Using Activity Theory to Examine Information Systems for Supporting Mobile Work

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Abstract

An information system delivers support for decision making; however the physical constraints associated with mobile work often means that such support is limited. Despite the limitations, mobile workers manage to get work done. A broader review of a mobile worker's information system use reveals information sources that are outside the usual analysis of the technology and data. Decision making in mobile work would benefit from the development of these alternative information sources. A comprehensive description of the existing information system of mobile workers is a vital step in supporting technology development. This paper considers two different mobile workers, their information system and how they interact with that system. To assist in presenting a holistic view of the case studies, Activity Theory is used as a lens of interpretation.

Keywords: Activity Theory; information; systems; mobile

1 Introduction

In the traditional office context, the work environment is configured by workers to optimise their resource access and to support decision-making. Office workers access *Tools* such as reference books, paper documents and computer stored electronic files, including local and internet accessible server records. In some office situations, the orientation of team members' desks is geared to support the work process (Perry et al.,

2001). To varying degrees, many workers are required to operate in a mobile sense, away from their traditional office and information resources. That is, as a requirement of their normal work, the mobile worker physically operates at different spatial locations.

A subset of these mobile workers will be required to perform complex decision making to produce their work outcomes. According to Drucker (1993), a key feature of knowledge workers is their ability to acquire and apply theoretical and analytical knowledge in their work. The class of mobile worker required to analyse and apply their knowledge (such as a Doctor on a ward) corresponds with the concept of knowledge workers as described by Drucker (1993).

Davis (2002) noted that an important component of work by knowledge workers is the accessing of data in order to apply their knowledge work. David states that knowledge workers [1] access data, [2] use knowledge, [3]employ mental models, and [4] apply significant concentration and attention. Remote mobile workers who are required to engage in analysing situations to gather data, apply their knowledge and make decisions in the course of their work, will be classified as 'Mobile Knowledge Workers' (MKWs).

The information system of a worker supplies support for decision making and through the use of mobile devices the information system of the MKW may be improved (Lehmann, Prasad & Scornavacca, 2008). The decision making of mobile workers can potentially be assisted by access to pertinent, up to date information. The development of innovations such as smart cell phones, personal digital assistants and laptops (Gebauer, 2008) hypothetically allows workers who are required to be mobile and away from their offices, access to information on demand while operating in the field.

The adoption and integration of a new technology by a worker can face barriers in several forms. For example, the introduction of a new technology may inadvertently produce a negative effect on the work, such as reduced adoption or selective use (Orlikowski, 1996). The broad range of literature that has emerged to explain these issues is beyond the scope of this paper to review, but includes authors such as Rogers (2003), Norman (1988), David (1991) and Preece, Rogers & Sharp (2002).

Engestrom and Nardi (1999) noted that the introduction of a new technology could result in a work process which undermines good but relatively 'invisible' work. To assist with the understanding of the information system used by an MKW, Activity Theory is used as a lens for focus. Although Activity Theory is essentially a theory of learning (Engestrom, 2001), many researchers such as Kuutti (2001), Kaptelinin and Nardi (2006), Engestrom (2000), Bodker (1996) and Bannon (1997) have previously applied Activity Theory to interpret their research, with Bannon (1997) noting that Activity Theory provides "a general conceptual framework for understanding and analyzing human activity" [work].

In contributing to this discussion, this paper maps the information system currently being used by (1) a group of medical doctors and (2) newspaper reporters, viewed as MKWs, as a pilot for a larger study. The following section briefly outlines Activity Theory,as a lens for understanding the information system of the MKW. Section 3 describes the methodology, while the findings from the case study interviews with doctors and newspaper reporters are outlined in Section 4. The conclusion is set out in Section 5.

2 Activity Theory

The basic components of Activity Theory as described by Vygotsky (1978) comprise an *Activity*, a *Subject*, an *Object* and *Tools*. A *Subject* is an individual or group of individuals involved in a common *Activity*. The *Subject* undertakes an *Activity* in order to achieve an *Object* (see Figure 1). The arrow in Figure 1 represents the *Activity*, i.e. the element symbolizing work. The *Activity* is the point of interest for our context, as it is the 'black box', detailing how the MKW gets work done.
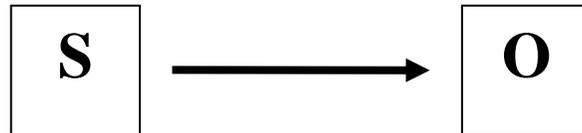
$$S \longrightarrow O$$

Figure 1: *Subject*, *Object* and *Activity* (Kaptelinin and Nardi, 2006)

The concept of Object-Orientation should not be confused with the same term used in the field of computer programming. In Activity Theory, reference to the *Object* alludes to the desire (theoretical result) that the *Subject* is trying to fulfill or the underlying motive for the *Activity*. The *Object* is what drives an *Activity*. As described by Kaptelinin and Nardi (2006, p.67) "*Object*s of activities are prospective outcomes that motivate and direct activities, around which activities are coordinated… *Object*s can be physical things 'such as the bull's eye on a target or ideal *Object*s such as 'I want to be a brain surgeon'."

According to Kuutti (2001),, all *Activity* contains or involves interaction with *Tools*. *Tools*, often referred to as artifacts, are created by humans and offer signs to the *Subject* which assist in directing them towards a particular action. "The idea is that humans can control their own behavior – not 'from the inside' on the basis of biological urges, but 'from the outside' using and creating artifacts" (Engestrom, 1999, p.24).
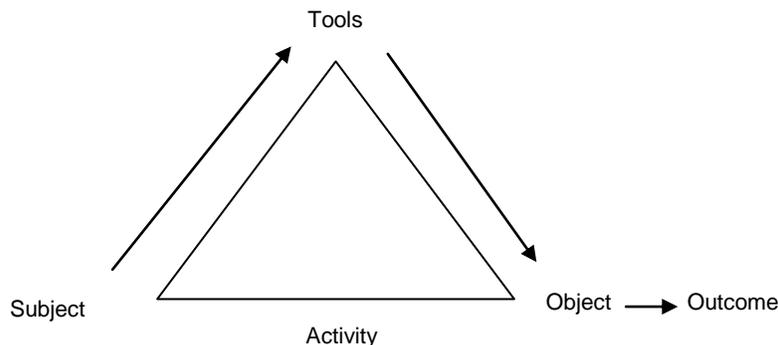
Figure 2: Basic model of *Activity* (Kaptelinin and Nardi, 2006)

As can be seen in Figure 2, the way in which the *Subject* approaches the *Activity* in order to achieve the *Object* is mediated through *Tools*. That is, the *Tools* humans use in their doing influences the way they approach an *Activity* and assists with their decision making, such as prompting the *Subject* to take a course of action. *Tools* can take various forms depending upon the context of the study; for example, they may range from instruments, signs, procedures, machines, language, methods, laws to forms of work organization.

Activity Theory centers on mediation and the concept that the way humans undertake an *Activity* is influenced by the environment around them, and their ability to develop an understanding based upon previous experiences in order to make logical decisions. This mediation is man-made in so far as the *Tools* that influence a *Subject* have been developed by the *Subject* or other people who have previously worked in the same context.

In their model, the Cultural Historic Activity Theory Model (CHAT), Hasan and Gould (2001) note that there are two mediators which influence the way an *Activity* is done, these being *Tool*s and the Community of Practice (see Figure 3).

The influence that the Community of Practice has upon an *Activity* is applied through *Rules* to which the *Subject* adheres. These *Rules* are implicit and explicit and govern the *Activity* of the *Subject*. Explicit *Rules* are easily identified as such things as documented codes of practices or standards which govern the requirements of workers. Implicit are the norms that the *Subject* accepts as requirements (informal procedures as well as the social relationship between the *Subject* and the Community), often derived from other more experienced workers.
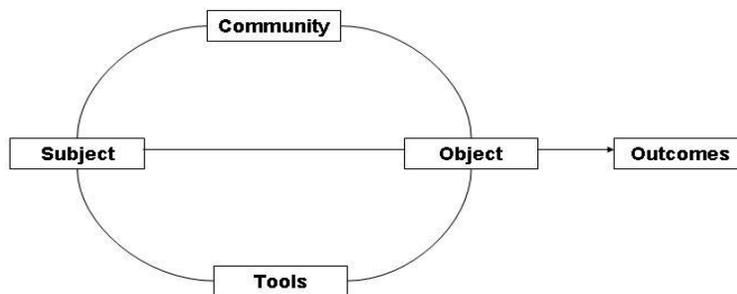
Figure 3: CHAT Framework of an Activity by Hasan and Gould (2001)

3 Methodology

The research described in this paper is an investigation focused on MKWs and their interactions with information. A qualitative case study was therefore an appropriate approach (Flyvberg, 2006). The development of the case studies was based on the use of

semi-structured interviews lasting approximately one hour. The data collected was then interpreted through the lens of Activity Theory. The applied interpretive case study methodology as described by Walsham (2002) uses theory as [1] a preliminary conduit to design and data collection; [2] as part of an iterative process of data collection and analysis; and [3] as a final product of the research.

The lens of Activity Theory encapsulates the decision making process into a model as a component of the work *Activity* of an MKW while in the field, with the *Subject* being the mobile worker while operating in a mobile sense, away from any formal office situation. The resulting framework adapted from Activity Theory identifies technical, social and environmental factors which influence the way mobile knowledge workers interact with information sources.

The selection of the case studies was based on the following criteria:

1. Workers were required to be mobile in order to do work;
2. The work done required complex decision making.

The first case study scenario examined doctors and the way they operated on ward rounds, working in a mobile manner from ward to ward and away from their consulting offices.

The three doctors interviewed were all specialists, two renal physicians and a cardiac surgeon. All had worked in the industry for a considerable time (see Table 1). Doctor 1 and Doctor 3 were initially interviewed and then re-interviewed to extract and clarify data. To ensure that data collected from the interviews was consistent with their practice (and ensure an added element of rigour), Doctor 1 was also the *Subject* of observation. Doctor 1 was studied while doing his ward rounds on several wards in two different hospitals.

Table 1: Doctors interviewed: Total number of interviews: 5

Participant	Experience with ward rounds (years)	Specialty	Number of interviews
Doctor 1	32	Nephrologists	2
Doctor 2	25	Physician	1
Doctor 3	25	Cardiac Surgeon	2

The second case study considered reporters working for a newspaper and their production of stories while in the field (away from their offices). Five reporters and one editor at the same publication were interviewed for this case study (see Table 2).

Table 2: Reporters interviewed: Total number of interviews: 5

Participant	Experience in Publishing Industry	Interview Round
Reporter 1	11 years	1
Reporter 2	6 years	1
Reporter 3	30+ years	1
Reporter 4	5 years	2
Reporter 5	10 years	2
Editor	13 years	2

4 Findings

The first case study deals with Doctors, while the second case study investigates newspaper reporters.

4.1 Doctors

Due to the complex nature of the human body, doctors specialise in a specific area of medicine. To work as a specialist, doctors require post-graduate qualifications (and experience) in their chosen area of expertise. Each patient is individual, with different characteristics, resulting in unique and personal complications that require individualised diagnosis and treatment. The information system used to support the doctors' work is dynamic in nature. Doctors operate from their consulting offices. This is their central point of information storage and retrieval, with historical patient details (in the form of individual patient case notes) as well as resource material such as reference books, despite the fact that much of their work is not carried out in the confines of the consultation office.

Much of the doctor's work requires first-hand observations of patients in a controlled environment in close proximity to support such as hospital operating theatres. Often, the Doctor is required to visit several patients across different wards, and sometimes across several different hospitals over the course of their rounds.

Doctor 2 noted that when making a decision with regard to the care of a patient, the main sources of information are the on-the-spot diagnosis of symptoms displayed by the patient and consideration of the patient's history in the form of case notes. These case notes are a *Tool* which influences the decisions of the attending doctor (their *Activity*).

Patients are admitted to a hospital to be treated. The patient is classified on admission as an inpatient or an outpatient. An outpatient is one who is initially attended to by a doctor in their consulting room, and an inpatient has an initial consultation in the public or private ward of a hospital. The difference between these two classes of patient is paramount to the information system. The outpatient information (case notes) are collected, stored and controlled by the specialist doctor, whereas the inpatients' records

are all kept by the hospital. Case notes are not necessarily shared between the hospital and the doctors' consulting office. This results in the doctor being *Subject* to a disconnected information system (inaccessibility to case notes exclusively kept in either the office or in the ward).

During their ward rounds, doctors often make critical, on-the spot decisions using a disconnected information system, as they are required to examine and diagnose patients to assess their health away from their primary information source in their consulting room. To overcome the issues associated with the lack of support available from the dysfunctional information system, the Doctors made use of a variety of monitoring technologies which provided the Doctors and Nursing Staff with information about the well-being of the patient (for example, temperature, pulse, heart rate).

The Doctors identified the following informal protocols, or *Rules*, associated with the information:

1. Preparation: Before Doctor 3 went on his ward round he would prepare by first going to his office and reviewing the case notes of patients he intended to see. He would often take the case notes with him on his ward round.

2. Collaboration: All the Doctors interviewed held informal discussions with other doctors about patients. These were often held in unofficial work situations, such as during a lunch break in the staff lounge or lunch room. Doctor 3 noted, "I probably learn more in the lunch room than any other place…" Opportunistic situations, such as passing a colleague in the hallway or in the lift, were also identified by Doctors 1 and 2 as being information sharing possibilities.

3. Personal Knowledge: Typical of knowledge work, decisions made by Doctors are often based on both their training and their past experience.

The medical information system is an extremely complex one, as many actors contribute to the care of patients, not only the doctor. These additional actors directly influence the decision-making of the doctor, usually through the provision of information, as illustrated in Table 3.

Table 3: Mediation on decision making of doctors by other participants

INFORMATION *Tool*	INFLUENCE ON *Activity*
Nursing Staff	Nursing staff provide ongoing care to patients on the ward while doctors interact with patients in a much more time-fractured way. The Nursing Staff monitor and record information about the ongoing condition of patients in case notes kept on the ward. These are verbally communicated to the doctor when he/she arrives to do their ward round.
Laboratory / Other Departments within the Hospital	Pathology laboratory staff take samples provided by the patients (such as blood) for assessment. The results are used by doctors to assist in determining a diagnosis and treatment for individual patients. These various other departments produce reports which are reviewed by the Doctor; however, in some cases the Doctor speak to someone in another department to obtain information.
Other Specialists	Doctors 1 and 3 commented that it is often the case that more than one specialist doctor could be involved with the care of a single patient. They pass information to each other because what they do is interrelated (for example, the prescribing of a drug could potentially have side effects).

The mediation provided by other health professionals is controlled by some unusual rules. For example, unless they were working in a training hospital (in which students would follow the doctor around as part of their training), Doctors would rarely do ward rounds together, even though as Doctor 3 pointed out, it would be of great benefit for information sharing.

Doctors also preferred to collaborate with doctors that they had worked with before. Doctor 1 stated, "Usually I will work with a doctor whom I know, that I have developed a relationship with. I work with a few doctors, we work very comfortably together. There's never any trouble, never. Some are domineering and I say forget it, I won't work [with them]".

Doctors were keen to respect and maintain disciplinary boundaries. Doctor 1 noted that "most doctors will know where their boundaries are, I'm the specialist of this, and I can't say to the cardiologist that you cannot use that. I would never do that [tell the cardiologist what to do]. I stay within my boundaries. Imagine giving a conflicting statement to the patient's relatives, 'Hey that doctor said this, how come you are doing that'… "

Passing of information was dispersed across multiple *Subject*s. Nurses were pivotal in the supply of information as doctors not only left them instructions on how to care for the patient but also gave them messages for other specialists. The Nursing Staff were also charged with organising tests for the Doctors, as well as returning the results.

The importance of the Nurse as an information source is highlighted in the fact that the role is reproduced in the consulting office scenario by the office secretary. When information held in the consulting office needs to be passed on to collaborating Doctors

from the office, the Secretary would be the person that actually gathers the information from files and sends it.

A broader influence was found in the environmental conditions and context of the ward round. This influence appears in two distinct forms: the Physical and Contextual Environments. In the Physical environment, this influence might be the opportunistic passing of information among specialist doctors, or the presence of monitoring equipment possessed by some wards, such as the Intensive Care Unit (ICU), but which general wards lacked. An example of the Contextual Environment is the urgency of work requiring an on-the-spot decision as opposed to referring to the information resources in the consulting office, where they could consult their full range of information sources.

A further example of the contextual environment is that generally, the passing of information is made through Nursing Staff, or opportunistically. In critical cases, however, the Doctor will ring another Specialist directly for a discussion. They do not wait for the opportunity to get information, rather they instigate access to the required information. As noted by Coiera (2000), the "value of any particular information technology can be determined only with reference to the social context in which it is used and, more precisely, with reference to those who use it".

4 .2 Reporters

For the majority of their work the reporters interviewed operated in an office environment. One day a week, however, the reporters would go into the field to gather information (for example, to conduct interviews with people of interest). The reason for this mobile mode of work is that it afforded a richer source of information. That is, although interviews could be conducted from the office using the telephone, by physically being at the source, the reporter is able to gather other information; for example, the reporter is able to make observations or talk to people who are in the vicinity of the story, providing a contrasting view. Reporter 1 noted that this mobile mode of reporting was preferred over the office based production of stories, but due to time constraints, most of the stories were produced in the office.

We have classified the mobile work *Activity* of the reporter into two components. The first is to elicit information from the field from where they are reportin, and the second is to construct and send in their stories for publication.

Similar to the way in which the doctors operated, the reporters also made use of preparation (research), collaboration (both formal and informal) and personal knowledge in their work. These actions were also subject to rules which mediated the way in which the *Activity* was approached.

1. Preparation: Prior to going out into the field, the reporter would research a potential story. If the reporter were going to cover a boxing match, for example, he/she would find out as much as possible about the two combatants. Typically, this preparation would take place in the office, where the reporter is able to access several sources of information. The *Tool*s which were accessible to the reporters included an in-house library, other publications, on-line material and other reporters in the office. A surprising source of information identified by Reporter 5 was the reporters from

rival publications. This reporter noted: "If it is a journalist at your paper or a journalist at another paper who is an expert in boxing or whatever… with the boxing I've got friends at the [opposition paper] who know about boxing and I have no trouble ringing them up and saying I have to cover this fighter – what is the story and what should I watch out for".

2. Collaboration: As noted above, an interesting source of information which materialises is collaboration. This collaboration is subject to a similar rule to that outlined in the doctor case study, in that there is much informal collaboration and that collaboration is subject to trust. Collaboration is an integral part of the reporter's ability to do work.

   This informal collaboration is further highlighted in the writing of a story. While in the field there are two methods of producing and submitting a story to the editorial staff for review and publication. The first is to use a laptop. Stories can be written, edited and sent using a Virtual Private Network (VPN). The second requires the reporter to phone into a copy-taking service and read out the story for transcription. Despite several advantages to using laptops being identified by the reporters and editorial staff, the predominant method of story production made use of the copy-taker. The main reason for this is that the copytaker is able to respond and edit the story from a "lay person's point of view". Reporter 3 noted "They [Copytakers] were invaluable because often you would get feedback from them about what you were writing, like they would say 'are you sure about that' or 'you have mentioned that further up the story do you want to say it twice' and you would say 'no, ok, thank you'. So having a human, instant response to what you're dictating is very important, a machine cannot do that. And sometimes if they laugh at a joke or something funny that you have put in, then you think: Great I've hit the spot. If they are shocked at what I say then: Great, I've hit the spot, I've captured it. If they cry, fantastic, you really got the story. A machine can't do that".

3. Personal Knowledge: Personal knowledge plays an important part in a reporter's ability to write stories. This knowledge is compiled from both formal training and tacit knowledge which has been developed from the individual reporter's experiences. Reporter 1 noted: "These reporters come over from England and they're hot [*sic*] reporters from Fleet Street but I think that there is a bit of a cultural problem with them because they do not have the cultural background that we have such as the knowledge that you carry around having grown up in Sydney. When someone says something happened at Maroubra or something happened at Kensington or Avalon to someone who has grown up in Sydney, we know straight away what that is. So that is part of the equipment which you carry around in your head all the time, whereas someone who has come over from England, they would not understand the cultural differences, even the geography… They wouldn't know what certain areas are known for or famous for."

The theme of the third mediating influence identified in the doctor case study, the Environment, is also persistent with the reporter. Information sources materialise and disappear as the reporter moves through the ever-changing environment. For example, Reporter 1 was engaged to cover a rugby league match, of which he knew little; however,

once at the game, he was able to gather commentary from not only the players but spectators and other club officials. Reporter 2, in a similar situation, made use of other reporters sent to cover the same match by taking notes while others asked questions of interviewees.

The social context of an Environment in which the reporters were operating also had a mediating affect. A clear example of this is the need to construct and submit stories directly from the field in order to meet publishing deadlines. Another example is described by Reporter 3 who noted that in order to maintain a professional atmosphere while conducting an interview, he would never break off to check facts [access information], as to do so would be 'unprofessional'.

5 Discussion

The focus of the research in the case studies was applied to knowledge workers while they were operating in a mobile mode. Clearly, the work of the Reporter and the Doctor are different (producing a story and looking after the health of patients respectively). Fundamentally, both of these mobile workers apply their knowledge to make decisions, and their ability to make decisions is supported through their information systems.

A second difference between the case studies is the environment in which on-the-spot decisions are made. The environment in which the Doctor operates is controlled [on the ward], allowing for Doctors to place support systems such as nurses and monitoring devices to provide 24 hour observation of the patient's condition. On the other hand, the mobile work environment of a Reporter can be totally open and unfamiliar. This places a high level of importance upon the planned support of their pre-mobile, office research and allows the Reporter to take with them appropriate printed material.

The Reporter operates in a mobile sense in order to gather information by assessing the situation and context in order to make a decision). Information support for Reporters is additionally realised from their open environment in the form of Contributors. Contributors are outside the organisational structure of the worker; they are not classified as Collaborators, nor are they within the Community of Practice. Contributors are 'bystanders' or other people who happen opportunely to be in the same vicinity as the Reporter and can provide information to assist the story.

While working in a mobile sense, the MKW is subject to a changing Environment. The physical and social landscape are subject to change in the mobile Environment which can result in variation of the sources of information and potentially a change in the Activity that is the *Subject's* focus. For example, a patient developing unforeseen complications may change the *Activity* of a Doctor on a ward round. The *Object* of the *Activity* may not necessarily change, but the Environment may change, requiring an appropriate response. In the Reporter case study, dramatic changes such as a bomb going off will change the topic of the story. In this case, obtaining the earliest, or possibly exclusive, report becomes the priority in the social context and Reporters will use whatever is at hand to do their work.

6 Conclusion

Doctors and Reporters are mobile knowledge workers. The identification of their interaction with their information systems is assisted through the use of Activity Theory. The two main categories of influence upon how an *Activity* is done include the *Tool*s and social dictates from the Community of Practice (in the form of implicit and explicit *Rules*). Of particular note is the identification of a previously overlooked information source which sits outside the organisation: that of the Contributor. Another significant finding is the preference for information provided by Collaborators over information supplied by information tools. The information provided by Collaborators was preferred as it was subject to the application of Collaborators' knowledge to the situational context.

A further potential influence revealed in this research is that of the situational environment. The necessity for the MKW to be mobile in order to carry out their work creates a dynamic physical environment and conditions from which opportunistic *Tool*s are provided. These *Tools* are manifest and vanish with availability. The Environment also includes the social context such as the urgency of the particular situation, as was seen in both case studies. In an urgent situation, Doctors tend to work in a close collaborative manner where there is a need for direct communication and information sharing.

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