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TACIT KNOWLEDGE AND HUMAN CENTRED SYSTEMS: THE KEY TO MANAGING THE SOCIAL IMPACT OF TECHNOLOGY

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ABSTRACT
In recent years the concept of knowledge management has become an important feature in automation literature, in particular as it relates to ICT (information and communications technology). To date, this literature focuses primarily upon knowledge, which can be extracted, explicitly stated and codified into large-scale databases or other knowledge capture devices and mechanisms. However, it is readily apparent that this notion of knowledge is extremely limited. In particular, in order to understand, appreciate and effectively design and manage complex technologies, we need to focus more on less-concrete forms of knowledge. These types of knowledge are often termed 'tacit' knowledge in order to emphasise their hidden nature. This paper reviews the current literature on tacit knowledge and relates it to current research and practise in AMAT and ICT. It then presents some empirical evidence to highlight the importance of tacit knowledge in engineering design and development work, and suggests a tacit knowledge-based framework.

KEYWORDS
Information systems, Information theory, Knowledge based systems, Social impact of automation, Systems design

1. INTRODUCTION

Knowledge is an extremely important concept in engineering research. Many modern systems incorporate concepts of knowledge management and capture into their designs, and purport to address these issues. However, many of these approaches fail to address human-centred-ness in the way they tackle systems engineering problems. So called 'hard' methods tend to ignore the relationship between knowledge and humans, preferring to emphasise codifiable data and information as 'knowledge'. This research trajectory is extremely limited, and fails to appreciate the enormous importance of tacit knowledge in the work of engineers, especially in the domain of the social-impact of the systems engineers create and deploy. This paper sets out a framework for addressing tacit knowledge, and indicates the current weaknesses in mainstream approaches to technology development. It then presents some empirical data to support the contention that tacit knowledge is extremely important to systems engineers in their work. It finally sets out some opportunities for research in this space, especially relating to human-centred systems.

2. TACIT KNOWLEDGE

Tacit knowledge is non-codifiable information that is acquired through the informal take-up of learned behaviours and procedures (Howells (1996)). Polanyi defines it as "knowing more than we can tell", meaning that we know how to perform a certain task, for example ride a bicycle, but we cannot explain to another person (s) how to perform that task successfully (Polanyi, (1961), p93). Tacit knowledge or "Intellectual Capability" is not easily catalogued. It is completely incorporated in the individual. It is ingrained in their practice and expertise, and can only be expressed and conveyed through proficient execution and through forms of learning that involve demonstrating and imitating (Fleck (1997)).

It is not possible to transmit tacit knowledge easily or directly. As task accomplishment and knowledge are specific to the individual involved and require the individual to make changes to their existing behaviour (Howells (1996)). Tacitness within the knowledge does vary and the more ambiguous this type of information is the harder it is for an organisation to assimilate it (Cohen & Levinthal (1990); Nelson & Winter (1982)).

Tacit knowledge is seen as an invaluable asset and a source of competitive advantage. Quinn (1992) observed that the competitive advantage of an organisation depends on 'knowledge-based intangibles', such as technological know-how and understandings. According to Baumard, "tacit knowledge is… a reservoir of wisdom that the firm strives either to articulate or to maintain if it is to avoid imitation" (Baumard, (1999), p23). If imitated the organisation would lose its competitive advantage. However, tacit knowledge can also cause problems for organisations, as it is difficult to formulate this type of unstructured knowledge. In addition this type of information "is often held in the minds of a handful of key persons and will be easily lost during any movement of staff" resulting in the firm losing its competitive advantage (Wong & Radcliffe (2000)).

Tacit knowledge is not easily distributed and can only be made known to other people through direct contact and socialisation. Wong and Radcliffe (2000) have stated that tacit knowledge consists of elements that can be successfully transferred via a demonstration process that is carried out by face-to-face contact between the user and the analyst.

According to Wong & Radcliffe (2000) there are six characteristics of tacit knowledge. They are:

- *Judgement facilitating*. This refers to the formation of an opinion about something: how the individual forms that opinion cannot be easily expressed.

- *Estimation and envisioning capability* involves understanding the current situation and actively evaluating what the possible outcomes may be, that is, the best guess.

- *Physical manoeuvring*, this includes physical body movement and co-ordination, for example sketching or using hand tools etc. These are often referred to as skills, but explaining and documenting them are impossible.

- *Efficiency enhancing* is generated through the possession of the knowledge learned in previous experience, and again this is difficult to vocalise and document.

- *Image formation and recognition.* When trying to complete a task the individual creates in his mind what the product of that task should be, for example creating a computer system. How the product is constructed is done using explicit knowledge, while the assembling and operation of the product is simulated using tacit knowledge already held by the individual.

- *Handling of human relationships*. This deals with the knowledge used in dealing with people in different circumstances, using the right criterion at the right place and time involves knowledge that is beyond articulation.

Wong & Radcliffe (2000) have stated that when a piece of information is used, it may display one or more of the tacit characteristics listed above and this highlights the tacit component of that piece of knowledge.

Grant & Gregory (1997) identified tacit knowledge as an accumulative process of learning. From this it can be deduced that tacit knowledge is continually being built upon and learnt (Howells (1996)). This dynamic know-how is developed through trial and error and from prior experiences of past successes or failures.

To summarise, tacit knowledge is accumulative knowledge that is embodied in the individual, escapes definition and quantitative analysis, is learned through trial and error analysis, and is transferred through socialisation, demonstration and imitation. Tacit knowledge is context specific. It is embodied within the social and organisational contexts of the individual (Roberts (2000)).

3. *HUMAN CENTRED SYSTEMS*

Kling & Star (1998) stated that Human Centred Systems refer to systems that are:

- Based on an analysis of the task being performed by a human that the system is aiding

- Performance monitoring in relation to human benefits

- Developed to take human skills into account and

- Easily adaptable to the changing needs of the human users

From this it can be deduced that Human Centred Systems are based on the social structures that surround the work and information being used by the individual. Human Centred Systems are developed to complement the skills of the user (Kling & Star (1998)). Tacit knowledge is an important factor in the way humans approach work, especially where they work with advanced technology. Consequently, an understanding and appreciation of tacit knowledge goes to the heart of human-centred systems approaches, and has been a central concern of the journal AI & Society from its very first issue (Cooley (1987)). A summary of recent European experience in one specific application domain is given by Brandt and Cernetic (1998).

The potential importance of the human-centred approach to tacit knowledge has been succinctly stated by Gill (1996), arguing that whereas knowledge is recognised as

the new economic resource, divorcing it from its social and cultural roots effectively limits the potential of new technologies for the transfer of knowledge and models of experience between and across cultures.

The following section of the research briefly sets out the experiences of a manufacturing site involved in the design and development of heavy engineering products. It indicates the importance of tacit knowledge, and how, as part of the introduction of a new technology (CAD) the company managed the diffusion of tacit knowledge.

4. EMPIRICAL EVIDENCE FOR THE IMPORTANCE OF TACIT KNOWLEDGE

A research study was conducted into the organisational impact of advanced technologies, and how firms managed these projects. The research utilised semi-structured questionnaire designed to elicit detailed, rich stories of the experiences of interviewees in the firm. This was part of a larger study into the organisational impact of advanced, complex technological systems. The research findings are set out here in story form, as told by management and engineers in the firm. Due to the sensitive nature of the data, it was agreed wit respondents that all reported data would be published anonymously.

Company X is a large multi-national operating electrical engineering manufacturing sites in the Republic of Ireland. The manufacturing site studied here employed approximately one hundred and fifty people in the manufacture of electrical products for the European market. The production and engineering processes at the plant involved some of the most advanced automation systems around, and the business was run using enterprise resource planning systems, advanced data collection system and robotics. The production facility is heavily unionised and has been in operation in Ireland for forty years, experiencing industrial relations difficulties from time to time, and often associated with the introduction of new technology.

4.1 The Context

A study into the organisational impact of complex technological systems the research explored the experiences of an engineering group in this firm who introduced a new computer-aided design tool. Some of the engineers working in the facility have been there since the facility was opened in the 1950s. Consequently, there was a very large body of tacit knowledge within the group. This was recognised by the Personnel/Manufacturing Resources manager who was ultimately responsible for the change process, of which the introduction of the new CAD system was one component. This manager, D, had worked for years as an Engineer at this firm, and moved over to personnel. One interviewee had told me how

'His predecessor had spent years in and out of the labour court. … The company's position was that you must pay in industrial relations problems now for new technology otherwise labour costs will increase forever, and you would stop development of the firm. It was brought to a head when D came in'.

The new manager had a complex problem to resolve. Firstly, he knew that the companies policy in this case would not work. He recognised that forty years of engineering knowledge would be lost to the firm. Simple replacing an aging engineering group with new graduates would set the company back decades in terms of expertise. On the other hand, he knew that the new CAD system had to be introduced, and that there would be enormous resistance. Quoting D, 'we had to avoid extremes. We needed both the level of experience of the existing engineers and the energy of the youngsters. We had one guy, for example, who was a good designer, with forty years design experience. But, he couldn't use a PC.'

The feeling was that the firm couldn't lose him and all that knowledge and skill. Furthermore, engineers at his stage of career were close to retirement, and had little to gain in attending training courses and education programmes designed to get them up-to-speed with the new technology. But the company felt that they had to introduce the new technology, and that in itself would create a lot of resistance amongst people who had little to lose in not adopting it. This was the dilemma faced by manager D.

4.2 Developing a Knowledge Retention Strategy

Manager D knew that he could not bully people into using the new technology, and that he could not risk losing the support of the older engineers who they might need to bring in from time to time after retirement, and whose knowledge had to be inculcated into the organisation. D did a number of things:

1. He subsidised the older engineers to buy home PCs.
2. Introduced a logbook based system which was non-computerised
3. Worked hard to build the trust and good will of people for the new system, and from there built
4. Succeeded in establishing a 'chemistry' in the team
5. Introduced a new position - 'senior engineer'

This strategy was designed to retain knowledge within the organisation, whilst simultaneously successfully introducing the new technology into the group. This strategy worked as follows:

4.3 Subsidised Home PC

This was designed to address people's fear of the new technology. An essential factor here was the fear of using personal computer-based tools. The engineers had drafted designs on papers for decades and were recognised as a very successful and competent design group. The introduction of new technology threatened this. By providing the engineers with subsidised home computers they could play with them at home and become familiar with the technology. Furthermore, they could keep the system for their personal enjoyment and become familiar with a technology that was now quite ubiquitous in Ireland.

This also sent out another message. It demonstrated clearly that the company was willing to invest personally in the people involved. By doing this it showed to the engineers that, if they were willing to cooperate with the firm, their jobs were likely to be secured. Interviewees described this as a significant 'psychological and philosophical change'. The money wasn't as important as the willingness to invest in the people. Small bonuses were also provided in this respect to key people who were seen to be 'key players'.

4.4 Non-computerised Log-Book System

This provided a work around solution in case the system failed, again addressing fears associated with the new technology. Also, by providing a computerised and non-computerised approach, it addressed problems associated with the 'insensitivity of youngsters' i.e. the older engineers had access to equivalent technology at home, and had a non-computerised solution that was useful to the group and of which the 'youngsters' would have no knowledge. This neutralised potentially dysfunctional power imbalances in the group.

4.5 Trust, Good Will and Ownership

D recognised that in order for people to be committed to the project, and for them to have a stake in its success, goodwill and trust had to be inculcated. He saw this as a central plank of the strategy. As one interviewee put it 'if you treat an employee unfairly you can undo years of work'.

4.6 Chemistry

When recruiting personnel, and organising sub-groups, D tried to 'get the chemistry right' between people. This meant placing certain people together, and was described as something which required patience.

4.7 The Senior Engineer Role

This position was created in order to establish the seniority of the older engineers. It was the key to the retention of tacit knowledge. By creating the senior engineer position D could ensure senior managers acted as mentors for the new engineers. Furthermore, it meant that the new engineers, who found it easier to familiarise themselves with the new technology, could perform most of the computer-based design work, under the guidance of the senior engineer. This effectively reduced the amount of computer-based work the senior engineer had to perform, whilst ensuring that the design skills of the senior engineer were learnt by the new staff.

5. TACIT KNOWLEDGE AND HUMAN-CENTRED TECHNOLOGY DEPLOYMENT

By combining these elements with technical instruction and a solid technical deployment of the new system, the engineering group were able to train up new engineers in the CAD system, whilst simultaneously passing much of the older engineers tacit knowledge to the novices. By adopting a human-centred approach to the technology deployment problem, the organisation was able to utilise a new technology project to ensure that important tacit knowledge was diffused in the firm.

Although 'Knowledge Management' has enjoyed something of a vogue in corporate circles, it has also attracted some criticism. Scarborough (1999), for example, sees it as an essentially technocentric concept, based on groupware and intranets, rather than on an appreciation of the nature and dynamics of knowledge *per se*. He argues that this "…technology-driven view focuses on flows of information, as opposed to people, in the enterprise. The issue then becomes one of redesigning the people around the systems".

The critical managerial insight in this case study was to perceive the problem in terms of a human activity system, which used embedded technology, rather than as a technology system to which humans must in some way be accommodated. Such a shift of perception is at the heart of the Human Centred Systems approach – even if Manager D was not explicitly aware of the connection. It is perhaps telling that D was approach the issue from a Human Resource (personnel) standpoint rather from a conventional system engineering position.

It is readily apparent that, for this company at least, the management of tacit knowledge was central to the management of the social impact of the new technology. This suggests the needs for a research agenda, which addresses, comprehensively, tacit knowledge for technology deployment. The next section briefly reviews the tacit knowledge literature. This is designed to provide an overall research agenda for this domain.

6. DIMENSIONS OF TACIT KNOWLEDGE: A RESEARCH AGENDA FOR HUMAN CENTRED SYSTEMS

The previous section sets out some empirical evidence for the importance of tacit knowledge in company X. It

then argues for a research agenda in this area, which might provide some direction for research in tacit knowledge and social impact. The literature indicates a number of important attributes for tacit knowledge which need to be taken into account in human-centred systems research. These traits can be divided into seven aspects of tacit knowledge for this research, namely:

1. *Implicitness.* This characteristic of tacit knowledge is extremely important. Throughout the literature tacit knowledge has been identified as being knowledge which one possess' but is unable to put into words (Polanyi (1966)). It has also been defined as a nebulous process, (Howells (1996)), intuitive (Wong & Radcliffe (2000); Argyris (1987)), highly idiosyncratic (Roberts (2000)), inarticulable (Grant & Gregory (1997);), subjective (Baumard (1999); Nonaka & Konno (1998)), subsidiary awareness (Polanyi (1961)) and deeply rooted in ideals, values or emotions of individuals (Nonaka & Konno (1998)). Implicitness is knowledge that cannot be non-analytical (Wong & Radcliffe (2000)) and is typically learned and transferred through experience (Alic (1993)).

2. *Experiential.* This aspect of tacit knowledge is identified in the literature as accumulative knowledge (Grant & Gregory (1997); Howells (1996)), derived from experience (Wong & Radcliffe, (2000); Roberts (2000); Fleck (1997)). This tacit know-how is gained through experiences, and through trial and error (Howells (1996); Roberts (2000)). Polanyi (1962) identifies that this feature cannot be learned from books. It is only through experience that the user will be able to decide on the best course of action to pursue. Polanyi states "[experiential knowledge] guides integration of clues to discoveries" (Polanyi (1966), p2).

3. *Interactive-ness.* This feature of tacit knowledge is detected in the literature as 'in the corridor' style of learning that is codified in local practices and communities (Wong & Radcliffe (2000)). It is culture bound (Grant & Gregory (1997)); the knowledge is developed interactively (Roberts (2000)) through socialisation between co-workers (Fleck (1997); Baumard (1999); Nonaka, Takeuchi & Umemoto (1996)).

4. *Show-how.* An important attribute of tacit knowledge, show-how enables this knowledge type to be transferred among communities through on the spot learning (Fleck (1997)) and face-to-face contact between colleagues (Roberts (2000)). Show-how has been described as learning by watching, learning by doing and learning by using (Grant & Gregory (1997); Howells (1996); Fleck (1997)). Show-how is codified into the local practices and communities (Wong & Radcliffe, (2000)) and it is through demonstration (Roberts (2000)), imitation (Baumard, (1999); Polanyi, (1961)) and practice (Nonaka & Konno (1998)) that this feature of tacit knowledge is made available to others.

5. *Context.* The context of tacit knowledge is the knowledge that resides in individuals about how they perceive themselves in their society / organisational culture (Argyris & Schön (1974)). This is a form of tacit knowledge know-how as it allows us to make sense of the world (Polanyi (1962)). It transferred through informal local practices amongst co-workers (Howells (1996); Wong & Radcliffe (2000)). This knowledge does not reside individually amongst workers but at an organisational level – it is specific only to that particular organisation (Cohen & Levinthal (1990)). The context of tacit knowledge can be further divided into:
   a) *Social.* Informal way of learning through direct contact with co-workers (Howells, (1996) Fleck (1997)). This form of tacit knowledge is learnt on the job (Fleck (1997)) and is deeply rooted in ideals and values of the individual (Nonaka & Konno (1998)).
   b) *Cultural.* Informal learning of behaviours within the organisation through socialisation with workmates (Roberts (2000); Howells (1996)). This tacit knowledge form has been described as being culture bound (Grant & Gregory (1997); Roberts (2000)) and critical knowledge that is firm specific (Cohen & Levinthal (1990)).

6. *Non-measurability.* In the literature this element of tacit knowledge is ascertained as being difficult to express (Fleck (1997)) and quantify (Howells (1996)), non-existent (Wong & Radcliffe (2000)), uncodifiable, (Wong & Radcliffe (2000); Roberts (2000); Grant & Gregory (1997)), and that it escapes observation and measurement (Baumard (1999)) as it is elusive and indeterminate (Polanyi (1966)).

7. *Personal.* In the literature tacit knowledge has been identified as having a personal trait. This has been defined as person-embodied (Howells (1996); Polanyi (1961)), second nature and highly proprietary (Wong & Radcliffe (2000)), subjective and intuitive (Baumard (1999); Nonaka & Konno (1998)), and mental processes (Polanyi (1966)).

Summarising, there are seven research issues that have been identified within the literature. These have been used to set out a research agenda for cross-cultural collaboration between Ireland and Wales. Waterford and Newport are geographically related regions of small countries, and both face the difficult transition towards a sustainable post-industrial economy. The problem of managing, developing and communicating the corporate tacit knowledge base in a state of rapid transition is a major concern for all companies. We are now planning to integrate research undertaken on both sides of the Celtic Sea in order to develop strategies which, whilst. Of immediate significance in our own localities, may also be of more general value – for example, throughout the enlarged European Union

7. CONCLUSION

It is readily apparent that tacit knowledge is central to any debate on the social impact of advanced technology in the workplace. It is also apparent that this form of knowledge is critical to engineers and technologists in very practical ways. At the same time, however, it is unusual to find an effective combination of domain tacit knowledge and human resource expertise in a modern company, and yet it is clear from our study that this is exactly what is needed.

Knowledge management is often greeted with suspicion by a skilled workforce, who may interpret it as the preface to deskilling or other forms of downgrading of their practice. The approach adopted in the project described above has demonstrated that this need not be the case. The Human Centred Systems Approach provides an effective set of tools for making tacit knowledge accessible throughout an organisation, whilst maintaining a sense of ownership and commitment on the pert of the skilled practitioners in whom the knowledge resides.

It is our contention that an effective organisation is one in which everybody both contributes to and has access to a culturally embedded corpus of tacit knowledge. Human Centred thinking offers a conceptual framework for the effective explication and transmission of aspects of the tacit knowledge components of skilled performances in a variety of domains, and, more importantly, for providing an understanding of the wider cultural contexts within which they are located. This makes it appropriate as a tool in the development of corporate knowledge management strategies for the twenty-first century.

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