of knowledge. In general, it can be argued that there has been too little emphasis on the sense - making aspects of information systems. This is becoming an increasingly important issue as information systems are increasingly used for collective meaning processing (:111).

Indeed the increasing sophistication of information systems has been a major factor in a number of organisational movements for example the migration from technology management to human based knowledge management. Another is the move from an information based view to a knowledge based one. A further example concerns the move from a hierarchical organisational view to a work activity view, for example the use of people on short term teams, based not upon their hierarchy in the organisation but the skills they bring to the team. One final example is that information systems are now not just information processing machines, rather they are now being geared towards providing a means of knowledge transfer, as in the example of Lotus Notes systems [34, 24].

The relationship of tacit knowledge to the workplace need not surprise us. Reasons for studying this phenomenon include maximising usage of organisational intellectual capital [7]. Another commonly cited reason relates to capturing the expertise of professionals, the most notable examples occurring within the *sensu latu* medical domains [31, 10, 28]. The capturing of professional expertise usually means articulating tacit knowledge in the form of generalisable principles so that these principles may then be transferred to others [28]. In other words novices will ideally be in a position to gain from a more experienced, yet perhaps not always present mentor. The expertise of a mentor often permits knowledge to be formulated and entered into an expert system, or at the very least a Lotus Notes system as for example at Roche [3]. Granted such knowledge has been explicated, but it was often tacit to begin with.

One major factor encouraging the study of tacit knowledge relates to the overall economic benefit it brings. The very issue of the economics of tacit knowledge is debateable and researchers tend to differ in their interpretations of tacit knowledge along philosophical lines, from the holism of system sciences to the methodological individualism adopted by economists. While, as noted, strictly speaking tacit

knowledge by its very nature cannot be articulated [16], it is interesting to note that economists arguing in reductionist terms consider that cost is the factor preventing its complete codification. A more extreme economic interpretation is "that tacit knowledge is just knowledge not codified (but potentially codifiable)" (Cowan, David and Foray 2000 in [16]).

The need for organisations to provide environments which support tacit knowledge transfer will have an impact on work practices. For instance it has been noted that telecommuting has had a detrimental effect on tacit knowledge transfer as far as junior employees are concerned as they are unable to pick up many of the workplace cues they require for on the job success [24]. In turn, those with more marketable skills (both articulable and tacit knowledge) are more likely to find employment at a salary that satisfies them.

Thus we see that individuals need to ensure that they are in positions to acquire tacit knowledge and organisations need to find economically viable means to facilitate individuals in this endeavour by providing environments conducive to its flow and also retention in the organisation. Let us consider next how capture can occur and how its flow can be measured and modelled.

4. Approaches to Tacit Knowledge Capture

The overwhelming majority of research to-date has focussed on the explicit (stage 3) or above stages of knowledge. Expert systems themselves can be viewed as mechanisms for categorising knowledge and thus reside at the fourth level. Current KBS research is predominantly concerned with the development of ontologies as a way of acquiring domain and task structures (e.g. [11]). Ontologies provide a formal model and thus fit into the fifth stage in our knowledge hierarchy in Figure 1. Similarly, the previous focus on the development of general problem solving methods (PSM) also fits in the final stage. We suspect this focus on stage three or above types of knowledge is due to the apparently increasing difficulty in capturing knowledge as we move down the levels. In support of this claim, we note that the shift to developing ontologies and general PSMs was a response to the problems associated with getting experts to articulate their knowledge into expert systems. These knowledge-level modelling [20] approaches were aimed at providing a structured means of acquiring and organising knowledge. Further they aimed to support the reuse and sharing of knowledge as another means of alleviating the knowledge acquisition bottleneck. While modelling and formalisation of knowledge has been a key focus of traditional KBS research and has offered numerous computational solutions, KM research has stressed the importance of implicit or tacit knowledge but offers few technological solutions for its identification and transfer. In both communities tacit knowledge is often treated as that knowledge which can't be captured.

In this section we consider two approaches, one from the KBS community and the other from the KM community, that offer supporting technology to capture tacit knowledge. Both approaches focus on the behaviour of experts rather than getting experts to describe what they know. In keeping with Sternberg's observation that tacit knowledge is transferred without the assistance of others both approaches elicit the

behaviour directly from the expert (or novice) rather than through an intermediary such as a knowledge engineer. However, in contrast to Sternberg's further observation that there tends to be low environmental support for acquisition of tacit knowledge, these approaches do offer some assistance.

4.1 Tacit Knowledge Acquisition and Modelling: A KBS Approach

First we very briefly introduce the Ripple Down Rules (RDR) [6] knowledge acquisition and representation technique. RDR is based on a situated view of knowledge. The situated view rejects the notion, that knowledge, including tacit knowledge, is stored in memory and simply needs to be retrieved in the appropriate circumstances. Instead, knowledge is seen to evolve and to be "made-up" to fit each situation. Thus, a situated view of knowledge places great emphasis on incremental techniques that allow change, capture context and which acquire knowledge without relying on a human to state or codify that knowledge.

RDR offers a way of capturing knowledge, both tacit and explicit, because it does not attempt to distinguish between the different types of knowledge but captures knowledge while the domain expert exercises his or her expertise. The domain expert is not asked to develop models of the domain or to offer explanations of their reasoning process/es. RDR facilitates articulation and performs the codification of the behaviour of the expert which is based on their already codified knowledge plus their tacit knowledge.

Knowledge acquisition involves running a case against the current knowledge base resulting in one or more conclusions being offered by the system. The user reviews each of the conclusions. If a conclusion is missing they can add a new conclusion. If they disagree with any conclusions they may choose to override each incorrect conclusion with a new one by assigning a new conclusion in its place. This forms the rule conclusion. The user is shown the case/s associated with the rule that gave the incorrect conclusion and the user must pick features in the current case that differentiate the current case from the cases previously seen by this rule. The features chosen are attribute-value pairs found in the current case, such as age=27 or age=young_adult. By picking features which differentiate between the current and previous cases, the approach ensures that the new knowledge does not invalidate prior knowledge. Thus addressing the maintenance and validation problems associated with traditional rule-based systems.

The update of the knowledge base occurs without the user being aware of the structure of the knowledge, the knowledge representation or that the conclusion chosen and case features comprise the rule conclusion and conditions, respectively. From the user's viewpoint, the process is simply one of: run a case, review system's conclusion, if they agree go on to the next case. If they don't agree, the user states what conclusion would be appropriate and why in the context of the features of the case. This is what experts do naturally.

Knowledge transference occurs when another individual uses the knowledge base (KB). Transfer is further assisted through the use of Formal Concept Analysis (FCA) [38] which allows retrospective and automatic development of knowledge models that the user can explore. In this technique FCA takes the RDR KB as input and generates

a set of concepts which are ordered into a complete lattice. When lattices from multiple experts are combined [25] the resulting lattice can be viewed as an ontology because the lattice provides a specification of a shared conceptualisation. By capturing knowledge in action, we support codification (stage 3) of articulable tacit know-how (stage 2) and acquire (and generate) knowledge at stages 4 and 5.

In summary, RDR is a hybrid case-based and rule-based approach. The cases provide the context in which the knowledge applies, and the rules, together with the use of an exception structure for knowledge representation, provide the indexes for storage and retrieval of the relevant cases. Context is also critical in the FCA technique and captured in what is known as a formal context. When we automatically convert the RDR KB to a formal context we can then visualise the knowledge in a line diagram. The combined use of RDR and FCA approach thus supports all types of knowledge in the knowledge hierarchy.

4.2 Tacit Knowledge Measurement, Modelling and Diffusion: A KM Approach

We now consider a different approach that is not concerned directly with the capture of tacit knowledge at all, but rather the identification of its existence (stage 1 to 2) and the transference process (stages 2 to 3). As noted, very little work has been conducted at these levels, with stages 4 and 5 already well researched in most disciplines. The knowledge captured is a side-effect which could be applied in a more traditional way to assist with decision making and knowledge transfer or even to determine whether someone is highly employable or not. This somewhat unusual motivation contrasts with KBS research and has come about because the focus is on tacit knowledge which by its very definition does not lend itself easily to articulation. Given that knowledge is highly contextual and to a large extent in the “eyes of the beholders”, measurement of its existence is in many cases as relevant as, and certainly a first step in, its actual capture.

While with RDR we did not attempt to define any of the types of knowledge being captured, in keeping with the goals of minimal modelling and effort, for this tacit knowledge work we needed to further refine our notion of tacit knowledge and define what was being measured and/or acquired. For the *practical* purposes of this research conducted in the Information Technology (IT) domain, tacit knowledge was defined to comprise the *articulable implicit IT managerial knowledge* that IT practitioners draw upon when conducting the “management of themselves, others, and their careers” [36]. This approach to the IT managerial nature of articulable tacit knowledge follows closely along the lines of [1]. When such tacit knowledge is shared from mutual experience and culture it gains a dimension within an organisation.

The details of the research goals, methodology and case studies are given in [4]. The essence of the work was development, deployment and detailed analysis of a survey conducted within a number of organisation. The questionnaire included an inventory of 16 IT workplace scenarios that sought to test how experts (as nominated by their collegues as part of the survey) responded to these typical scenarios. See Figure 3 for an sample scenario and answer option. This approach to tacit knowledge testing follows along the lines developed by Sternberg [33] from the field of

psychology. The responses of the peer-identified experts are treated as the tacit knowledge oracle and compared against the responses of novices to measure who has and how much tacit knowledge within the organisation To determine if there are differences between population groups (age, gender, ethnicity, educational background, employment tenure) and the levels of tacit knowledge present within the groups, and whether this knowledge is likely to be passed from and among these different groups we also gathered biographical data via the survey. The responses of the experts and novices, together with their biographical characteristics were analysed using statistical methods and modelled qualitatively using Formal Concept Analysis [38], which permitted more fine grained analysis in a graphical form.

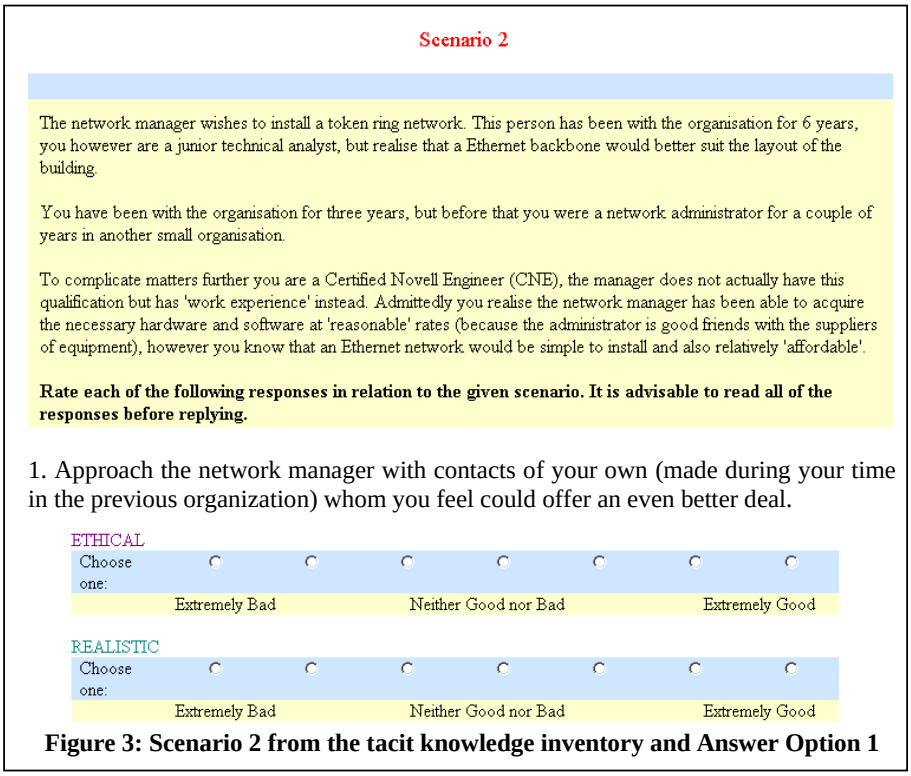

Figure 3: Scenario 2 from the tacit knowledge inventory and Answer Option 1

In addition to modelling the knowledge and the features of the knowledge holders, we sought to map the likelihood of intra-organisational diffusion of aTK among information technology personnel. The term likelihood is used here, because absolute knowledge transfer is difficult to prove other than through the ability of reading another's mind. In order to gain an insight into knowledge flows, we need to be able to map the social relationships that take place between employees. The application of Social Network Analysis (SNA) [27] permits us to illustrate such relationship patterns in the form of questions answering who is seen, how frequently, the meeting

importance and the formality of the meeting (for example, a chance meeting at the coffee machine vs. a formally organised and conducted meeting).

Our research involved 128 participants across 3 organisations of size small, medium and large. While at this stage our extrapolations are restricted to the organisation studied, we were able to determine that:

- experts gave significantly different responses to certain (types of) questions as compared to novices (via formal concept analysis combined with statistical analysis of the survey);
- as a follow on from the previous point, we were able to conclude a number of general behavioural characteristics of experts as compared to novices such as experts being prepared to say they are overcommitted and are less likely to "pass the buck".
- some individuals in the organisation were behaving like experts but had not been recognised as such by their peers (we called these the expert non-experts) (via FCA),
- biographical parameters did not play a *significant* role with regard to tacit knowledge utilisation and information technology personnel, that is, experts did not belong to a certain demographic (via SNA and statistical analysis).
- tacit knowledge flow from experts and expert non-experts to novices was best achieved in the small-sized organisation (via SNA),
- tacit knowledge bottlenecking could be seen to exist particularly in the largest firm (via SNA)
- the characteristics of the optimal firm include a single clique arrangement, a lack of widespread use of electronic forms of communication, a dense communication pattern insofar as daily meetings involve all staff, and meetings held are largely informal (via SNA).

In conclusion we note the following similarities and differences between this work and the work described in the previous subsection. In both approaches: knowledge is acquired using grounded examples in the form of cases or scenarios; experts are identified by their peers; and FCA is used to model the captured knowledge. In contrast, the knowledge captured via RDR is in the form of rules which support deductive reasoning and there is an explicit attempt to articulate knowledge. The tacit measurement and diffusion work captures a range of responses which are seen as alternative solutions of varying suitability and identification of who has tacit knowledge rather than being concerned with what that knowledge looks like. Thus the approach can be used to determine unidentified experts. The knowledge acquired via RDR is closer to the traditional expert system approach where the KB is based on the view of a single expert, though FCA has been employed to support knowledge comparison and integration [25]. On the other hand, the tacit knowledge measurement and diffusion work is focused on comparison of experts and novices and the likelihood of tacit knowledge diffusion through the use of SNA. RDR or FCA do not consider knowledge flows. The key similarities that make them suitable for tacit knowledge acquisition is that both are grounded in cases/scenarios and concerned with knowledge in action.

5. Related Research and Conclusion

Within the KM literature the work by Noh et al. [21] bears many similarities as it is also case-based and uses cognitive maps which are in some respects like the FCA concept lattice. However, just as we have found in our review of other work in the KBS area, Noh *et al*.'s approach begins with a formalisation phase in which the user is required to develop a cognitive map. The cognitive maps are stored in a case base. Given the difficulties associated with acquiring and, even more so, validating models we have some reservations with starting with formalisation by the user. We also have a reservation regarding the cognitive maps themselves based on our experience into causal modelling which found that getting experts to formalise causal knowledge was extremely difficult since this knowledge was often unknown. A better approach was to automatically generate possible causal links and allow the user to review and revise these [17]. Kolodner [14] suggests the use of cases as the starting point in domains where causal models are not well understood. However, in the approach by Noh et al. 2000, causal knowledge must first be acquired from which cases are developed. From Kolodner's remarks we could conclude that the knowledge being captured is actually explicit and codified knowledge rather than tacit knowledge. Following the formalisation phase in [21] is the reuse phase. In this phase the case base is adapted to fit the new situation using fitting and garbage ratios to retrieve appropriate cognitive maps from the case base. Indexing, retrieval and adaptation of cases are not simple tasks. To overcome these difficulties, the RDR approach uses rules specified by the expert in the course of problem solving as the indexes to our case-base. The final phase of [21] is problem solving where the adapted cognitive model is applied to the new problem and then stored in the case base. The two approaches we offered begin with the user performing problem solving on cases/scenarios and formalisation of the acquired knowledge into a concept lattice is handled by the system rather than the user.

The incremental, action-driven and context-based nature of our work is also found in the work of [26] who have developed a knowledge-enhanced email system known as kMail. When a user sends an email they can include links to organisational memories such as databases or websites which results in a memory-concept association being developed. As in our approaches, knowledge acquisition/maintenance is performed by the user and occurs when the user deems the context to be appropriate. Knowledge in action is captured incrementally without the need for the user to prespecify knowledge models. The simple nature of interaction in kMail is another feature that we share and commend. KMail demonstrates that if you allow knowledge to be captured in action, the distinction between explicit and tacit knowledge becomes irrelevant. Despite these fundamental similarities which demonstrate the importance of handling knowledge in context and getting the human computer interaction side of the system right, the kMail system differs in the knowledge acquisition technique, the knowledge resources, the nature of the problem and the purpose of the systems.

The combined RDR/FCA approach is novel within the KBS community. There are other approaches which emphasise the role of the user, (e.g. the Protégé family of tools [11]) or which do not ask the expert to describe their knowledge but allow the knowledge to emerge through various interactions (e.g. tools based on personal

construct psychology [30]. However, in the first case there is still reliance on the user to define the knowledge models up front. In the second case, the techniques are not incremental in that user must consider the whole domain and specify the context at the start. The RDR approach is incremental and the context evolves as new cases are seen.

The triangulated KM methodology offers more than a unique combination of three existing approaches. Previous work into the measurement of tacit knowledge has been primarily within the field of psychology. The Sternberg means of testing for tacit knowledge is considered to be the most practical approach for undertaking research in the organisational domain. Busch differs from the work of Sternberg in that the tacit knowledge inventory (the workplace scenarios) were based in the IT domain, rather than business management, and the questionnaire approach is combined with FCA and SNA. In Sternberg's work participants tended to be students or military personnel and thus he was able to select the appropriate population size. Our study however was based in actual organisations of varying sizes with varying levels of access to employees given to us. To complicate the access issue was the fact that since we needed to gather relationship data for the social network analysis component we were unable to make the questionnaires anonymous and this further reduced the number of willing participants. Given that psychological approaches to testing tend to rely heavily on both descriptive and analytical statistics and we were faced with (sometimes small) sample sizes beyond our control, FCA became a valuable alternative means of data analysis. The application of FCA to the visualisation of questionnaire data is quite novel, with the exception of the work by Kollewe [13] which represented the data in an alternative way and Spangenberg and Wolf [32] which also used FCA for displaying the results of likert scales. FCA has proven useful not only in interpreting biographical and tacit knowledge inventory results specifically but also in the identification of those who behaved similarly to experts but who had not been deemed by their peers to be experts. Through identification of this third group using FCA we were able to obtain statistically significant differences between the novices and experts (peer-identified plus FCA-identified). The other major component of the research which also distinguishes it from the work of Sternberg was to assess the soft knowledge flows within three specific organisations.

In summary, this paper has considered the nature of tacit knowledge and where it fits into a hierarchy of knowledge, noting the difficulties associated with capturing tacit knowledge and in conducting tacit knowledge research. We speculated on the process by which tacit knowledge becomes codified and offered two quite different approaches: Ripple Down Rules and Tacit Knowledge Measurement, Modelling and Diffusion. The latter was explicitly concerned with the tacit knowledge component but not necessarily its capture and the former explicitly concerned with its capture but not just the tacit knowledge. Nevertheless, both managed to acquire tacit knowledge through a focus on the behaviour of experts as they interacted with situations rather than the more mainstream approaches to knowledge acquisition which require its articulation by a domain expert typically via a knowledge engineer. It is through this focus on knowledge in action, that we go beyond the capture of codified (explicit book) knowledge to also achieve capture of tacit (implicit know-how) knowledge.

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