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An Activity-based Model of Collective Knowledge

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Abstract

In the challenges faced by organisations in the area of knowledge management, there is clearly a role for information and communications technologies in supporting the exploitation of business knowledge. This paper proposes a model of knowledge processes, based on the concept of “activity”, i.e. what people do, as determined by the Cultural-Historical Activity Theory. The evolutionary development, of an implementation of the model in currently available technology will be described, together with the results of an evaluation of its suitability and effectiveness. This work is substantiating both the practicability of the implementation and the usefulness of the structure for the extraction of rich information that can support group memory and knowledge processes.

1. Introduction.

This paper explores an innovative structure for computer-based systems, which support the difficult task of managing collective knowledge. Knowledge management (KM) is clearly an interdisciplinary research area and there is debate as to whether knowledge management, in business practice, should be considered a technical issue, a human resources issue, a procedural issue or a part of strategic management. KM should therefore be considered socio-technical and cross-functional but is often viewed as simply the latest in a long line of applications of information and communication technology (ICT) for the provision of business solutions in organisations [1]. The problem is that application designers do not have accepted models for the large invisible and complex nature of work that knowledge management systems are expected to support

and there is a critical lack of understanding by technologists of the situated work practices of user communities [2].

A possible solution to this problem may come from methodological approaches, traditionally used in the field of information systems (IS), to the application of technology in organisations. Researchers and practitioners in this field have, over several decades, developed and refined techniques for modelling the real world and these techniques are routinely used to design a large range of computer-based business systems. The resulting systems invariably have a structure determined by some practical “unit of analysis”, such as a “record” in a relational database [3], an “object” in an OO program [4] or a “rule” in an expert system [5]. In this work a suitable unit of analysis is sought for knowledge management systems (KMS).

Given the close relationship of collective knowledge to work practices, it is proposed that a promising “unit of analysis” on which to base knowledge management systems is that of “activity”, as determined by the Cultural-Historical Activity Theory [6]. According to recent adaptations of the theory [7], activities have identifiable components, exhibit a well-defined structure and are related in specifiable ways. An activity-based knowledge system would have the richness of the Activity Theory philosophy and yet addresses the issues of practical implementation from both the technical and organisational perspectives.

This paper begins with a discussion of the challenges faced by organisations in their efforts at knowledge management, adopting the stance that the role of ICT is to support business knowledge processes rather than store knowledge. An activity-based model of knowledge processes will be described, together with the results of an evaluation of its suitability and effectiveness. This evaluation took the form of planning session of three groups of professionals who would be typical users of this

approach to management of their knowledge processes. The paper will conclude with a brief description of how this model is being implemented in currently available technology. This work is substantiating both the practicability of the implementation and the usefulness of the structure for the extraction of rich information that can support group memory and knowledge processes.

2. Knowledge in organisations.

The widely-used concepts of organisational knowledge [8], knowledge work [9], organisational memory [10] and the learning organisation [11] imply that knowledge processes in organisations are complex, distributed, context dependent and dynamic [12]. Each of these attributes will now be discussed.

The complexity is evident from the tensions between the old and the new, between the desire for change and the need for stability, between ambiguity and clarity in sense-making [13], between improvisation and ordered decision making, between diversity and consensus, between the different natures of tacit and explicit knowledge [14], and between the push for competitiveness in business and the need to cooperate for knowledge sharing. There are constant conflicts between individual, group and organisational goals between intentional information seeking and scanning for general sense-making [15]; between rational computer-based system requirements and the nebulous nature of knowledge in people. Knowledge management could be thought of as the quest for achieving a balance between the extremes on each of these dimensions.

In order to understanding how knowledge is distributed it is useful to draw on the concept of distributing cognition across the human and technological members of a critical team situation [16]. A major shift, associated with the advent of ICT, is a shift from individual notions of expertise and merit to shared information, knowledge and teamwork, i.e. from individualism to collectivism [11]. Organisational knowledge creation occurs when people combine and exchange their personal knowledge with others and there is little doubt that organisations that will excel in years to come, will be those that understand how to gain the commitment of employees at all levels and continually expand their capacity to learn, supported by ICT systems [17].

The question of context arises in the debate between the view of knowledge as object, extracted from its context, and knowledge in its context, embedded in individuals. McLure-Wasko and Faraj [18] identify a third perspective, that of knowledge embedded in the community, perceived as a public good that is socially generated through actions and interactions, maintained and

exchanged within communities of practice [19]. The view of knowledge embedded in community activity implies that organisations are best conceptualised as a collection of overlapping communities of practice. Employees do not receive, or even construct, abstract, objective individual knowledge rather they learn to function in a community. Knowledge, in this view, supersedes any one individual and the knowledge capital of the organisation can be considerably more than the sum of the individual knowledge of employees. This is the sense of the metaphorical concepts of organisational memory, while the creation of new collective knowledge is reflected in the term the learning organisation, where the collective context of knowledge is retained.

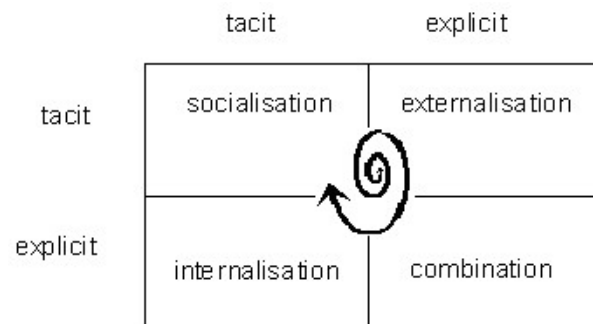


Figure 1. The knowledge creation spiral of Nonaka [12]

The dynamic process of KM is described in the model of Nonaka [12] in which explicit and tacit knowledge in organisations are exchanged and transformed through four modes (Figure 1). Socialisation is the process whereby tacit knowledge is transferred from one individual to another. Combination allows the existing explicit knowledge to be integrated into new explicit forms. Externalisation is the process of converting tacit knowledge into explicit knowledge in the form of concepts and models. Internalisation allows individuals to absorb explicit knowledge and broaden their tacit knowledge so that new knowledge could be developed. This has led to the knowledge creation spiral of Nonaka and Takeuchi [14], shown in Figure 1, which views organisational knowledge creation as a process involving a continual interplay between the explicit and tacit forms of knowledge, through the four transforming modes, and evolving from the individual level, through the group level, to that of the organisation as a whole.

3. Designing knowledge repositories.

It could be argued that the current interest in KM is related to the capability for ICT to store, manipulate and distribute large quantities of information in real time for competitive advantage. Many managers see knowledge management systems as knowledge repositories that collect and store knowledge in much the same way as a database manages data. In proposing an effective design for a KMS it will be assumed here that the role of ICT is to support business knowledge processes rather than store knowledge. Such a KMS needs to accommodate the complex, distributed, context dependent and dynamic aspects of organisational knowledge described in the previous section of the paper. The structure of an effective KMS must be built on a genuine representation of real, distributed work and business processes, which can be implemented in ICT without losing its context. "Activity" as a representation of knowledge work, functions as a unit of analysis and forms the basis of a structure and technique for modelling the real world in order to design effective computer-based KMS. Any such unit of analysis must be capable both of dealing with collective knowledge and of forming the basis of model to be implemented in ICT. These two requirements will now be discussed.

There is no shortage of candidates in the KM literature for a unit of analysis for collective knowledge. These include knowledge objects, knowledge assets, knowledge creating activities [20] and knowledge management episodes, such as making a decision, solving a problem, conducting an experiment and performing a scenario analysis [21]. Fowler [22] approaches this diversity by recognising the existence of different ways of conceptualising and representing knowledge through, for example, anecdote, metaphor or diagram. The same piece of "knowledge" can be used in different ways, depending on the context and transformation process involved in satisfying goals from information inputs.

As mentioned previously, in the field of IS the analysis and design of ICT systems for business are based on models of the real world. The most common of these is the relation database where records in tables represent business data and transactions [3]. Other common data structures, arrays, lists and trees represent structured collections of things. Business applications are designed using entities, processes, dataflows, datastores, and more, as units of analysis. More abstract constructs for organising data and information are tags, keywords, metadata, templates and forms, projects and tasks. Aspects of these have been taken into account and have influenced the current work which seeks a more holistic unit of analysis for a KMS.

One attempt at a holistic approach to application development is the object-oriented (OO) paradigm [4].

An object encapsulates both data and process, kept separate in traditional information systems. When introduced, the OO approach was expected to revolutionise the application development process as it was assumed that objects would be easily identifiable from real world entities and could be accumulated in a library for reused. While not the whole solution for a unit of analysis of a KMS, there is certainly aspects of the OO theory that should be useful.

Another approach to application development, that may have some relevance for knowledge management, are the knowledge-based, or expert, systems [5]. These traditionally use the concept of "rule" as a unit of analysis, although more recently other constructs, such as frames, have been introduced. Time has shown that expert systems are only successful in restricted domains and do not appear to be useful in a wider context. It is not likely that real experts think rationally in terms of rules when making decisions. Another aspect of expert systems that is a concern is that their basic premise is to capture the knowledge of experts and make it available to the layperson. There is often no appreciation of the relevance of context, particularly in the intuitive decision-making of experts.

Another body of IS literature has focussed on the use by experts of patterns when accumulating and applying knowledge. This was originally developed through the field of architecture [23] and more recently adapted to systems development [24]. Patterns develop in experts through repeated experience of solving similar problems and have qualities similar to metaphors, rules of thumb and stories. Pattern languages offer a way to enhance explicit knowledge through capturing context using a standardised set of attributes. To date however patterns have only been used to capture knowledge in design-related work so their general applicability is yet to be tested.

Objects, rules and patterns all have something to offer as units of analysis in ICT systems and a representation of knowledge processes may be similar to these. Typically, knowledge work involves the setting of objectives, keeping records of meetings as minutes, producing reports and procedure manuals, measuring and analysing performance and so on. The resulting documents and records form a considerable part of organisational memory. Traditionally these have been filed either in hard copy or electronically. More recently these are kept on Intranets or Document Management Systems, sometimes with keywords, and able to be searched online. What is proposed in this paper is there be a structure whereby the content of this knowledge repository is stored with a more structured unit of analysis so that the retrieval and scanning of the information is more meaningful and indeed supports the knowledge transfer and knowledge creation processes among members of the organisation.

Work or “activity” is a common element in any business and it is the focus of attention of the workers. The Cultural-Historical Activity Theory provides a holistic, rich yet structured view of human work and so the remainder of this paper will explore the suitability of activity as the unit of analysis for an effective KMS.

4. The Cultural-Historical Activity Theory.

4.1. Addressing the issues of Complexity in Context, the Distribution of Knowledge and the Dynamics of Learning.

There are several researchers who are using frameworks based on the Cultural-Historical Activity Theory, often referred to as Activity Theory, for work related to KM. They believe that it provides a unifying approach to the study of what people actually do. It provides a meaningful unit of analysis, incorporating culture and history, and which is both situated and contextual. Engeström’s [7] research, using activity systems as cycles of expansive learning in work practices, is the best-known, but not the only, application of the theory. Blackler [25] investigated knowledge by considering organisations as socially distributed, collective activity systems, which include the significance of history and a prevalence of incoherence and dilemma. Hasan [26] has identified the pivotal role of the sense-making activity in executive decision-making. Choo [8] appreciated the mediated, situated and pragmatic aspects of the CHAT approach to organisational knowing.

Kuutti and Virkkunen’s research [10] on learning network organisations focuses on the relationship between organisational memory, teamwork and organisational learning. They investigated candidates for the unit of analysis, which included a rational, management-driven approach, a learning-by-doing approach, and one of encoding practice into routines, but they concluded that an approach based on Activity Theory was most appropriate. They use activity systems as a representation of a common object of work saying that organisational learning cannot be studied by reducing the scope to one or another element, but a minimum meaningful system as a whole should be taken as the unit of analysis and intervention. According to Kuutti [27] Activity Theory is a philosophy and cross-disciplinary framework for studying different forms of human practices and offers a set of concepts, structures and terms that are eminently suited to research undertaken within the communities of practice.

Activity, according to Leontiev [6], is a system that has structure, its own internal transitions and transformations, and its own development. It implies a

two-way concept of mediation where the capability and availability of tools mediates what is able to be done and tools, in turn, evolve to hold the historical knowledge of how the communities behaves and is organized. It is through this dynamic process that learning occurs, both in the individual and distributed throughout the society as a whole. Engeström introduced the concept of cycles of expansive learning, shown Figure 4, is not unlike the knowledge creation spiral of Nonaka shown in Figure 1. The psychological theory of Vygotsky [28] on which Activity Theory is based, also has parallels with the Nonaka approach with well-developed notions of internalisation and externalisation, recognising that all human knowledge is socially constructed. The concept of internalisation is described by Vygotsky as the underlying mechanism for the origin of mental processes. Mental processes are derived from external actions through the course of internalisation.

4.2. Activities and the structure of activity systems.

Activity Theory is based on the notion that human activity is a dialectic relationship between subject (person) and object (purpose). This relationship is mediated by “Instruments”, or “Tools”, (artifacts, language, ideas, models) and the “Community” (context, environment, culture), which defines the rules and roles within which the subjects act. Individual or group interpretations of the meaning and potential of these mediators stimulate the need for strategic decision making about the form of activity. The perceived “object” of an activity can be physical or ideal, and may be distinct from its observable outcomes [29]. Engeström’s triangular representation of Vygotsky’s concept of activity (Figure 2) is used as a means of identifying the structure of each activity.

This representation shows the central subject-object relationship of the activity leading to outcomes and being mediated by tools (instruments) and the community. The community imposes rules on the subject and establishes the division of labour needed to conduct the activity, which is defined by its object. The structure of an activity depicted in Figure 2 affords a representation for dealing with the complexity of what people do in a holistic and meaningful way. The incorporation of the community in a mediating role brings context into the representation.

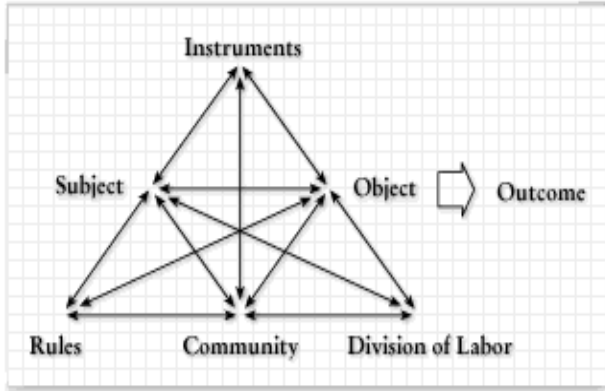
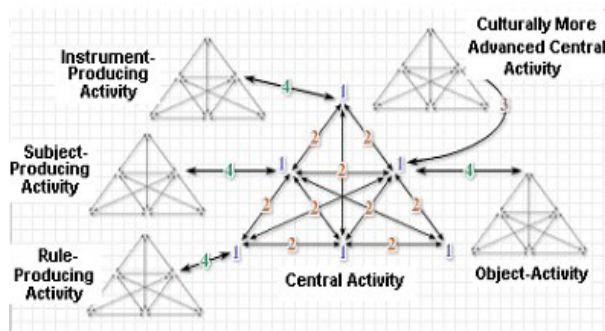


Figure 2. The components of an activity [7]

The depiction of “activity” in Figure 2 has been popularised by Western research in Activity Theory since introduced by Engeström in the 1980s to study work in organisations. It has a form comparable to an “object” in OO or a “rule” in an expert system and can therefore be considered as a “unit of analysis” for an ICT system. As with sets of objects in OO systems, an entire activity system is composed of an interrelated set of activities as shown in Figure 3 where Engeström’s [30] taxonomy of relationships between activities is illustrated.



- 1: Primary inner contradiction (double nature) within each constituent component of the central activity.
- 2: Secondary contradictions between the constituents of the central activity.
- 3: Tertiary contradiction between the object/motive of the dominant form of the central activity and the object/motive of a culturally more advanced form of the central activity.
- 4: Quaternary contradictions between the central activity and its neighbour activities.

Figure 3. Four levels of contradictions in a network of human activity systems Engeström [30]

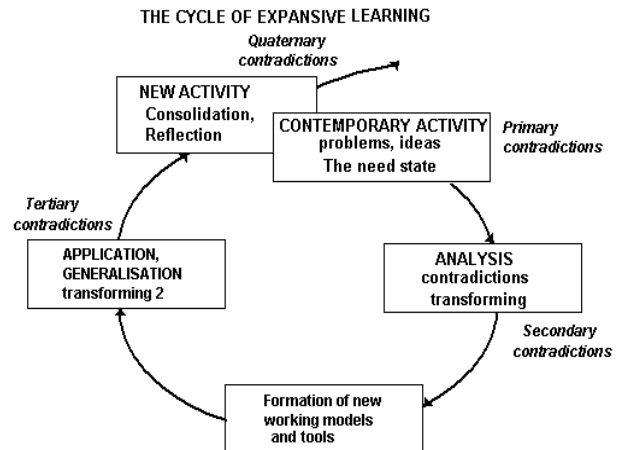


Figure 4. Engeström’s dynamic view of collective learning in activity systems

Another well-known structure giving another dimension to activity is the hierarchy of Leontiev [6]. Leontiev, a student of Vygotsky, was the first to propose that “activity” should be the unit of analysis in the study of sustained human endeavour and placed this at the top of the hierarchy shown in Figure 5, associated with purpose and motive. This is a conceptual level above the level of goal-oriented actions at which most business analysis takes place. Activities are carried out by a collection 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 in computer systems, as they become standardised.

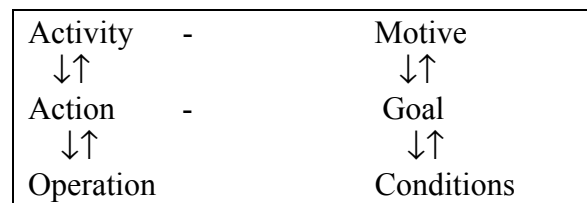


Figure 5 The hierarchical structure of activity [6]

For an in depth explanation of this dynamic hierarchy the reader is referred to Leontiev’s original treatise (*ibid*) but the following illustration is relevant to this paper. The activity of publishing the results of research, in a paper such as this, is purposeful and motivated, both by the desire to make public the findings of the research and also by personal career requirements for publications. An

action, such as the editing of the paper, has the specific goal of producing a readable manuscript, as required by the publisher, but is not an activity in itself. The author would not spend time editing manuscripts if it were not part of a purposeful activity! With the advent of word-processing tools, the typing of the script has become an operation, whereas, under conditions where the only tools were pen and pencil, the writing would have been done differently.

5. An activity-based model for a knowledge management system.

Having established the need for a unit of analysis, and having identified activity as a worthy candidate, the research has proceeded as follows:

- A practical activity model has been developed and constructed from the structures of Figures 2, 3 and 5
- The meaningfulness of this representation of work has been tested with three typical workgroups
- An evolutionary prototyping process, with regular usability testing, has been used to produce an implementation of the model in ICT.
- A process of continued development and evaluation of the system in use will focus on two critical issues:
 - the motivation of people to continue to enter content throughout the life of the system and
 - the meaningfulness of information and knowledge that can be extracted from the contents of the system

5.1. Constructing the activity-based model.

Table 1. Elements of the activity-model for KMS

Activities: who is doing what, for what purpose
Components of each activity as listed in Table 2
Relationships between those activities.
Actions and Operations by which Activities are carried out
An historical record of the above elements

The activity-based model combines the activity systems of Engeström (see Figures 2 and 3 and Table 2) and the activity hierarchy of Leontiev (see Figure 5). These have been integrated into an explicit set of definitions and diagrams that have been shown, in

previous research [26] to be meaningful to strategic managers and groups. The elements of the activity-model are summarised in Table 1.

5.2. Identifying activities and their components.

Table 2 Components of activities according to Engeström

Component:	Definition and Clarification
object	the purpose and motives that define the activity.
subjects:	the person or people who carry out the activity
outcomes:	both intended and unintended results of carrying out the activity
tools/instruments:	both physical and non-physical instruments that are used in the conduct of the activity
community:	the community in which the subjects carry out that activity
rules	the formal and informal rules that the community imposes on the subject
division of labour	relationships in the community that determine the roles that subject have in carrying out the activity

The components of a single activity (Figure 2) are summarized in Table 2. Most groups have a few core activities such as those that are identified in the group's mission statement. The activity-based approach begins by identifying these activities by their purpose.. The subjects (people) engaged in that activity are then identified, the intended outcomes are established as well as the tools (resources) required by the activity. In addition there are other activities conducted by the group that must be identified. These activities usually support the central activities, such as group management, or result from the central activities, such as publishing reports of outcomes.

5.3. The Relationships Between Activities.

Relationships between activity systems have been the topic of much of Engeström's research and Figure 3, taken from his work, is a useful guide as it shows some typical relations between one activity and its neighbours. In this diagram there is a central activity and five others, although there could be more. Three of these, those on the left, are quite straightforward. The instrument-

producing activity creates the tools to be used by the central activity. For example a curriculum development committee may produce a curriculum that is used by the central activity of a teaching unit. The subject-producing activity could be one to train people for specific skills used in the central activity. Similarly the rule-producing activity could produce rules or guidelines that govern how members of the group should act when conducting the central activity, for example they might determine how people handle disputes in their community. The relationship that has guided most of Engeström's research into learning by expanding is shown at the top right of Figure 3, where a new activity is a more advanced form of an older activity.

5.4. Identifying Actions and Operations.

In assisting groups to identify their actions, it should be made clear that activities are usually associated with long-term functions of the group and always have a significant purpose or "object" while actions are more short term and specific "goal" orientated. Leontiev's hierarchy, shown in Figure 5, plays a useful role in distinguishing between "activities", driven by motives, and the other levels of the CHAT hierarchy. Activities, at the top of the hierarchy, are carried out by means of "actions", undertaken to achieve specific "goals" while "operations", at the bottom of the hierarchy, are the steps used to perform "actions" under specific "conditions". Operations are the easiest to automate and can often be built into an ICT system.

6. Testing the meaningfulness of the activity-based model.

In order to determine whether the activity model made sense in real situations, two hour planning sessions were conducted with each of three workgroups: a research group of five people, a university department of 20 and a cross-organisational project team of 8. The researcher acted as a facilitator at each of the session, firstly, to introduce the concept of "activity" and then, encourage participants to identify the main activities of their group, the components of each activity, the relationship between the activities and some actions, with their goals, within the activities.

At the end of each session the participants agreed that they had produced a set of related activities that was a workable representation of what their group did. It was clear that some guidance was required by the facilitator to distinguish activities from actions but participants felt that, at the end of the session, they had made sensible choices. One insight that emerged from the sessions was that most activities were either part of the work, for which

the group existed or activities that helped support or manage the group. Another insightful observation was that there were generic activities and then instances of these. For example the university department's main activity was the delivery of courses. At any one time, there were particular course offerings that were instances of this generic teaching activity.

The three sessions helped determine more meaningful terminology to use for the implementation of the model. These are shown in Table 3.

Table 3. Meaningful terms.

Activity Theory Concept	Term to use
Subjects	People
Tools	Resources
Object	Purpose and Motive
Actions	Tasks
Outcomes	Planned, Intended Outcomes Unintended Outcomes
Goals	Set time to complete

The sessions also brought to light a set of common relationships that could exist between activities. These are shown in Table 4.

The participants in the session indicated that they could see that a system that held information about their work activities in this way could have a number of uses including:

- a useful tool for the induction of new members into the group,
- a way of recording progress on less structured work to help write required reports,
- providing information for performance evaluation of members for career appraisals and,
- keeping track of resource usage.

Table 4. Relationships between Activities.

One activity is the output of another
A central activity transforms into an advanced form
One activity is a component or part of another activity
An Activity trains subjects of another activity
One activity creates or maintains the tool for another activity
One activity provides support for another activity
One activity spawns another

6. Learn by implementing in an evolutionary prototyping.

The model has been implemented in Microsoft Access using an evolutionary prototyping methodology and populated with records of the activities of the author's research group over a period of one year. The prototype has gone through a number of iterations with an evaluation by the group at each stage and their recommendations incorporated into the prototype's design.

The database consists of lookup tables for people, resources and types of relationships, tables to store records of new activities, actions and relationships between the various entities as in any standard relational database. Every table contains fields to record the date-time that each record is entered and a field to record who enter that record.

No content is ever lost, i.e. deleted or changed, from the systems unless it is found to be wrong or untrue. In order to retain information in an historical context a series of extra tables are included in the database to record any changes or extra information about any of the standard entities in the system. For every standard entity table there is a second table to contain record of changes or update information about the entities. For example if a group member is promoted, the new job designation is not written over that person's entry in the *people* table but rather a new entry is made in the *people-update* table. This table contains a *people-id* field, which is a foreign key linked to the key of the original *people* table and has, as its key, a composite of the *people-id* field and the *date-time* field. This means that if you are looking for information on the state of an activity in the past you will see people as they were then not as they are now.

The evolutionary process of developing the prototype has greatly contributed to our understanding of the issues inherent in this research. In fact, considering the research described in this paper as an activity, this evolving prototype is a tool, which mediates the research activity and is itself mediated by the activity. In particular, the development processes has informed the decision as to what Activity Theory concepts to include in the model and how to integrate those into a workable structure.

7. The activity-based KMS in use.

This research has shown that there are three phases that must be perfected in order to make this system effective as a KMS:

1. The group who use the system should understand the planning and setup process of identifying the activities that are important to the group, and be able to enter them into a new instance of the

systems, together with the components, relationships and actions associated with these activities. The results of the three sessions described above indicate that this can be done.

2. The interface of the system should be so intuitive that entering records into the system becomes an integral part of work and continues to be done over the lifetime of the group. This is the objective of the next phase of the prototyping process where a graphical direct manipulation interface will added to the system. The interface will be tested for usability through each cycle of the evolutionary development process. It is hoped that the system may replace some current activities such as the taking of minutes in meetings.
3. Users should be able to extract information from the system that is a source of knowledge for the group and assists them in managing group knowledge in a creative and innovative way. The activity-based structure should enable this. Multi-dimensional concepts from on-line analytic processing [31] will influenced this phase of the research. It is planned to produce an engine that will allow users to "slice and dice" and "drill up and down" though the structure along various dimensions as needed. For example:
 - a. to induct a new member of the group it will be possible to track the historical records of any activity,
 - b. managers can extract a set of record pertaining to the use of a particular resource,
 - c. to conduct personal performance appraisals it will be possible to extract a set of record pertaining to the work of one person,
 - d. the state of all activities at any particular time in the past can be retrieved
 - e. material for annual reports can be extracted into a work document and reorganised as appropriate

Progress to date indicates that it is feasible to construct an ICT KMS, based on the activity model, that will effectively meet these demands.

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