The graphical interpretation of plausible tacit knowledge flows

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Abstract

Many organisations make effective use of their codified knowledge, but they often fail to make most efficient use of their tacit knowledge stocks. What we define here as tacit knowledge is the 'articulable implicit IT managerial knowledge', that organisational personnel to varying degrees of success make use of. In this paper we present a graphical interpretation of selected results from what we label as organisation Z. These results have been obtained through a tacit knowledge questionnaire and visualized using formal concept analysis. The results are balanced with social network analysis, which aid in determining if tacit knowledge is being passed from one individual to the next.

Keywords: AL01 Knowledge representation; AL04 Knowledge acquisition; AI0102 Case study, AI0106 Exploratory study, AI0801 Positivist perspective; DD07 Information flows; Social Network Analysis; Tacit Knowledge; Diffusion of knowledge

1. Introduction

At the dawn of a new century, the principal assets of many (perhaps most) corporations are now held in the intangible form of intellectual capital. The primary market value of Microsoft, for example, lies not in its buildings, equipment, or receivables, but instead in the smarts of its people, software development capacity, patents, copyrights, and trademarks (Housel and Bell 2001 :xi).

Codified knowledge for Microsoft is the software that has been developed, the patents, copyrights and trademarks that have also arisen out of the software development process. The 'smarts' that Housel and Bell (2001) refer to, represents a far more important concept, namely that of the *tacit* knowledge that the employees have within their heads.

2. Tacit knowledge: An initial definition

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 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.

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" (Wagner and Sternberg 1985 :436, 439). We tend to use the term *articulable tacit knowledge* (aTK) which in our case is basically *implicit managerial IT knowledge* to refer to the component of tacit knowledge that may be made explicit and passed on.

3. Difficulties inherent in tacit knowledge research

One of the major hurdles to tacit knowledge related research stems from its soft nature which by its very character does not lend itself easily to articulation and therefore to measurement. Sternberg (1999; *et.al.* 1995) and his research team shows us that tacit knowledge is able to be tested for, where the majority of researchers seem typically to be content with discussing its existence. Nevertheless, Sternberg has also had his critics (Jensen 1993; Ree and Earles 1993; Schmidt and Hunter 1993). Reber (1993; 1989), and Lewis (1977) have shown us that alternative means of testing for tacit knowledge do exist drawing upon the research of others (Dulany 1984; Perruchet and Pacteau 1990 in Reber 1993), although nevertheless this research is still along the lines of expecting control groups to undertake various grammatical and memorisation tests and attempting to explicate normally inexplicable knowledge. For our intents and purposes within the IS domain, we are constrained by the fact that we do not

necessarily have captive control groups on whom we are able to employ grammatically based testing regimes, to which end the Sternberg based approaches are more feasible, especially as we seek to also map diffusion of such knowledge within the organisational domain.

4. Primary reasons for undertaking tacit knowledge based research

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. 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 (1999) had envisaged as including the more effective utilisation of tacit knowledge.

4.1 Improvement of work-team performance

The relationship of tacit knowledge to the workplace need not surprise us. Reasons for studying this phenomenon include maximising usage of organisational intellectual capital (Curtain 1998). Another commonly cited reason relates to capturing the expertise of professionals, the most notable examples occurring within the *sensu latu* medical domains (Cimino 1999; Patel, Arocha and Kaufman 1999; Chambers 1998; Meerabeau 1992; Goldman 1990; Scott 1990). 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 (Scott 1992). In other words non-experts 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 (Broadbent 1998).

4.2 The economic benefits of 'capturing' tacit knowledge

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. For on the one hand, it is argued that some tacit knowledge can never actually be articulated (Langlois 2001; Leonard and Sensiper 1998). Others argue that tacit knowledge by its very nature cannot be articulated (personal communication with Assoc. Prof. Frada Burstein 2001). Strictly speaking this is correct. Nevertheless it is interesting to note that economists arguing in reductionist terms consider that "only cost considerations prevent residual forms of tacit knowledge [from being] codified" (Ancori, Bureth and Cohendet 2000 :281). A more extreme economic interpretation is "that tacit knowledge is just knowledge not codified (but potentially codifiable)" (Cowan, David and Foray 2000 in Langlois 2001 :81).

4.3 Attaining competitive advantage

Codified knowledge is usually available either freely or through direct payment for patents or intellectual property settlements. Tacit knowledge on the other hand tends to be withheld from direct transfer. This latter form of knowledge plays a direct role in enabling an organisation to attain a competitive advantage as the knowledge is itself difficult to acquire (Johannessen, Olsen and Olaisen 1997; Lei 1997). Or as Sternberg (*et.al.* 1995) would say, "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 potentially difficult to transfer. Certainly a major proportion of tacit knowledge research is focused on attempting to make tacit knowledge explicit, a process which Nonaka, Takeuchi and Umemoto (1996) refer to as externalisation. Broadly speaking however, tacit knowledge is gained either through (a) personal experience over time (and perhaps place) (personal communication with Dr. John Antonakis 2001, Yale University), or (b) by serving in an apprenticeship fashion with someone who is senior and able to pass the knowledge on to the 'trainee' (Goldman 1990). 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.

5. Means of undertaking tacit knowledge research

Whereas many researchers in the knowledge management domain attempt to focus on the tacit component (Donaldson 2001; Horak 2001; Athanassiou and Nigh 2000; Osterloh and Frey 2000; Thorburn 2000), few means actually exist to measure this type of knowledge. Sternberg's (1999) Yale University based approach could be said to be the most practical because of its more applied nature. Other known approaches to tacit knowledge measurement involve mental scanning (Reed, Hock and Lockhead 1983), or grammatical memorisation tasks (Reber 1993). The latter two approaches tend to involve lengthy testing sessions with captive subjects. The Yale based approach alternatively tends to be more workplace oriented and involves situational workplace inventories, for which employees are asked to make decisions as to how they would handle soft knowledge situations.

6. Methodology

Given that 'soft' tacit knowledge among IS personnel within organisation Z is under consideration, we combine a number of approaches, although positivistic in nature. We seek firstly to determine proficient persons from lesser proficient personnel, along the lines of others (Sternberg 1999; Colonia-Willner 1999). We use the term *proficient*, rather than *good*, because the former was considered to be less value laden. The people who have been identified as proficient, we make our 'expert' sample group against whom we may have some comparison of results. What is meant by proficient is proficient in relation to usage of *articulable implicit IT managerial knowledge*. Secondly we seek to determine if there are differences between how identified proficient persons answer our tacit knowledge inventory as opposed to non-proficient identified persons. Thirdly we wish to examine social interaction between personnel, to determine whether soft knowledge may likely pass from one individual to another (proficient or otherwise). To this end the term plausible has been used in the title. In short we seek to determine whether 'knowledge bottlenecking' is taking place within the IS domain.

It was felt that the most feasible way of performing some form of empirical tacit knowledge testing was to use the Sternberg workplace oriented tacit knowledge inventory, except in this instance specific to the IT workplace domain. The questionnaire was composed of three sections: biographical, social network analysis (to gauge people's workplace relationships with one another) and the tacit knowledge inventory itself. In the social network analysis section of the questionnaire, we asked respondents to identify whom they felt were proficient at what they achieved. The resulting list of names, thus became our expert sample. At the same time we sought to find out with whom people interacted in the workplace, how often, the level of importance of the person in relation to themselves, and the type of meeting they conducted with the other person. These factors were felt to be important from a tacit knowledge point of view. Further details may be obtained from our other publications.

In order to feel confident that the questionnaire was considered industrially robust enough, a series of pilot studies were undertaken that asked IT practitioners to correct any mistakes in the initial questionnaire. The main purpose of the sequence of pilot studies was nevertheless to (a) test formal concept analysis as a means of presenting questionnaire results. And (b) to establish a test bank of tacit knowledge scenarios and answer options along Sternberg lines that could be used in the major study. Further details of the design and pilot stages of the research may be evidenced in previous publications (Busch and Richards 2000; Richards and Busch 2000; Busch, Richards and Dampney 2001), we provide only a short introduction here.

Although our approach is along the lines of the research being conducted at Yale University by Sternberg (1999), we differ insofar as we incorporate formal concept analysis (FCA) as a means of visually presenting results, which would otherwise be meaningless in purely numerical form. Our research also differs insofar as we make use of social network analysis (SNA) to map the information flows that are likely to take place between individuals. In this case we are interested in the soft or tacit knowledge flows. It should be noted that FCA and SNA are viewed as tools for the purposes of our research. That is to say the research itself is not about further developing the tools in themselves. The reason these tools have also been chosen was due to the expected small sample sizes likely to be obtained through the questionnaire process. In other words, information that would not ordinarily be meaningful in purely numerical format may be made more meaningful through visual presentation of data. As it turned out the sample sizes obtained were small and both FCA and SNA did permit much-improved visualisation of results that would have appeared far less meaningful in numerical format. Results were obtained for organisations X (108 responses), Y (7 responses) and Z (12 responses). In this paper we focus on some aspects of organisation Z.

6.2 Organisation Z

Organisation Z is a national Australian furniture supply company with an integral IT branch. The IT branch exists to support the business needs of the organisation. The Sydney based IT branch is composed of 15 personnel, although only 12 staff members chose to participate in the study. The ACS levels and remaining biographical details for the company may be seen in table 1. It may be noted that staff tend to be placed in the junior to middle ACS level.

7. Result processing

As the tacit knowledge questionnaire was electronic in format, this enabled participants to fill out the questionnaire quickly. The questionnaire (examples in figures 3 and 5) was coded in Javascript™ with a CGI backend. Data was then manipulated into spreadsheets and from there to various databases, from which specialised software was able to continue processing. Although descriptive statistics permit analysis of data, it was felt that a graphical way of presenting results would be beneficial given the low sample size in this instance. Anaconda™ and Toscana™ were used to process the survey results and display them for comparison as a concept lattice. Netmap Analytics™ was used to produce social network analysis flows.

Gender	
Female	1
Male	10
Undef	1
Age	
20 – 24 years	3
25 – 29 years	2
30 – 34 years	3
35 – 39 years	2
50 – 54 years	2
55 – 59 years	1

Current job title	
Business Development Manager	1
Business Systems Analyst	1
Contractor	1
Help Desk Support	3
Network Manager	1
Programmer	1
Project Director	1
Project Manager	1
Software Engineer	9
System Administrator	1

Highest Qualification	
High School Certificate	2
Bachelor Degree	6
Graduate Certificate	1
Graduate Diploma	1
Graduate Bachelor	7
Masters	2

Years of IT Experience	
0 – 4 years	5
5 - 9 years	3
10 – 14 years	2

Table 1: Organisation Z

20 – 24 years	2

Position	
Permanent	9
Contract	3
Years with the organization	
7 – 12 months	1
1 – 2 years	3
3 – 4 years	1
5 – 6 years	3
7 – 8 years	2
9 – 10 years	1
No. of Subordinates	
None	6
1 – 4	3
5 – 9	2
15 – 19	1
ACS levels	
ACS-2	4
ACS-3	5
ACS-4	1
ACS-5	2

ACS Level 1: Little practical experience in IT work, may be supervising ancillary staff

ACS Level 2: Experienced and capable of performing wide range of general IT work

ACS Level 3: Experienced in specialised IT areas, well developed liaison skills

ACS Level 4: Managing a number of teams and the allocation of resources

ACS Level 5: Typically report to CEO, manage major function, extensive IT coordination

8. Selected tacit inventory results

For an example of result visualisation on biographical data we can see from figure 1 below that 3337, 3342 and 3344 (all non experts, as no E appears after their identifiers), were not in the IT industry 6 years ago, were not in the industry 3 years ago and now perform the task of help desk support.
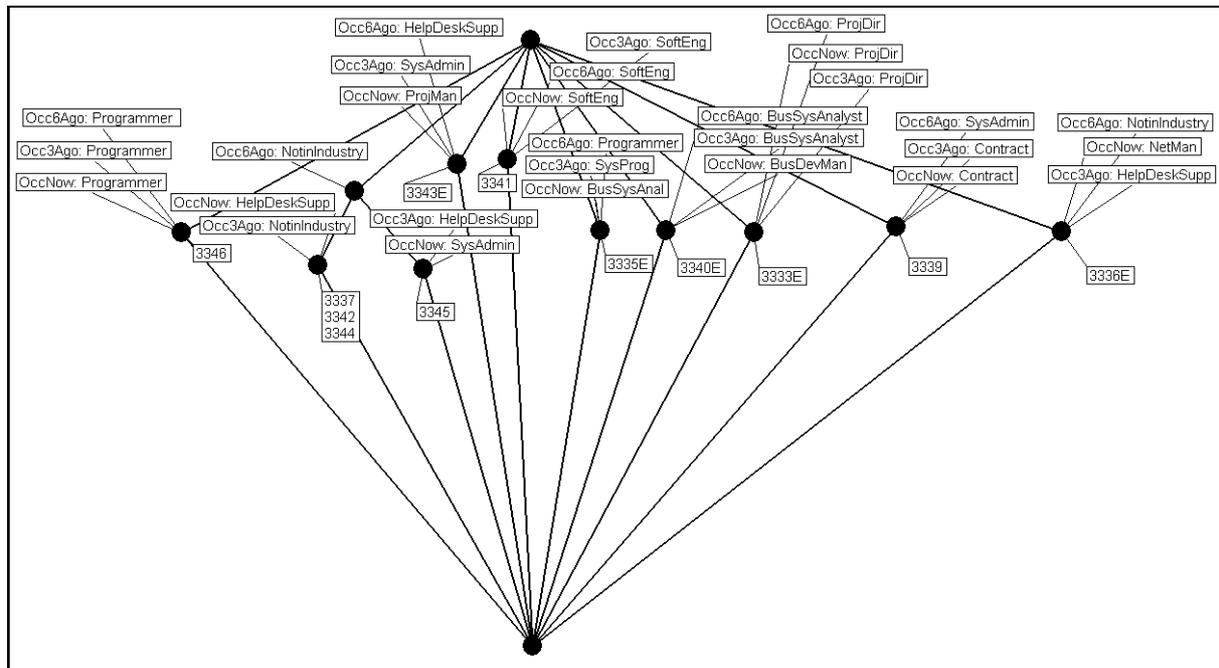

Figure 1: illustrating concept lattice indication previous and current occupations of survey participants in organisation Z

Expert 3335 on the other hand was a programmer 6 years ago, a systems programmer 3 years ago and is now a business systems analyst. Expert 3333E has been a project direction for the last 6 years. Expert 3340E has been a business systems analyst for the last 6 years, but is a business development manager now. The concept lattice approach thus permits a visualisation of data. By using such a technique we are able process our biographical data to best effect.

If we briefly examine figure 2, we can see that the majority of the staff are formally educated, with a concentration of staff possessing a bachelor's degree. A couple of the staff members have a master's degree. The strength of the concept lattice for these survey results is that we are able to see the number of years of IT experience, whilst examining their highest qualifications, parallel with understanding the characteristics of the individual employees. We can see that one of the experts has a masters degree (3335E), whilst the other experts (3336E, 3343E, 3340E, 3333E), are located around the bachelors degree lattice node.
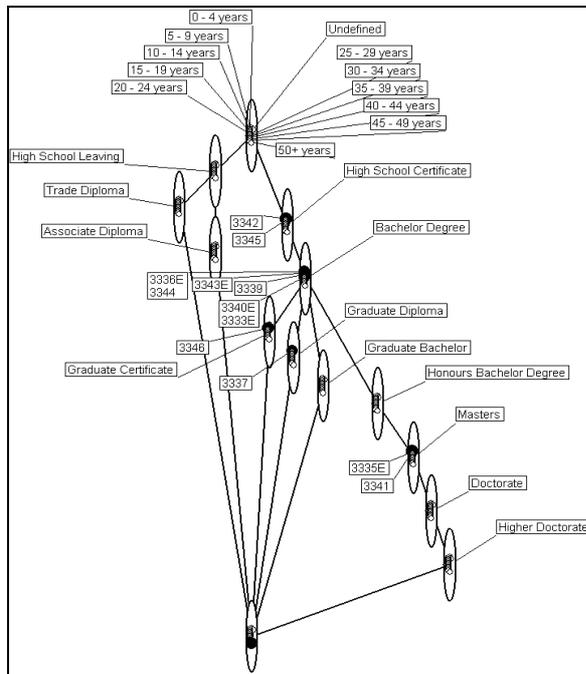
Figure 2: illustrating years of IT experience by highest formal qualification achieved by respondents in organisation Z

Turning our attention to the tacit knowledge inventory results themselves we can see an example of a scenario (figure 3) Scenario 4 has been chosen in this instance along with answer 6. In response to the scenario, participants were asked to choose an ethical and realistic Likert value (Extremely Bad through to Extremely Good). Clearly the scenario given (Scenario 4) deals with IT managerial knowledge. However it is a knowledge set that is not necessarily explicitly taught, rather something that the IT practitioner must learn for themselves over years of experience, or perhaps through a mentoring relationship with a more senior IT staffer.

And in figure 4 we see the questionnaire results for the extract presented in figure 3 above. Notice how the experts (3333E, 3336E), who answered questions relating to this scenario, selected *Extremely Bad* value choices for dealing with this particular situation, yet the non – experts did not feel so negatively. Furthermore the experts felt negatively both from an ethical point and realistic point of view. A nested lattice is used where the seven central large ellipses represent the *ethical* values and the *realistic* answers are provided as another lattice structure within each of the seven major ellipses. From the lattice, we note that non–experts tended to be more noncommittal about answer option 6 (choosing *Neither Good nor Bad*), whereas the two experts tended to feel strongly that answer option 6 was *Extremely Bad* for dealing with Scenario 4 in this way.

Examining figure 5, we may see yet another scenario and answer option. This scenario concerns itself once again with another IT managerial situation, this time focusing on 'passing the buck'. Remember these scenarios were developed through a pilot study 'reality check' process which is discussed in further detail elsewhere. Suffice it to say that once again we are testing respondent's opinions in relation to articulable implicit managerial IT knowledge.

The results for scenario 8 (figure 5) appear below in figure 6. Note how the experts (3333E and 3335E), feel more positively about answer option 2 for dealing with scenario 8. Admittedly expert 3333E feels that answer option 2 is *Neither Good nor Bad* realistically, ethically however 3333E feels that answer option 2 is *Very Good*. Expert 3335E feels that answer option 2 is *Very Good* both ethically and realistically. Notably the two non – experts who answered this question tended to be more non-committal, as can be evidenced by their more central responses (Neither Good nor Bad to Bad) in regard to answer option 2.

Let us however turn our attention to another aspect of dealing with tacit knowledge flows in the intra-organisational domain which makes use of Social Network Analysis as a means of mapping the plausible tacit knowledge flows between individuals. We have in the first section ascertained if there are differences between how tacit knowledge questions are answered. Let us now examine if information is likely to flow from experts to non-experts for example.

Scenario 4

The design for a system rests heavily upon your group. As you are the leader your reputation is at stake, this is exacerbated by the fact that you are senior and considered to be quite experienced within the firm.

Working with you in the team, are a couple of junior programmers from the company for whom your team is developing this software.

You notice reasonably quickly however that the visitors seem to be fairly incompetent, furthermore they are actually holding up the entire design process with what appears to you to be totally irrelevant issues. For instance you realise that much of the software can already draw upon modules that have previously been coded, however the visitors insist that some software be recoded because they would like to see different colours appear on the screen. You explain that that is quite trivial and can easily be coded in, however you begin to feel the visitors 'like the sound of their own voices'.

Rate each of the following responses in relation to the given scenario. It is advisable to read all of the responses before replying.

6. Take on board everything the visitors have to say and if the project is overdue wash your hands of the issue and state that the visitors had their ideas which needed to be incorporated

Figure 3: Sample scenario examining implicit articulable IT managerial knowledge for scenario 4, answer option 6
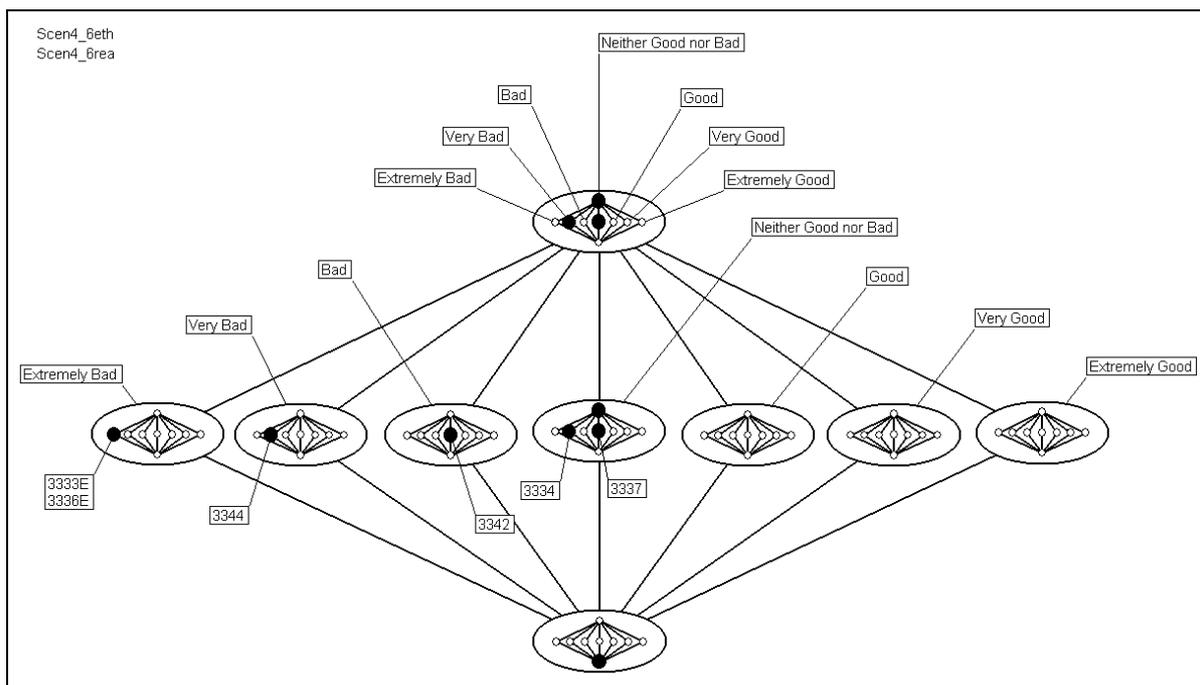

Figure 4: Illustrating Formal Concept Analysis results for scenario 4, answer option 6 (note the disparity between expert choices versus non-experts)

9. Social Network Analysis

Social Network Analysis (SNA) essentially maps the relationships between individuals and has numerous practical applications having its origins in fields as diverse as anthropology, graph theory and sociology (Knoke and Kuklinski 1982; Scott 1991). In our original methodology we planned to use participant observation as a means of measuring the tacit knowledge diffusion we assumed would take place within the organisational domain (Richards and Busch 2000).

Figure 5: illustrating scenario 8, answer option 2

However, due to its many advantages, we have replaced participant observation with SNA. Participant observation of tacit knowledge is difficult because IT practitioners on the whole do not undertake physically active tasks to the extent of say nurses (Scott 1990; 1992), police officers or fire-fighters, therefore attempting to view the actions and knowledge transferral of IT practitioners is difficult. Our use of social network analysis is for the purposes of this paper restricted to clique patterns produced using Netmap Analytics™, for we merely seek to illustrate the approaches we are using to track tacit knowledge flows within the IS domain.
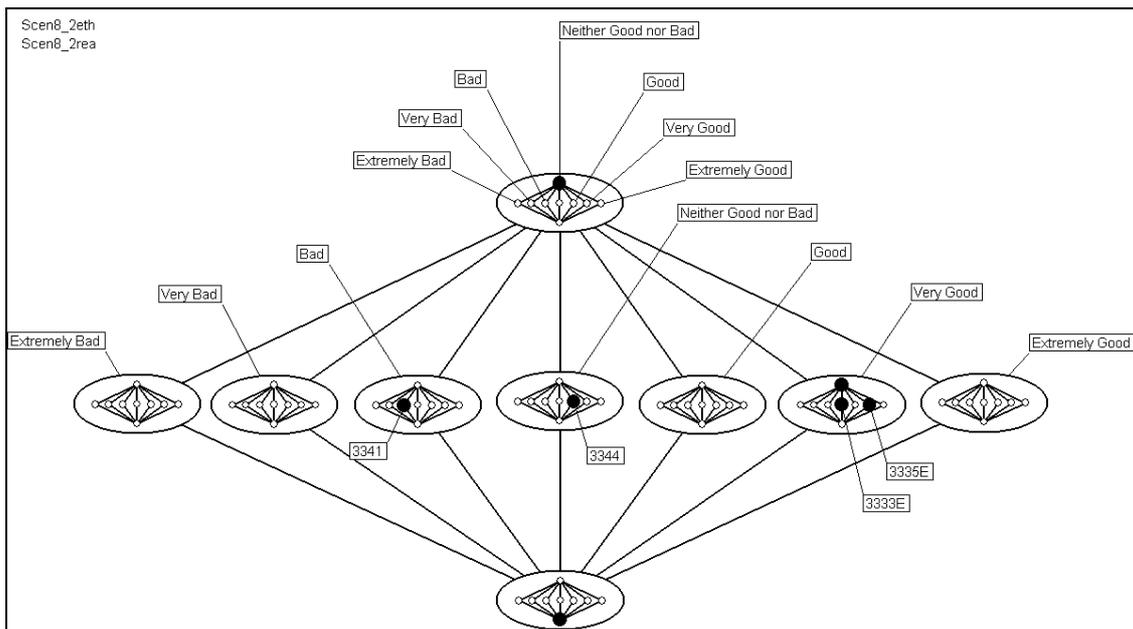

Figure 6: illustrating FCA lattice result for scenario 8, answer option 2

9.1 SNA results

An examination of figure 7 reveals some of the interconnectedness between personnel in organisation Z. An arrowhead is indicated by the break in the line. Cliques are often used in social network analysis as a means of identifying information flows between individuals. In figure 7 we can see an example of a clique between the non-expert group.
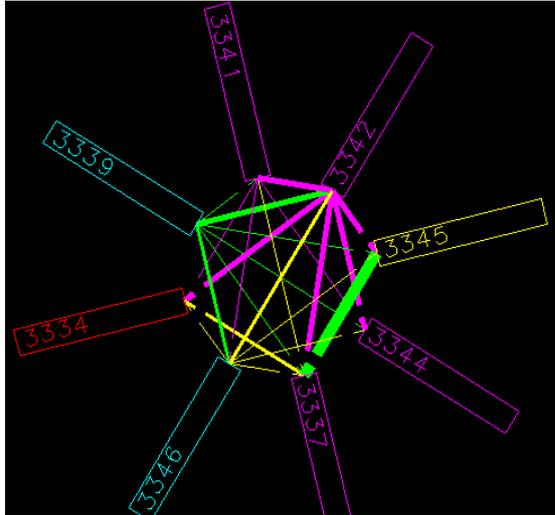

Figure 7 illustrating the clique among the non-expert group.

We can note the strong HAVE to see the person directional flow from 3345 to 3337 in the diagram. Similarly non – expert employees 3334 (although 3337 noted they could get by without seeing 3334), 3337, 3344 and to some extent 3345 seem to be in demand for their services. If we examine our networks from a different point of view (Figure 8), namely the importance of certain individuals within the organization, we can build up a picture of who the more important people are. Perhaps not surprisingly figure 8 illustrates the importance of the expert sample group (namely those individuals represented on the right hand side).

Although our questionnaire asked for the type of interaction, choices being those of `{Routine/formal organisational meeting; Fairly spontaneous yet nevertheless pre-arranged meeting; Lunch/Morning Tea/Afternoon Tea; Tend to just 'bump into' the person around the workplace; Send the person an email; Send the person a fax; Phone them; Usually see the person outside of work}`, for the purposes of tacit knowledge diffusion the evidence seems overwhelming (Sternberg 1999; Curtain 1998; Howells 1995a, 1995b), that tacit knowledge is diffused in human to human interaction.
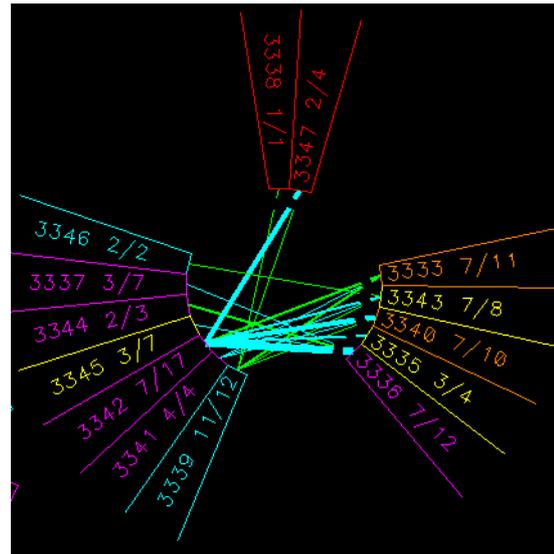

Figure 8 illustrating HAVE to see and Very important to see the person. Note again the direction of the edges in the graph, indicated by the break in the edge.

If we examine figure 9 however, we can see a great deal of email interaction takes place, and principally from non-experts to experts. Note the individual represented in red at the top of the diagram has chosen not to present their gender and hence has been placed separately by the social network analysis software.
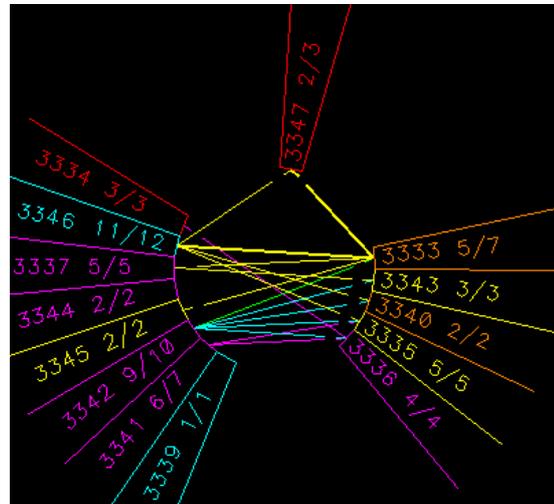

Figure 9 illustrating send the person an email or fax. Again note the direction of the edges in the graph.

10. Discussion of data visualisation

We choose to use visualisation as a means of presenting results for essentially two reasons. The first is that numerical presentation of results would be less meaningful with the small sample sizes that were obtained during the study. The second is that visualisation permits interpretation of how personnel answered the scenarios from both an ethical and realistic perspective concurrently. The

FCA lattice structure also permits similarities to be determined in relation to respondent's biographical details and how they answered questions in the tacit knowledge section of the questionnaire. As researchers we wish to know if the person's background will have a bearing on their 'street smartedness' as Sternberg would say.

Furthermore from a social network analysis point of view we are able to quickly gain an understanding of the directions the knowledge flows are plausibly taking place in. At the same time the presentation of the visual SNA data permits us to determine by way of colour and thickness of line or edge of the graph, the type of interaction that is taking place from one individual to the next. The line permits quick visualisation of the direction of the information flow or the level of importance of the meeting (whether a formal organisational one, through to emailing or faxing someone, through to seeing someone outside of work).

From the node data presentation point of view the use of colour and thickness of the nodes can also prove meaningful. For example we choose to use slightly thicker nodes to indicate permanent staff as opposed to contract members of staff who are expressed by way of thinner nodes. Management interviewed early on in the research for example were keen to understand if having contract based staff was likely to be detrimental from a tacit knowledge loss point of view. That is to say will contract staff take their soft knowledge with them when they leave the organisation? Node visualisation also allows us to determine the years of IT experience of a group of individuals, or the gender, or their highest qualification, from which generalisations may then be deduced in terms of how well or otherwise any one group under study may be seen to be networking with one another. This latter factor in turn permits us to draw conclusions as to whether personnel are passing on their tacit knowledge. Our use of visual node differentiation also permits us to illustrate the differences in communication flows from our 'expert' (proficient people), to non-expert (but possibly still proficient) sample. We can for example already see that certain flows tend to be uni-directional (people not surprisingly seem to need to see experts, but not necessarily vice versa).

Ultimately if greater use could be made of mentoring as well as encouraging personnel whose tacit knowledge scores rate similarly with those of the expert sample, it is possible that the diffusion of tacit knowledge (i.e. implicit articulable managerial IT knowledge) could be improved. Granted there will always be tacit knowledge that cannot be transferred, but a certain proportion can be.

11. Conclusion

Here we have only presented a subset of organisation Z. For tacit knowledge assessment we have chosen a Yale university based approach. Our definition of tacit knowledge is that of articulable implicit managerial IT knowledge. Given the social nature of tacit knowledge it is only reasonable that a social network analysis tool has been adopted to map the likely diffusion of tacit knowledge within the intra – organisational IT domain. We have used the expert sample largely as a means of providing a reference as to how people should ideally answer tacit knowledge related questions. Results seem to indicate there are differences to varying degrees in terms of how experts feel about soft knowledge issues compared to non-experts. The results would also seem to indicate some intra-organisational information flows could be improved, insofar as too much use may be being made of electronic means of communication that may hinder knowledge flows. Furthermore the ability to spot potential mentors by way of our technique may mean that lesser experienced personnel could benefit from working closer with the 'tacit knowledge savvy'.

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