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Innovative Socio-Technical Systems for Complex Decision-making

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Abstract

This paper views the complex activities and decision-making of self-directed groups as socio-technical systems. Seven innovative ICT-based tools are presented that underpin such activities. Three projects are then described where suitable selections of these tools are used creatively in harmony with human and social processes. The Activity Theory hierarchy is used to explain how, in these three projects, the capacity of technology is exploited, where appropriate, to automate *operations*, while the choice and execution of *actions* remain with the people engaged in the *activities*. This provides a picture of decision support systems as socio-technical in nature, involving the exploitation of collective tacit knowledge rather than just the use of explicit information. The paper concludes with the proposition that this is not just a conceptual and theoretical issue, but is also highly practical in consideration of the creative decision-making processes of self-directed, innovative groups.

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1. Introduction

Strategic decision-making is traditionally seen as unstructured, and hence complex, but made easier and more effective through the supply of relevant information. However, what was once the 'Information Age' is now the 'Knowledge Age' where organisational systems can be viewed though a 'knowledge lens' thus giving a new perspective on decision-making. In the 'Knowledge Age', the Internet, together with other information and communication technologies (ICT), has enabled companies to spread their operations and influence across the globe. This is changing the way organisations are structured and managed, with implications for their decision-making processes. This is described by Allee (2003 p 4) in the following way. "The centre of power is shifting out to the edges. Decisions are moving out from corporate headquarters to individual business units. Business units in turn distribute power and decision-making to self-managed teams and profit centres." This is the basis of the concept of knowledge work where workers have control over their own activities through knowledge acquired through both training and experience.

It is through loosely connected self-directed teams in network-centric configurations that many organisations seek the agility and flexibility to adapt to the ever-changing market place in which they must now do business (Miller & Stuart 2005; Warne et al 2005). Complex creative activities frequently occur in small, informal groups rather than in the work of individuals alone, or in the formal endeavours of large organisational divisions (Linger & Warne 2001). Dynamic group activities are complex phenomena, particularly when group members are not co-located, but regularly communicate and collaborate online. Technologies that support such group collaboration are not as well understood as those designed for use by individuals, such as word-processors and web-browsers, or the large systems which automate the operations of organisations. To better understand the complex decision-making processes in this context, it is therefore useful to regard the human factors of groupware as one aspect of a dynamic socio-technical system rather than mere isolated interactions of individuals with the technology.

This paper concerns the complex activities and decision-making of self-directed groups. It begins with a discussion of socio-technical systems in the context of activity theory followed by the justification for locating creativity and innovation in informal group activities. It then presents a set of ICT-based tools that can underpin socio-technical systems to support the decision-making activities of self-directed groups. Three decision-making activities are then described as socio-technical systems using suitable selections of these tools in harmony with the human and social processes. A critical analysis is made of the way these socio-technical systems support the

collective actions, knowledge and decision-making of innovative groups, teams and networks. The paper concludes with an interpretation of how, in such socio-technical systems, a suite of flexible ICT tools can complement the fundamental human and social processes of decision-making.

2. Socio-Technical Systems and Collective Activity

A focus on the technological issues in any system, without consideration of the social processes that surround them, is a recipe for failure. However, bringing together the social and technical demands of systems is not easy. Systems that include a variety of people and technologies routinely adopt different social roles within an organisation, and these roles have a major influence on a system's acceptability (Masterton & Watt 2000). People will develop and use the technical components of information systems in a purposeful way, while the social system, which underpins most of the day-to-day operations, develops in an ad hoc fashion (Benson & Standing 2001). In particular, groupware systems, which connect people to people directly or indirectly, are best understood as the interrelationship of organisational, cultural and technical elements (Boland & Tenkasi 1995).

The term *socio-technical* has historically been applied to the relationships between the social and technical parts of a system, particularly those involving information and communications technologies (ICT) in organisations. The socio-technical movement flourished from the 1950s to the 1980s; a highlight being Cherns principles which included concepts of minimalist design, multiple perspectives, support for congruence, consideration of information flow, and human values (Cherns 1976). Thus *socio-technical* became a holistic way of thinking about systems design and use. Following a period of relative quiet, the term has re-appeared in the literature. Coakes (2002) recently described the goal of socio-technical design as being: to produce systems capable of self-modification, of adapting to change and of making the most of the creative capacity of the individual for the benefit of the organisation. Scholtz (2002) sees the socio-technical perspective as valuing small independent work groups engaged in highly varied tasks, managing their own activities, often supported by technology. Bødker (1990) distinguishes between systems as artefacts (an end product or outcome of a development activity) and socio-technical systems as evolving tools that mediates, and are mediated by, the activities for which they are used. The Activity Theory on which Bødker's work is based, defines activity systems as the tool-mediated, purposeful work of small communities (see also Engestrom et al 1999).

This recent literature provides evidence that the applicability of socio-technical principles, and the methods of applications associated with them, can help contend with the complexity in the human, organisational and technical aspects of change (Coakes 2002). It is clear that socio-technical principles involve more than just an analysis of the interaction of people and artefacts, particularly as technologies are often used in ways unintended by the designers who may not have fully understood the nature of the social practices in the system. Activity theory places the emphasis on the purpose or activity for which the system is being used which is the basis of the research described here. Within the complex mix of components and their inter-relationships that make up dynamic systems there are issues of instrumentality and agency that must be acknowledged in achieving this purpose. Investigation of these issues necessitates a sound understanding of culture and relationships, human social interactions, and communication where socio-technical systems are considered an integrated whole that enables the creative process to occur.

As already suggested, the principles of socio-technical systems are closely associated with dynamic and creative activities, which are most likely to occur in independent, self-directed groups and communities. There is a growing body of literature (Boland & Tenkasi 1995, Engestrom 1999, Toulmin 1999, Wenger et al 2002), which promotes a view of socially-constructed, collective activity as the predominant source of learning, creativity and innovation. Chae et al (2001) describe human activity systems, together with the terms 'communities' and 'networks of practice', as relationships among persons, activities and worlds. One of the key principles of activity theory is that all human activity is mediated by tools (Engestrom et al 1999) and ICT-based tools are particularly exciting when viewed from this perspective. An activity is therefore a dynamic socio-technical system where tools and context mediate human work and decision-making.

From this perspective a set of innovative ICT-based tools will now be described that can be applied together with human interventions and actions to carry out innovative projects in groups and communities. This will be followed by descriptions of three such projects that are being undertaken with the aid of these tools and being studied using a developmental research approach. This involves the formation of new knowledge (i.e. research output) through the process of building and implementing a product or program, in this case a socio-technical system, for the purpose of improving either the thing itself or the situation where it is used or both. The research is holistic, contextual and evolutionary, incorporating many forms of data collection and analysis in order to obtain a rich understanding of the phenomena.

3. The Suite of ICT Tools

This section of the paper gives a brief overview of seven innovative ICT-based tools that are being used in combination with each other and connecting human processes to guide and support decision-making. This set of tools is not intended to be exclusive, as new tools are regularly being added to the mix as required. However they will be used to illustrate holistic approaches to decision support in complex situations.

3.1. Zing: a Facilitated Group Decision Support System

Zing[1] is a groupware system consisting of a mix of hardware and software that allows for group brainstorming and decision making. Hardware enables multiple keyboards to control cursors of a PC or laptop on which the Zing software can be loaded and projected onto a screen to be viewed by the participating group. Templates of questions that facilitate a group discussion session have been developed through research and many years experience In a session, a suitable template is loaded and used to guide the dialogue on a given topic or problem. Each participant types in ideas and responses on their own keyboard into their own anonymous window. When ready, they then fire up to the public section above (see figure 1). These statements can then be reviewed, summarised and stored by the group.

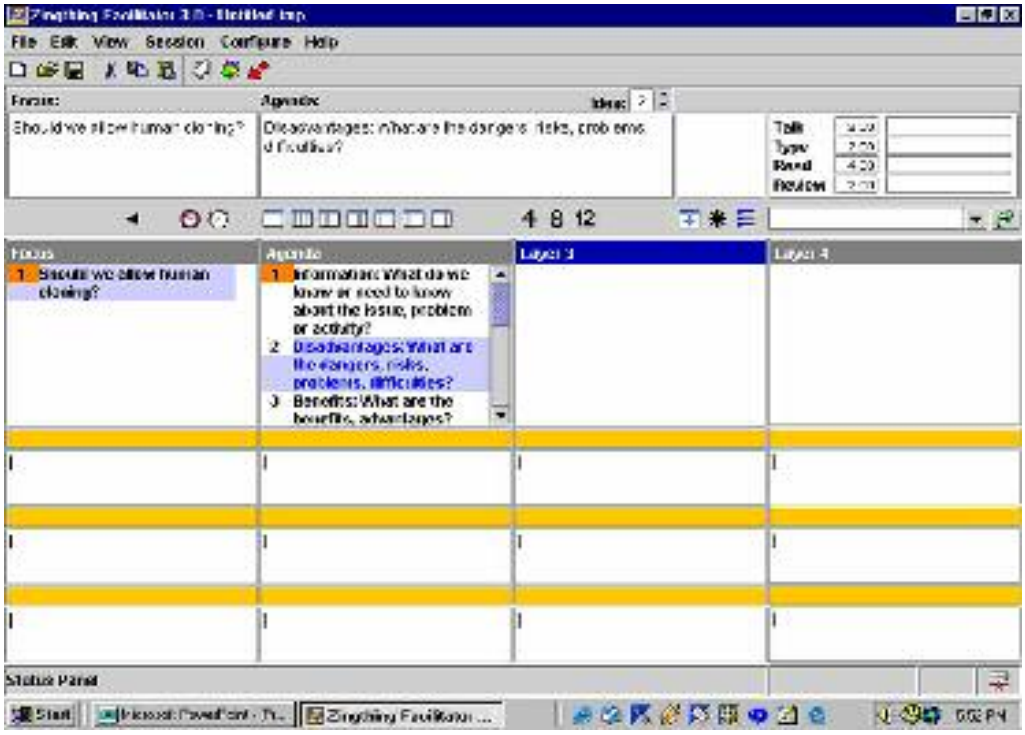

Figure 1 The Zing display: Questions on the topic are loaded into a Zing template for a facilitated session. Participants control individual cursors in the twelve windows at the bottom from their own keyboards.

[1] http://www.anyzing.com/

Zing is therefore is a facilitated decision-support system, applicable to small group problem solving and knowledge creation through democratic learning processes that can lead to cultural transformation and accelerated innovation. In addition Zing is used in classrooms to promote teaching and learning in teams which can be facilitated by the students themselves. "The software includes thinking methods and scaffolds for problem solving, planning, creative writing, feedback, hypothesis formation, playwriting, criticism, logical reasoning, ethics and team and self evaluation" (Zing 2005). Zing is portable and can be used remotely over the Web.

3.2. Q-Method: Capture of Subjective Perceptions and Factor Analysis

Q methodology[2] provides a standard set of procedures for analysing qualitative data by eliciting the subjective understandings held by participants. The source of the data is frequently based on individual viewpoints about a particular topic, view or event.

The process typically begins with a concourse, which can vary from a single brainstorming session, to a research based selection of published views that will eventually be expressed as "statements". The concourse as a group activity is one of the great strengths of the methodology as it provides the participating individual with access to the views of the others and, in the process; new views, thoughts or ideas often arise.

The next step is conducting the sort, which involves asking each participant to rank the statements of ideas expressed on a topic with reference to their own views. This is accomplished by having a sort sheet where there is one position available for each item. This has the effect of "forcing" the participant to make decisions between statements; a process that tends to increase the level of involvement by the participant. Once the sorts are complete, Q Method software is used to factor analysis the sorts so that a number of factors emerge that reflect the views of the participants. There is also the opportunity to interview chosen participants to get further insight into the reason for the positions taken in the course of the sorting. This methodology is recommended as a research tool when attempting to identify the perceptions of the participants (e.g. see Meloche et al 2005).

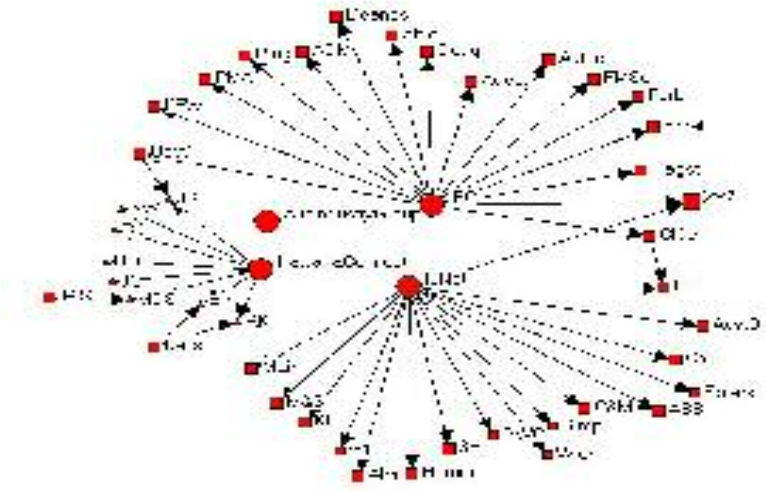

Figure 2. A growing SNA of a regional network of associations (circles) businesses (squares) and people (triangles) in the area.

3.3. Social Network Analysis – Relationship Capture and Visualisation

Social Networking Analysis (SNA) is a means of identifying, analysing and representing the various relationships between individuals and groups in an organisations or community. This gives a view of its social structure and dynamics. NetDraw[3] is a computer software program for

[2] http://www.qmethod.org

[3] www.netdraw.com

introductory SNA. An example of its use is in the project shown in Figure 2, which represents data on the links in a network of businesses and business organisations in a region.

3.4. Leximancer – Concept Mapping from Content Analysis

Content analysis is a tool used for determining the presence of words or concepts in collections of textual documents. It breaks down the material into manageable categories and relations that can be quantified and analysed. These extracted measurements can be used to make valid inferences about the material contained within the text (such as the presence of propaganda), properties of the writer or speaker (such as his or her psychological state), the audience to which the material is presented, or properties of the culture of the time in which the material was written. Many approaches to content analysis have produced highly reliable and valid results.

Leximancer[4] is a computer-based tool for content analysis and it can be used to analyse any form of verbal communication from written to spoken forms. It can be used, for example, by social psychologists to compare groups of individuals non-invasively by analysing their natural social interactions without the need for creating artificial settings or scenarios. Furthermore, as text documents tend to exist over long periods of time, the technique can be used to extract valuable historical and cultural insights. The information is displayed by means of a conceptual map that provides a birdseye view of the material, representing the main concepts contained within the text and how they are related. Apart from viewing the conceptual structure of the information, this map allows users to perform a directed search of the documents in order to explore instances of the concepts or their interrelations as shown in the example of Figure 3.

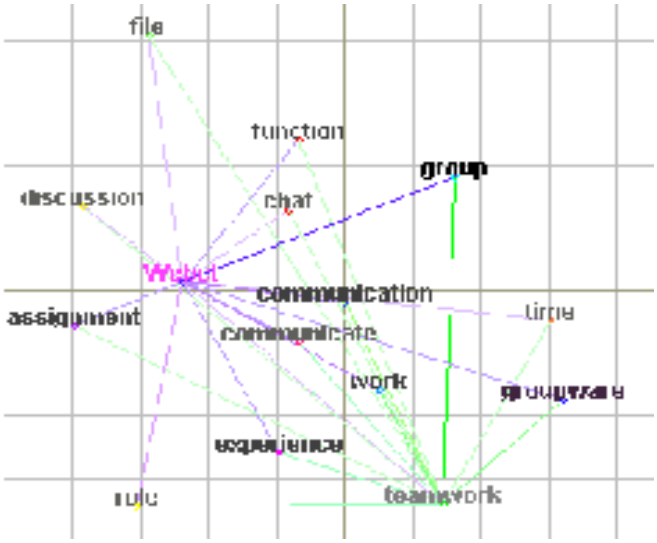

Figure 3 A concept map from a study of groupware where the brightness of a concept is related to its frequency, the brightness of links relate to how often the two connected concepts co-occur closely within the text and the Nearness in the map indicates that two concepts appear in similar conceptual contexts

3.5. Stella Systems Modelling – Systems Thinking and Dynamic Simulations

Dynamic Systems Modelling is a technique used to imitate, on computers, systems exhibiting complex, time-dependent behaviour. From the simulations, data are collected as if a real system were being observed that can be used to estimate performance measures of the system. New policies, operating procedures, decision rules, information flows, organizational procedures, and so on can be explored without disrupting the real system. Time can be compressed or expanded allowing for a speedup or slowdown of the phenomena under investigation. It is possible to replicate patterns of behaviour and gain insight about the interaction of variables. Safety can be ensured especially when trying to study the effect of extreme conditions.

[4]http://www.leximancer.com

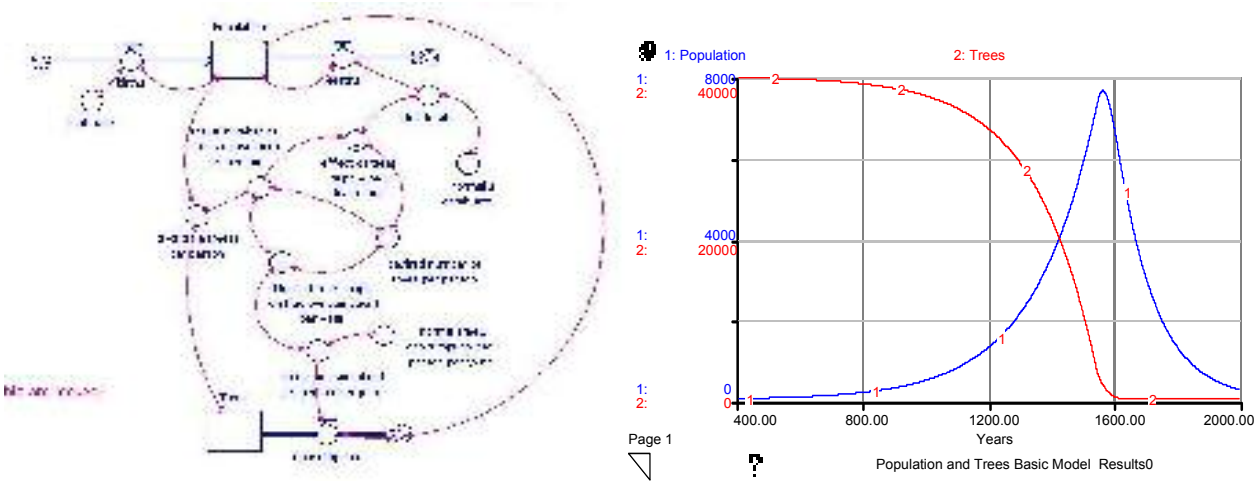

Figure 4 This example of a Stella[5] model shows a theory of how the population of Easter Island disappeared because of their reliance on trees. The model shows the flows (birth, death, consumption), stocks (Population, Trees) and influencing converters. The graph shows the changes in the two stocks.

3.6. Go*Team – Gaming, Team-building, and Cooperative Profiling

Figure 4 An example of the server screen of the Go*Team game.

Go*Team is a computerised team version of the ancient strategy game of Go, developed in China between three and four millennia ago. Unlike standard Go, in which the players take turns to place their stones, a GoTeam player's next turn can be taken after a 'relaxation time', specified via the server, regardless of whether or not the opposing team has done anything in the interim. As far as the game software is concerned all team members are peers; there is no 'team leader' with more power or capabilities than other team members. The Go*Team game has, therefore, been created to place its players in an environment exhibiting a number of the features outlined above in order to explore how they function in that environment, the techniques they prefer to use, the techniques that are more successful, and the barriers that may inhibit them from operating as effectively as they otherwise might. The client screens for each player show only a partial view of the board so that there is a need for team members to communication their view of the board to others as well as to discuss strategies. Players on the same team make use of modern communication tools such as voice over IP, chat rooms and the like, to provide the interaction they need to play successfully.

3.7. Eviva – A Web-based Groupware System for Communities

Web-based groupware applications, such as Eviva[6], shown in Figure 5, have been developed to support the online activities of communities. This product has evolved throughout the research and

[5] http:// www.iseesystems.com
[6] http://www.eviva.com.au

continues to do so as more is discovered about the needs of the communities (D'Souza & Crawford 2005; Hasan & Crawford 2003a, b). While it is important that the technical product is robust, with a high degree of integrity, usability, security etc, it is also important that the functionality is not over designed and does not dictate the way the community operates. As it stands now, the online application is a customisable, secure private workspace with synchronous and asynchronous modes of communication. It enables a community of users to work either as individual members of the whole community or collaboratively in teams. Further, the community may work on many different projects to which community members can be assigned. Each user can be assigned different levels of privileges in the community as a whole and within each project, where there is access to various resources such as online forums, quick polls, file systems, news, etc. These resources are secure to users in relation to their respective levels and privileges. The tool also allows users to customise their private team spaces so that a sense of personal attachment to the tool can be established.

Figure 5 Part of the interface of the Web-based groupware system used in the research showing a community poll.

4. Three Activities involving Decision-Making Socio-Technical Systems

This section of the paper presents three projects that use combinations of the technological applications described above, together with human practices. The projects are viewed as integrated socio-technical activity systems where the choice of technologies and the decision-making processes that integrate the technologies, are the human ones.

4.1. Design Decisions for a Medical Web-based Information Exchange

Public sector issues concerned with health have extensive data and information implications. Huge amounts of data are collected by governments and other agencies to produce information on which to base decisions, from individual cases to national resource allocation. Perhaps due to the complexity of the context, the medical profession and associated services have lagged others in their take up of ICT-based applications. Introducing new systems is complicated by the variety of stakeholders including medical, administrative, regulatory and consumer groups. Their needs must be considered in conjunction with life-critical issues such as safety, security and confidentiality.

This project concerns the determination of the requirements for a new web-based system to collect data, provide information and facilitate communication between all stakeholders of intensive care units across the state of New South Wales in Australia. A Web-site and online forum had been set up at the state level, but was not being utilised at the local level. The following process has been used to capture the complex mix of needs and concerns from the users themselves, in order to make advantageous design decisions for a new system.

In order to gather subjective ideas from the wide variety of stakeholders a Q-methodology was found to be most appropriate. However, it proved impossible to get enough stakeholders together at

one time for a concourse. Although many were keen to participate they were busy people, on call for emergencies and widely scattered in hospitals across the state. It was therefore decided to combine the mobile and web-based capability of Zing to collect statements electronically, which could then be much more easily refined and prepared for the sort. As this resulted in large numbers of statements on different user issues and system requirements, among which there could be different themes, Leximancer was also used to assist the project team to stream the statements and combine duplicates. Although the three technologies did not directly interface, their use made the work of the people viable so that results could be obtained in a workable and timely fashion and thereby support the web design decisions.

4.2. Encouraging a Community Network

This project concerned a regional endeavour to create a locally-based community network to stimulate bottom-up economic growth. The project emerged from a SME cluster which has already realised the benefits of networking. They initiated an expanded community venture in the form of a Virtual Innovation Community (VIC) among other local organisations. The steering group needed to raise local awareness of the need for, and possibilities of, such a venture. An SNA, an early version of which is shown in Figure 2, was drawn up to show the relationships between existing business groups and highlight the traditional rivalries between them which were hampering the economic development of the region. It is hoped that the SNA will also show links on which the new venture could build. The VIC needs technical support with a carefully designed shared web site with web based collaborative working spaces that can be used to coordinate emerging new projects. For this, the Eviva system could be used to provide a platform for collaborative activities. It is proposed that the virtual community network will be used to coordinate an expanded small business network as a vanguard for future innovative economic development in the region. Under the leadership of the group, there has been in principle support from the education sector, industry groups, state and federal governments, small businesses, the ICT Cluster, and the City Council who would normally be suspicious that such an initiative would compete with their status in the region. Data from the group formation in Eviva can then be fed back into the SNA to support future decisions on network formation in the region.

4.3. Introducing Cooperative Activities into a Competitive Environment

This project was initially focussed on the military who are concerned with developing a network-centric environment within their traditional hierarchical top-down structures. Modern operations call for personnel who can work across boundaries of type of service, culture, etc. The Go*Team system has the potential for training teams to be cooperate in a competitive environment and to profile the characteristics of personnel in their ability to perform in situations that call for cooperation and trust when making field decisions under stress, relying on others to provide information in virtual networks. The challenge was to develop protocols for training and profiling with Go*Team, identifying and calibrating the various factors it can set and measure. These include stress, caused by varying the relaxation time, modes of communication among separated team-members, the content of the communication, as well as issues of how performance at the game indicates the degree of cooperation and competitiveness of the players. To conduct studies to explore these issues, a process of recording, observing and analysing some preliminary sessions of Go*Team game was combined with collaborative efforts to model the dynamics of the play in Stella. This is showing which measurable variables appear to be aligned with what factors and their relative importance. This will inform more controlled experiments with the Go*team system and support decisions on team-building and information sharing in military and business organisations.

5. An Analysis and Interpretation of the Phenomenon

The three projects outlined above are real, ongoing and dynamic. They are chosen as illustrations of socio-technical systems that support the collective actions, knowledge and decision-making of self-directed groups, the location of much creativity and innovation. In these socio-technical systems, the human and social processes of decision-making are aided by tools selected from the set

of ICT applications described previously. In each case the higher order strategic decision-making is performed by human knowledge workers, while the tools, albeit sophisticated computer-based applications, take the support role.

This phenomenon can be analysed and interpreted by the dynamic Activity Theory hierarchy shown in Figure 6. Leontiev (1981) proposed that *activity* should be placed at the top of the hierarchy, associated sustained human endeavour with a long-term purpose and strong *motives*. This is a conceptual level above where most business analysis takes place, which is at the level of *actions*, undertaken towards specific, and often short-term, *goals*. Under certain conditions, conscious *actions* can be driven to a lower level of automation, often embedded in computer systems, as they become standardised as *operations* suited to local *conditions*. In summary, an *activity* is comprised of sets of *actions* (towards specific goals) and *operations* (routine and well known habitual cognitive or behavioural processes, now commonly the domain of ICT systems). *Actions* are planned with specific goals and are not meaningful in themselves unless they are part of an *activity*. Flexibility and adaptability comes with the recognition that there may be legitimate alternative sets of *actions* that can enable the successful performance of an activity. For example: it is common practice in IS development to assess the feasibility of different design solutions to an organisational problem and then choose one solution to implement based on a cost benefit analysis. However there may be instances where it is feasible to allow separate concurrent solutions (i.e. different sets of actions) for an activity under different circumstances.

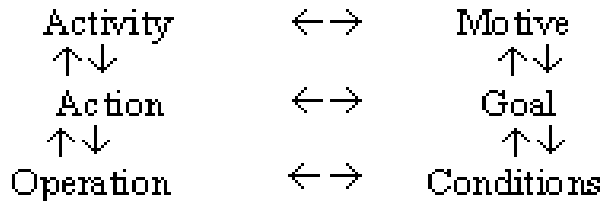

Figure 6 The definitive Activity Theory hierarchy of Leontiev (1981).

6. Conclusion

In the three projects used as illustrations, the capacity of technology is exploited, where appropriate, to automate operations. However, control of choice and execution of actions remain with the people engaged in the activity making use of their evolving tacit knowledge. Each of the projects concerns decision support: the design decision for the medical web-site; how to stimulate the formation of community networks; and how to stimulate cooperative behaviour in competitive environments of military and business organisations. Each of these three decision support systems, involving several of the seven technological applications described here, are brought together by human decision makers in innovative and productive socio-technical activities.

The thesis of this paper is that these integrated and dynamic socio-technical systems demonstrate what is meant by self-directed knowledge work where people, engaged in a collective activity, are allowed and enabled to choose the technical components as needed to automate *operations,* leaving them with more time to deal with the knowledge components of their *actions*. The type of ICT applications described above, provide the functions that collect and manipulate complex data as well as to trial solutions and to connect people together in a supportive virtual space thereby giving more flexibility to the whole dynamic system.

This is not just a conceptual and theoretical perspective but is also highly practical. In practical terms it endorses the 80-20 rule, one interpretation of which says that 80% of the potential value of an ICT project is created by 20% of the possible effort and the remaining 20% of value would take 60% of the effort. Thus there should be a pragmatic decision as to where the last 20% the project is worth implementing. In respect of the three projects described here, the ICT components were taken off the shelf and used to advantage. Pushing to develop the ICT part of the system further through technological integration would be possible but would require much more effort. Thus much of that work was done by the people involved. It is, however, probable that each of the

projects will involve further combinations of the ICT products, for example the Zing – Q-method role, used in the first project for subjective perception gathering from participants, may also be used in the other two projects at some future stage. Likewise, Eviva may be used to support a Go*Team user communities and so on. This flexibility and creativity is essential to provide effective decision-support for knowledge workers in the current environment and within the foreseeable future.

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