Managing Collaborative Expertise: Issues and Challenges

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Abstract

In this paper we examine the challenges of managing the work of a multi-disciplinary team of experts struggling to develop a computerised mammography system. We argue that work systems intended to develop such innovatory products represent a new form of working both in terms of complexity and in terms of the pace with which they are expected to work. Drawing on the insigts provided by an experienced project manager working with the team, we employ Activity Theory (AT) to identify some key issues – the link between motivation and object formation, supporting boundary crossing and working with contradictions – which seem crucial to fostering the development of such a collaborative work system. However, the necessary project management tools to support such processes are currently lacking.

Keywords: Collaborative Expertise , Activity Theory, Motivation, Boundary Crossing, Boundary Objects, Innovation

Suggested track: The nature of knowledge work and knowledge workers

1. Introduction

In a previous paper (Kinti and Hayward, 2004) we described the development of a multidisciplinary expert team working at the cutting edge of technology who were striving to develop a prototype for digital mammography in the UK. The argument we set out in that paper was that such project teams designed to develop and share expertise in order to solve poorly defined problems were likely to be characterised by high levels

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of uncertainty, tension, conflict and contradiction[2]. Rather than being seen as problems to be managed away, we subsequently argued that such characteristics were actually central to the development of this type of work activity system through a process of expansive learning (Hayward and Kinti, 2004). However, the evidence we have collected to date indicates that episodes of expansive learning were quite rare and of short duration in the work group we followed. As a consequence the full potential of the system was not achieved, a phenomenon akin to *process loss* (Steiner 1972) and *coordination decrement* – " the invariant of difficulty arising when all members attempt to work together at their full potential" (Fiore et al., 2003, p. 341).

In this paper, written jointly with members of the project team, we aim to take forward this discussion to explore the challenges of constructing work systems where the goal of the activity is either not given or is very poorly defined. It is our contention that such work situations are common during processes of innovation, and stand in contrast to other types of work situation where the goal of the activity is usually more clearly defined and typically given, and where employees work within, and are socialised into, pre-existing practices with their associated rules, tools and divisions of labour. In our case, individuals from different organisations have to establish and develop their own work system. The question we wish to explore, in particular, in this paper is the nature of such innovatory work and what constitutes management practice in teams designed to share and develop collaborative expertise. To achieve this we again focus on the eD project, part of the larger e-Science innovation in the UK.

2. Collaborative Expertise within an e-Science Pilot Project

The Department of Trade and Industry (DTI) defines e-Science as:

" Science increasingly performed through distributed global collaborations enabled by the Internet using very large data collections, terascale computing resources and high performance visualisations." [3]

[2] We use the term contradiction as in Engestrom (2004, 150) to mean sources of change and development. Contradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems.

[3] http://e-sceince.ox.ac.uk, accessed February 2005.

To achieve these ends involves the use of a new type of computer technology, Grid Computing developed and applied within the context of a range of e-Science pilot projects. These pilot projects are attempting to build the platform that will enable the desired large scale scientific collaboration using the Internet. It is through this emergent e-Science Grid that collaboration amongst scientists and other actors from across universities, research and development labs of manufacturing corporations, hospitals, research institutes, government agencies etc will result in a combination of their expertise to help tackle the big scientific questions hitherto unexplorable (David, 2004).

The potential implications of the restructuring of work practices inherent in the e-Science initiative is explored in this paper using the lens of Activity Theory and a case study of one pilot e-Science project: eD. This was a two year collaborative research project aiming to prove the benefits of grid computing in the domain of healthcare, in particular for Breast Imaging in the UK. The need for this project derived from the professional recognition that the stresses upon the national Breast Screening Programme and for Breast Imaging in general were increasing, putting an already stretched service under more pressure. Specifically, the project was set up to design a large distributed database of mammograms which, using the infrastructure of the Grid, could be accessed from many different hospitals and research centres nationwide. By enabling clinicians to retrieve and examine mammograms on their computer screen through the Grid instead of using the film, as in current practice, the eD prototype was intended as the first step towards developing a potential tool to assists radiologists in the UK in earlier and better diagnosis of breast cancer.

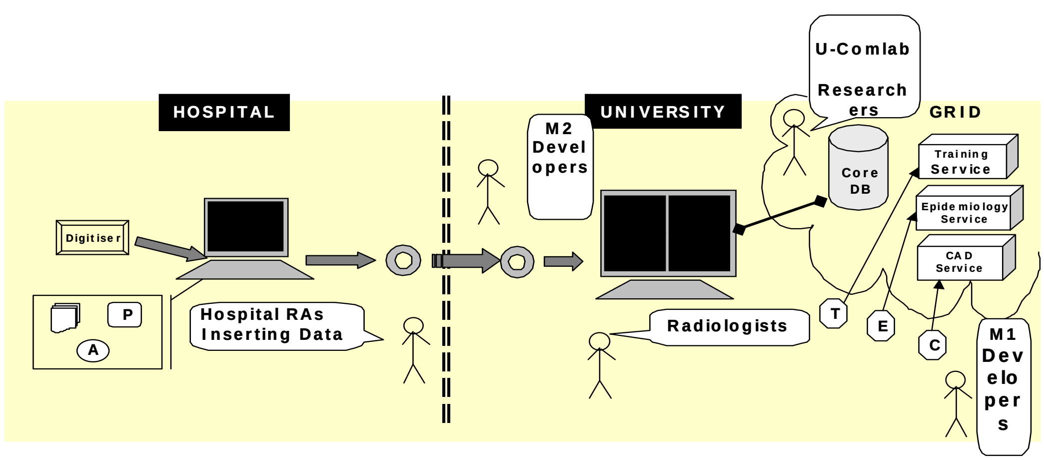
The eD project group comprised partners from: a) five university computer labs; b) two manufacturing firms, M1 and M2 and c) four hospitals. Almost forty scientists specialising in software engineering, technology management, computer systems development and integration, digital imaging, radiology, epidimiology, and ethnographic analysis of medical work, came to work for eD in the course of two years. During that time, these actors liaised in the context of multiple face-to-face and video-mediated work meetings in order to deliver the new system. Other experts[4] involved, however, did not come to project meetings. They were actually working for the project in a more

[4] The term "experts" is not used to denote superior and stable individual performance (Ericsson and Smith, 1991:3). Rather it is used to refer to individuals who "tackle problems that increase their expertise" (Bereiter and Scardamalia, 1993:78, cited by Engeström, 2004: 147) as they face and resolve novel situations for which they have "little or no directly applicable practice" (Engeström, 2004: 146). The issue here is to examine how different experts come together to co-configure knowledge, to shape their knowledge together in order to build a new technology.

virtual way. At different levels of participation across different time spans, project members organised the activity of prototype design and development around collaborative work teams.

At the centre of that newly created project organisation, a core R&D group was set up. The Project Solution Team, formed by university researchers and systems developers from the two manufacturers, was responsible for delivering the digital mammography prototype. Then, there was a slightly more dispersed group of clinical researchers around the Solution Team whose task was to assist in the technical development of a clinically useful prototype. Around that group, there was a group of hospital radiologists, involved to play the role of end-users by checking and testing in practice, with clinical researchers, some of the developing prototype's functions. These were the most peripheral of the actors involved in the design and development of the digital mammography prototype. Thus, the expertise needed to develop eD was, in principle, distributed across the whole of this network. In addition, there was also a Management Board to oversee the project, including university principle investigators, other lead academics and top management executives from the two manufacturers.

Figure 1: The nature of multi-disciplinary work in the group



While bringing all those experts to work together, each one of the parties involved was charged with delivering a different component of the final prototype (Figure 1): the central university computing laboratory was responsible for designing the distributed database of the new system; M1, a large international hardware manufacturer, was responsible for designing the architecture and developing the grid infrastructure of the distributed database. The grid services, screening, training and epidemiology, were developed with the assistance of clinical researchers. In particular M2 developers had to work closely with the clinical team in order to develop the software for the radiologists' workstation. Applying grid technology for diagnostic use in healthcare is still generally regarded as innovative. In this case, it implied the Solution Team's capability to draw upon and to coordinate different streams of expertise from delivering ethnographic analyses of clinicians' workflows, converting those to requirements specifications, architecting, designing and developing the system, programming to fix applications, interfaces etc, and testing system's performance with prospective users, a sample of hospital radiologists and radiographers in UK. Thus, the work of such a team can be considered an example of collaborative expertise as proposed by Engeström (2004, 1):

> *"There is a new generation of expertise around, not based on supreme and supposedly stable individual knowledge and ability but on the capacity of working communities to cross boundaries, negotiate and improvise "knots"[5] of collaboration in meeting constantly changing challenges and reshaping their own activities".*

The e-Science initiative in general, and the eD project in particular, could be conceptualised as involving just technological innovation. However, it can also be seen as an organisational, social and psychological challenge in that developing the grid infrastructure is likely to involve new forms of collaborative working hitherto not experienced by computer scientists. However, whilst Government policy, for example, extols the innovatory potential of such new ways of working, there is little insight into the challenges of how such teams might be constructed and how the development of collaborative expertise might be fostered. In the case of eD, these challenges were amplified by the inter-disciplinary nature of the team; its inter-institutional constitution which led to debates, for example, about cutting edge research versus commercialisation; its mixed mode of working (distributed and face-to-face); and the inherent problems of its object of activity: human health care systems[6].

[5] The notion of knot refers to rapidly pulsating, distributed and partially improvised orchestration of collaborative performance between otherwise loosely connected actors (Engeström, 2004: 153).
[6] For example, in the case of this project there were ongoing ethical debates about distributing the mammograms across the grid, debates over the ownership of clinical data.

3. The Challenges of Managing this Multi-disciplinary Expert Group

This section provides a personal insight into the challenges of developing and managing this particular type of work system from the perspectives of the project manager[7]. In the next section, we[8] will respond to these challenges and issues raised using an Activity Theory (AT) perspective in an attempt to theorise the problems identified, from which potential solutions might arise.

Projects such as eD are characterised as follows: they often have multiple stakeholders with different visions and different drivers; they have a complex mix of research and non-research staff who are used to working in different ways and with different project approaches; the partners have very different project drivers; there are disparate teams so it is likely that the project team rarely meet as a group; there is a disparate user community, all with different requirements and views.

The eD project team comprised resources from two commercial organisations, four clinical sites, and five academic institutions. The project commenced in October 2002, but it took until June 2003 for all staff to be recruited. The team members from several of the collaborating organisations were already recruited so were better positioned to commence activity, if somewhat directionless, over the early months. The project manager commenced employment in February 2003 resulting in five months of activity without any clear processes in place. University resources commenced prior to that date in order to capture user requirements to ensure that development was not held up further.

The characteristics above make the management of such project resources challenging. Often the nature of the research grants means that the funds are released from a project start date and resources need to be recruited and become effective within a short space of time. Within eD, the recruitment process was lengthy and due to the variety of organisational drivers, the process of getting the team fully up to speed on the project and able to understand the goals and expectations of the various collaborators took over eight months. In a project with a duration of only two years, this is of course problematic, and it is clear that the reuse of effective teams who have learnt to work

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together and trust each other would be beneficial to the outcome of many of these research projects.

The management of the prototype development utilised standard project management methodologies in terms of, for example, defining ultimate goal, staging requirements and tracking activity using Gantt charts. The prototype that we were developing had been scoped through extensive requirements capture with a complex user community and subsequent scope limiting to fit the deliverables into the short project timescales. It should be noted that the user community only represented a small fraction of the potential use base in the UK and each of the clinicians the project team worked with had different expectations. There was a need for a product management approach in determining the base level requirement for such a prototype that would be refined over time. A challenge in delivering this prototype was in the individual partner drivers. Clearly, a commercial partner would want to push for their technology to be adopted as part of the solution as any potential exploitation would result in higher sales for their organisation. eD had a technical architecture team straggling several entities and had a technical architect working for the main commercial organisation. This resulted in difficulty in making technical decisions on the eD architecture, as the committee argued extensively over decisions. A better solution would have had the decision making process independent of any commercial vendor.

A further complexity resulted in the nature of research funding which required the universities to employ research assistants on these projects. These research assistants are expected to publish papers but are often tasked with fast track development to ensure delivery of these prototypes. The University research staff not only had to manage the design of data management systems but also the systems administration of a complex and novel grid architecture.

This aspect of the eD project could be aligned to the management of normal projects but proved to be difficult in that: there was no real customer, but several competing users, it had research staff performing development, and experienced conflicts with cross-organisational decision making. While the project team followed the process of gathering requirements, designing an architecture and planning multiple phases of deliverables, this process was more like product management than project management due to the need to align the development with known constraints and potential markets.

The role of the project manager in this type of work system, therefore, is a diverse and challenging one. The key responsibility of this role is to ensure the delivery of a planned result, whether it is an office move or a complex computer system. This activity involves not only definition and planning, but also the prediction of project risk and the planning, organisation and control of activity to complete the project as successfully as possible despite the risks. Whilst the role of project manager evolves often from previous involvement and experience of the activity to be managed, an effective project manager develops additional skills that are critical to the ability for that resource to manage a project effectively. These skills include the ability to follow and adapt processes and the complex skill of managing resources. For example, Reiss describes project management as a combination of management and planning. This implies that project management builds on the principles of management, including leadership, and thus knowledge and ability to carry out a process is insufficient.

The management of collaborative teams, as typified by the multi-disciplinary research projects funded through the UK e-Science Programme, is a complex activity that requires, in particular, skills to understand how to motivate collaborators from different organisations. These organisations are typically drawn from both the commercial and academic sectors, with all possessing different (and sometimes conflicting) organisational (and individual) goals and motivations. These motivations determine how experts collaborate, and without this understanding, it is a difficult task to ensure that a multi-disciplinary team works towards common project goals.

One of the failings of such collaborations is an inability to understand why particular organisations have chosen to engage in the same project: partners have not identified how they anticipate benefiting from the project or what they expect to contribute (and on what terms); rather the focus is on who will deliver what and by when.

Further challenges arise from the reporting lines of staff, in that the management of these resources is often through company representatives. This can lead both to delays and conflicting messages. Additionally, individuals utilised by organisations may change over the course of a project, which can mean that it is difficult to establish sufficient rapport between teams that span organisations. When coupled with the difficulties of a lack of focus on commercial exploitability in the research field and the frustration this breeds within the commercial organisations – where often it is considered a fruitless activity to try something in the interests of producing a publication – this area of management of collaborative expertise is a challenging one.

Key to the effectiveness of these teams is a clear understanding or the roles and responsibilities and the reporting lines as well as a common understanding of the project aims and vision. Poor organisation and no clear goals breeds de-motivation and often results in a team that is frustrating to work for. The building of an effective team is crucial where there are expectations for cross-organisational delivery. The Project Solution team required development from both the University and the main commercial partner. The process of understanding what impacts the way resources work and what enables career enhancement in their organisations is critical to ensuring that resources are able to contribute and benefit from their involvement. These drivers may be the need to publish papers in their research field, or to promote technologies or to develop patents. Rarely are collaborators in a position of seeing all their partners' cards before a project commences and rarely are these details captured in any collaboration agreement. It is clear from experience that this activity needs to be addressed in the early stages of a project. By understanding these drivers, the team begins to both trust their colleagues more by understanding their actions, but also develop a more open and effective working relationship resulting in a more harmonious working environment. A staff questionnaire at the project kick-off workshop can be used to determine whether resources understand the project objectives, what the partners and collaborators consider as their contribution to the project, and what the partners and collaborators expect to get from the project. Key to this activity is honesty and explaining to the staff involved why this information is important in terms of the management of the project and resources is crucial.

4. The Challenge of System Coordination: can Activity Theory help?

The description provided by the project manager highlights the huge problems of coordinating, sharing and developing expertise in this particular work team. The problem in this work system is how to coordinate expertise across these various institutional actors, how to motivate them towards sharing and achieving common goals, whilst remaining sensitive to their personal drivers and the commercial/research needs of the organisations employing them. The project manager provides us with a helpful set of categories of problems - motivation, time pressures, conflicts and contradictions - which are, however, essentially descriptive. The issue addressed in this section is how we might move from such a description to a more theoretical conceptualisation of these problems in order to understand how such teams might be enabled to better coordinate their activities.

First, we need a theoretical perspective that deals with development and change in practice. This would enable us to identify the specific circumstances that trigger evolution of work activity in this complex system. Specifically, what we need is a theoretical tool that enables us to understand how work development is *mediated* in this particular context. Second, in order to understand the complex nature of the interactions generated in this work group across time, we need a theoretical perspective that can operate across different levels of analysis: individual, group and institutional. For these reasons, we considered Activity Theory (AT) as a useful lens in order to theorise the descriptive account provided by the project manager. Especially, because AT relishes contradictions in work practice as a means for development - which were often identified in the account given by the project manager. For instance, a tension emerged in the Project Solution Team as soon as it was revealed that the individual drivers of university researchers, who were oriented towards academic publications almost conflicted with those of M1 developers who were oriented towards patents. However, this tension generated at the individual level, triggered the emergence of a *contradiction* at the institutional level of activity as it became evident that the partners involved employed different *rules* (in AT terms) at their respective organisations in order to measure staff performance. This is an example that helps to establish AT as a potential candidate for theorisation in this context as opposed to other paradigms such as that of Communities of Practice (Lave and Wenger, 1991) which focuses specifically on socialisation in pre-existing practices. On the contrary, the actors involved in the development of the eD prototype, as demonstrated by the project manager, had to lay down a new community of practice, new rules, tools, and division of labour. Essentially, what they were requested to do was to develop a new activity system " from scratch", with different experts crossing from their organisational homes to a new project environment where, to a certain extent, they were expected to disengage from their previous work practices and develop new methods of working together. It is for these reasons that we adopted AT as a starting point for understanding the nature of work in this particular context. This could help to predict what might be useful in the future.

A brief analysis of Activity Theory

Broadly defined AT is a philosophical and cross-disciplinary framework for studying different forms of human practices as development processes, with both individual and social levels interlinked at the same time (Kuuti, 1996). In that respect, according to Bedny (2000) one of the most important principles of AT is the unity of consciousness and social behaviour identified by Rubinstein (1946). It was, however, Vygotski who laid the foundations for studying cognition as a socially mediated process. Leont' ev took Vygotski' s Cultural Historical Theory of the Development of the Mind further to introduce the central concept of " activity " as a system of historically coordinated actions within a social group oriented towards a goal. In its current form, as developed by Engestrom[9], AT can help us to conceptualise work system development with the help of five principles. Of these, three are crucial to our current analysis.

The first principle is that a collective, **artefact-mediated** and **object-oriented** activity system, seen in its network relations to other activity systems, is taken as the primary unit of analysis. Objects in AT terms should not be confused with goals. Goals are primarily conscious, relatively short lived and finite aims of individual actions. The object in AT terms is a heterogeneous and internally contradictory, yet enduring, constantly reproduced purpose of collective activity that motivates and defines the horizon of possible actions (Leont' ev , 1978, Engestrom, 1995). According to the Finnish tradition of developmental work research, the objects of expert work need to be traced as they move in space and time across various situations and boundaries. In the case of eD, we have experts from a wide variety of backgrounds moving across multiple boundaries as they struggle to construct a common object of activity.

The second principle is the **multivoicedness** of the activity system. An activity system is seen as a community of multiple points of view, traditions and interests. The division of labour in an activity creates different positions for the participants as they carry their diverse histories. The multivoicedness is multiplied in networks of interactivity systems. It is a source of trouble and innovation, demanding actions of translation and negotiation (Engeström, 2004). The commentary of the project manager and our own observations of the activity system combined with interview data from the key actors are redolent with

[9] We take seriously the point made by Bredny (2004) that there are several versions of AT. However, here we draw mainly on the version developed by Yrjo Engestrom in association with colleagues at the University of Finland and Mike Cole at the University of San Diego.

the idea of multivoicedness. For instance, the project manager stresses out the difficulty emerging for that work group to move forward because of the involvement of many actors with different interests in the decision making process.

Such multivoicedness, in turn, is linked to **contradictions** as the essential driving impetus of change and development in activity systems. Note that by contradiction we do not mean conflict or problems but fundamental, accumulating historical tensions. For example, the tension between undertaking academic work, on the one hand, and commercialisation of that work, on the other hand, which lies at the heart of Government policy on innovation through industry university collaboration. Contradictions are ‘ the principles of [an activity system’ s] self-movement and {…} the form in which the development is cast (Il’ enkov 1977: 330 quoted in Engeström, p. 150).

> “ As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from its established norms. In some cases, this escalates into collaborative envisioning and a deliberative collective change effort. An expansive transformation is accomplished when the object and motive of the activity are reconceptualised to embrace a radically wider horizon of possibilities than in the previous mode of activity (Engeström, p.150)” .

Such questioning and deviation is in turn linked to the development of a process of **expansive learning** which, from the commentary of the project manager was singularly lacking but deemed essential to foster the development of the activity system we were studying.

A representational means

Activity Theory provides a means for constructing heuristic visualisations of the ongoing activity of work teams. Figure 2 recasts the work of this particular team in Activity Theory terms. Three things are immediately noticeable. First, the members of the central solution team are drawn from a wide variety of other activity systems. Within those activity systems they are embedded in developing sets of values and schedules of incentives that collectively form the cultural drivers of the systems.

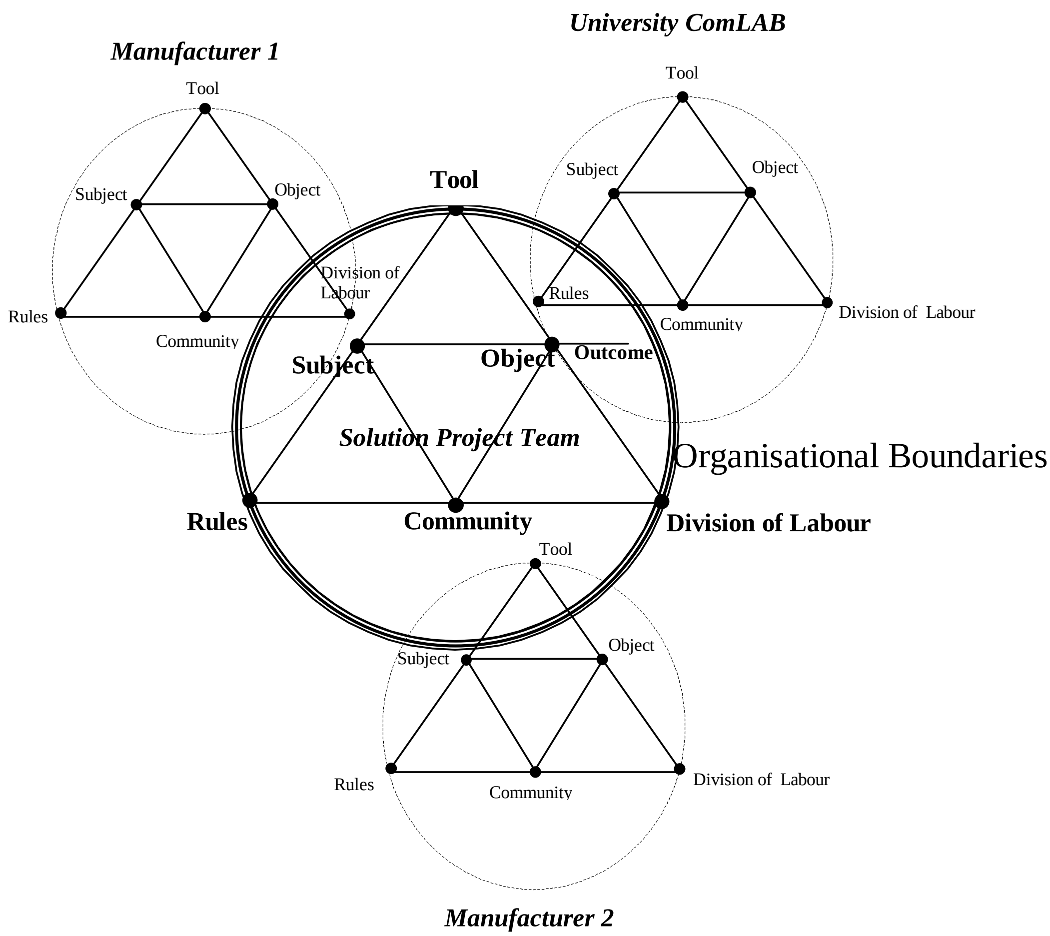

Figure 2: An Activity Theory representation of the Solution Team

Thus, participants do not come to the new activity system as tabula rasa: they bring with them both their expertise and their particular representations of the purposes of their work construed as set – " a pre-disposition toward a particular activity, composed of tendencies to perceive, interpret, formulate a goal and act in terms of predisposition (Bredny et al., 2000, p. 169) This leads us to view experts as:

" …operating in, and move between, multiple parallel activity contexts. These multiple contexts demand and afford different, complementary but also conflicting cognitive tools, rules and patterns of social interaction" (Grohn, Engestrom and Young, 2003).

Second, to reach the new system involves a process termed boundary crossing. " Boundaries are social objects fashioned out of spatial locations, personal identifications, patterns of interaction, and legally defined distributions of rights and obligations." (Barley and Kunda, 2001, p. 78). Thus, a series of steps need to be taken to facilitate boundary crossing if expertise is to be shared effectively. We return to this point later in the analysis.

Third, the diagram identifies a range of starting categories that we can use to conceptualise the social mediators that underpin work practice development within an activity system. Of these, tools both physical and symbolic are highlighted here as of crucial importance for supporting boundary crossing.

Motivation, needs and objects

A continual theme in the project manager's narrative is the need for motivation. The original rationale for establishing this work system was to meet a need – albeit a poorly defined one: to develop a prototype for sharing digital mammograms across the Grid. However, AT reminds us that whilst the impulse for beginning an activity may be a response to a need, the simple of emergence of that need does not necessarily lead to activity.

> Activity begins only when the image of an object or event capable of satisfying needs appears. The object can thereby become the goals for an activity. Needs that induce human activity and are redirected towards certain goals are called motives. (Bedny et al., 2000, p. 177)

Reinterpreting the project manager's concerns about motivation in this light, alerts us to the need to consider motivation not as an internal state but as a socio-historically constructed process linked to the object of activity for this system. The Solution Team work system appeared to have a common object at the beginning of the activity, as all partners came together to develop a prototype for digital mammography. However, in the course it is revealed that partners and actors shared different needs and therefore what emerged along the way was a fragmented object with some of the partners drawn towards fast commercialisation, others towards long term customisation and others towards cutting edge research. In the absence of a jointly shared object, which would to some extent at least be given from above in a 'normal' work context, we would expect there to be a lack of motive despite the identified need for the system. In these work systems intended to promote collaboration to foster innovation this is not the case. Rather the actors have to develop their own object and the evidence indicates that the actors continually struggled to do this. Providing them with opportunities to establish a joint object of activity is clearly seen as important by the project manager but the means of achieving this, given the short time spans involved and the complexity of the system, are extremely uncertain.

Supporting Boundary Crossing

A feature of innovatory work practices is polycontextuality where experts are not simply engaged with the work of one activity system but increasingly find themselves participating in multiple systems. This involves frequent transitions across boundaries, as indicated above. However, boundary crossing is " a broad and little studied category of cognitive processes … that involves encountering difference, entering into territory in which we are unfamiliar and, to some extent therefore, unqualified" (Tuomi-Grohn, Engeström and Young, 2003, p. 4). Ideas about boundary crossing might be supported through boundary encounters and brokers (Wenger, 1998) and the development of boundary crossing places (Lambert 2003). However, little is known about the effectiveness of such arrangements. Perhaps the most promising idea for promoting boundary crossing is the development of boundary objects (Star, 1989) – " objects that are shared and shareable across different problem solving contexts" (Carlile, 2002., p. 451).

In Star's (1989) study of heterogenous problem solving, she observed that in despite of the tremendous differences between scientists in various disciplines, they nevertheless were often very successful in co-operating to produce " good science". She describes boundary objects as objects that work to establish a shared context that sits in the middle. (Carlile, op. cit, p.451)

The need for boundary objects we believe is voiced by the project manager through her focus on questionnaire at the kick off meeting. However, the team also developed their own boundary objects during the course of the development of this activity system, for example, a TWiki collaborative text tool and the " 5 Buckets" tool, a symbolic tool which helped in order to rearrange the division of labour. However, these boundary objects have very different affordances for different institutional and individual actors in the team and ultimately their use faded as the work progressed (see Hayward and Kinti, 2004). Again this in an area for further research, particularly to understand the key design features of boundary objects that support a shared syntax of language through which individuals can collaborate and share their expertise.

Working with Contradictions

An essential feature of AT is the importance of contradictions which provide the developmental impetus for an activity system. The eD project abounds with contradiction. However, identifying which contradictions to explore is highly problematic here. Examining the nature of contradictions, and helping actors to deviate from normal patterns of practice to resolve them, is a key feature of work-development research as developed by Engeström and his colleagues in Helsinki. However, the sorts of tools being used to develop alternative practices to the treatment of chronically sick children in the Helsinki health care system do not seem particularly relevant in work systems such as this one given the constraints of time and the highly fractured nature of the object of activity. Thus the idea of a learning laboratory, for example, does not seem to fit well with the pace of development being experienced by these actors. This leaves open the question of how the resolution of contradictions through processes of supporting expansive learning, which we see as fundamental to this type of innovatory work practice, might best be supported. Indeed, we wonder whether the size of the contradiction between academic and commercial work may be so great under current circumstances in the UK that policy intended to promote co-operation between commercial and university partners may be at risk of frequent implementation failure. This raises a number of questions about the extent to which the UK will be successful in developing " high-skill ecosystems " (Finegold, 1999) around its major research universities.

5. Conclusion

In this paper we have sought to argue that Government policy on innovation resulting from the interaction between commercial and university partners is potentially more challenging than it may at first seem. The sorts of interactions between the various partners appear, albeit on the basis of one case study, particularly complex and difficult to manage in order to achieve desired outcomes. An experienced project manager, providing an account of her experience of trying to manage such a team using conventional project management tools, identified a number of issues and problems that produced barriers to effective collaborative sharing of expertise. These were reinterpreted from an AT perspective, which provides a more formal theoretical language and systems of representations with which to understand the problem of developing collaborative expertise and working. To some extent at least, we feel that AT does provide insights into key processes – the link between motivation and object formation, boundary crossing and the resolution of contradictions as the driving force for the development of an activity system – which at least alert us to the need for new forms of mediation and 'tools' to support the work of these teams. To some extent our team invented such tools but this was not a particularly efficient process. Thus, we are left at the end of this research process with a clear identification of need: for new project 'management' tools to support the development of innovatory work practices. Such tools need to take due account of social, psychological and organisational needs in addition to technological problem solving in order to help newly created activity systems to develop within project time horizons. Ideas such as boundary objects provide a starting point for the development of such tools but their exact nature needs to be ascertained.

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