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Where Theory meets Practice: A Case for an Activity Theory based Methodology to guide Computer System Design

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Abstract: Computer system developers are increasingly being challenged to develop tools that are not only usable, but more importantly *useful* in the sense of assisting the user to achieve desired goals. This requirement has highlighted the importance of accounting for the social and cultural issues of the computer tool user when developing a computer system. Activity Theory (AT) has emerged as a suitable framework for analysing social and cultural issues because it provides a language to describe what people do in context. However, many computer system developers have failed to benefit from this insight mainly due to lack of established methods to operationalise ideas from this framework for the purpose of guiding the design process. This paper proposes a methodology developed to direct the application of a version of AT based on Engeström's (1987) conceptualisation in order to support requirements capture during computer system design.

Keywords: HCI, Activity Theory, methodology, design, requirements capture

1 Introduction

Practitioners in the field of Human-Computer Interaction (HCI) have long strived to introduce design methods and guidelines that enhance the usability and usefulness of computer systems (Gilmore, 1995; Norman, 1998). In addition, the recognition of the complexity of human information processing, which draws from contextual issues in the environment has prompted researchers in this area to seek additional guidance from other fields (Bannon, 1990b; Bannon & Bødker, 1991; Kuutti, 1996). This, together with the realisation of the importance of the context in which a computer is to be put to use, mainly due to the works of Nardi (1996) has led to an increased interest in Activity Theory (AT). The effect of this increased interest in AT has been to prompt a search for ways of applying AT in order to use it to improve computer system design. This paper represents one such effort by introducing an AT based methodology to guide the requirements capture stage of computer system design. The methodology being proposed demonstrates how a version of AT based on Engeström's (1987) model of human activity can be operationalised in order to guide computer system design.

The paper begins by presenting an overview of issues in HCI that led to the consideration of using AT ideas. This is followed by a general discussion of computer system design and methodologies. Thereafter, an introduction to AT is given with special reference to Engeström's model of human activity – the activity triangle system. This is followed by a discussion of the relevance of using AT to guide computer system design. A general description of the methodology being proposed is then given. Thereafter, a case study is used to demonstrate how the methodology was applied to analyse work practices in an organisation for the purpose of informing the design of a computer system to support those work practices. The paper concludes by highlighting contributions and perceived benefits of using the proposed methodology during computer system design.

2 Computer System Design

The design process like any other creative activity varies depending on the type of product being developed and the resources available. Key to this activity is the methodology used to guide the design process. Over the years, various computer system development methodologies have been introduced. These include but are not limited to the 'waterfall model,' which represents the traditional approach to

software engineering, right up to the HCI design model, which emphasises user-centredness during the design process (Norman and Draper, 1986). Even though differences do exist in their execution mechanisms, most design methodologies are targeted towards solving particular design problems. The methodology used during the design process can determine the usability and usefulness of the resulting product.

The rationale behind the proposition of this methodology was inspired by the need to incorporate within the design process the richness of AT, by providing a mechanism to capture the social, cultural and psychological aspects of the user in context. The methodology being proposed is intended for use during the requirements capture phase of design only. The requirements capture stage of computer system design is usually performed to establish what it is the end-user wants from the proposed computer system. In order to conduct a critical analysis of this nature using the AT framework, there is a need for a structured methodology to guide the data gathering and interpretation process. The information gathered regarding user needs determines the type of functions and interface features that are finally introduced into the system. Interface features represent the means by which the user interacts with the computer tool as they strive to fulfil their needs by executing actions that enable them to achieve desired goals. AT can enrich this process by accounting for social, cultural and psychological aspects of the user in context.

3 What is Activity Theory?

Activity theory is a theoretical framework for analysing human practices as developmental processes with both individual and social levels interlinked at the same time (Kuutti, 1996). This framework uses 'activity' as the basic unit for studying human practices. Activity or 'what people do' is reflected through actions as people interact with their environment.

AT has its origins in the Vygotskyian concept of tool mediation and Leont'ev's notion of activity. Vygotsky (1978) originally introduced the idea that human beings' interactions with their environment are not direct ones but are instead mediated through the use of tools and signs. This notion is usually portrayed by what has come to be known as the *mediational model* of human interactions with the environment (see Figure 1).

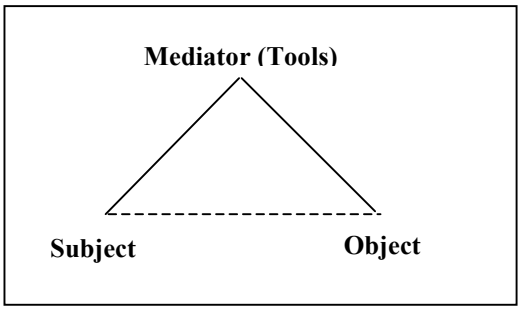

Figure 1: Mediational Model (Vygotsky, 1978)

The model highlights the idea that the relationship between the *Subject* and the *Object* is not direct but instead mediated through the use of *Tools*. The notion of tools will be explained later in the discussion. Leont'ev (1978) further developed Vygotsky's ideas of social and cultural mediation by developing a hierarchical model of human activity.

Inspired by this thinking, Engeström (1987) extended Vygotsky's original conceptualisation for the mediated relationship between the *Subject* and the *Object.* He introduced an expanded version of the mediational model so as to incorporate Leont'ev's social and cultural aspects of human activity. Engeström therefore, offers a general model of human activity in the way of the expanded *activity triangle model* to reflect the collective and collaborative nature of human activity.

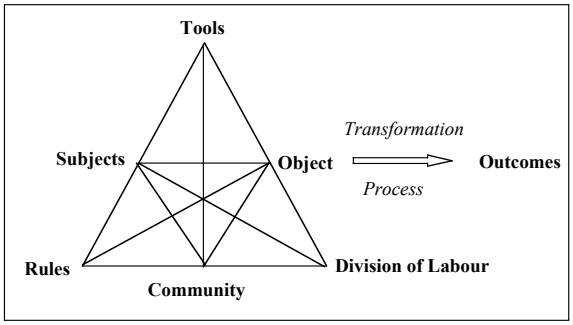

Figure 2: Activity Triangle Model (Engeström, 1987)

The activity triangle model incorporates the *Subjects, Object, and Community* components; also mediators of human activity, namely: *Tools, Rules* and the *Division of Labour*. These components are discussed below.

The *'Object'* component reflects the motivational or purposeful nature of human activity that allows humans to control their own behaviour. Human activity is targeted towards the satisfaction of identified objectives. Therefore, in this paper, the term *'object'* is used in the "*objective"* (see Leont'ev, 1981, Pages 46-69) sense, so as to emphasise the purposeful nature of human activity.

The 'S*ubjects'* component of the model portrays both the individual and social nature of human activity as reflected through collaborations and consultations in order to satisfy a shared objective. The subjects' relationship with the object or objective of activity is mediated through the use of tools.

The *'Tools'* component of the model reflects the mediational aspects of human activity through the use of both physical and conceptual tools. Physical tools are used to handle or manipulate objects whilst conceptual tools are used to influence behaviour in one way or another.

The *'Community'* component of the model puts the analysis of the activity being investigated into the social and cultural context of the environment in which the subject operates. This notion reaffirms the suitability of AT to the study of human practices in an organisation.

The *Rules* component highlights the fact that within a community of actors, there are bound to be rules and regulations that affect in one way or another the means by which activity is carried out. These rules may either be explicit, or implicit, for example, cultural norms that are in place within a particular community.

The *Division of Labour* component refers to the allocation of responsibilities and variations in job roles of the subjects as they carry out activity in the community.

4 Using Activity Theory to guide Computer Systems Design

The ideas presented in AT enhance and extend the practical concerns of tool usage, which are traditionally addressed by the HCI discipline by linking the design solution to socio-cultural and psychological aspects of the tool user. This approach highlights the importance of the tool user's cultural behaviour revealed during tool usage. It seems to be the view that by analysing human activity in context, using this framework, the computer tool developer can fully account for the complex and intertwining issues that impact on the usefulness of the computer tool through its design.

Although the ideas presented in this framework sound promising by providing a much-needed common vocabulary for describing human activity, there is no standard method for putting AT ideas into practice (Nardi, 1996). The lack of a standard method for applying AT could be attributed to the fact that there are several basic principles of AT (Kaptelinin, 1996) on which one could base their analysis. In addition, the framework itself is continuously evolving. As a result, concepts from this framework have been interpreted and applied in various ways in different contexts. *This flexibility has introduced difficulties in replicating, comparing and criticising the approaches taken to applying Activity Theory.*

Putting theory into practice is not an easy task. The use of a theory to inform computer system design requires the justification of the method used to operationalise the theoretical concepts, together with the provision of clear evidence of the mapping between theory and the design representation that is finally produced. The role of AT in computer system design has often been reduced to descriptions of the benefits begot as a result of using AT without necessarily explaining how AT was applied. AT in this paper is used both as a descriptive tool for understanding what is happening in an activity system and also as a practical tool for guiding the design process using the proposed method.

The motivation to introduce this methodology does not rise so much from the need to discredit or underplay earlier efforts to operationalise AT for the purpose of design (Kaptelinin, Nardi and Macaulay, 1999). It emerges instead from the need to systematically explain and demonstrate in a replicable manner the means by which AT can be used to guide the design process in different contexts. Such an approach can benefit computer system developers without necessarily requiring them to become experts in AT.

5 AT Methodology Description

The methodology was developed in the context of analysing work practices in an organisation for the purpose of informing the design of a computer system to support those work practices. The expanded activity triangle (see Figure 2) was used in this study as a heuristic model that captures and unifies concepts from AT, which are relevant to the analysis of work practices and tool design. The triangle model offered a useful starting point for interpreting and applying AT ideas in relation to the analysis of work practices in an organisation. It was also believed that using this model to investigate human activity would put the study into the social and cultural context of the community whilst paying attention to the mediating aspects of that activity

through the tools, rules and division of labour components. The process of operationalising AT using the activity triangle model was accomplished by applying the following procedure:

Stage 1. Model the situation being examined
Stage2.Produce an Activity System of the situation
Stage 3.Decompose the situation's Activity System
Stage 4. Generate Research Questions
Stage 5. Conduct a detailed investigation
Stage 6. Interpret Findings

These six stages will be explained in the following sub-sections.

5.1 Model the situation being examined

The study began by interpreting the various components of the activity triangle (Figure 2) in terms of the situation being examined. This involved the development of an *Eight-Step-Model* (shown below) incorporating open-ended questions based on the various components of the activity triangle representation.

The Eight-Step-Model

Identify the: -

1. *Activity* of interest
   - What sort of activity am I interested in?
2. *Object* or *Objective* of activity
   - Why is this activity taking place?
3. *Subjects* in this activity
   - Who is involved in carrying out this activity?
4. *Tools* mediating the activity
   - By what means are the subjects carrying out this activity?
5. *Rules* and regulations mediating the activity
   - Are there any cultural norms, rules or regulations governing the performance of this activity?
6. *Division of labour* mediating the activity
   - Who is responsible for what, when carrying out this activity and how are the roles organised?
7. *Community* in which activity is conducted
   - What is the environment in which this activity is carried out?
8. What is the desired *Outcome* from carrying out this activity?

5.2 Produce an Activity System of the situation being investigated

Using the Eight-Step-Model whilst answering questions in relation to the situation being examined enables the investigator to acquire basic knowledge about that situation. This is necessary for the purpose of mapping Engeström's model (Figure 2) onto the situation in order to produce an activity system of that situation. This approach helps to identify areas to be focused on during the investigation and also in deciding on what resources would be necessary during the analysis.

5.3 Decompose the situation's Activity System

The activity system produced in section 5.2 can be very complex because it incorporates the various sub-activities that together make up the main activity system being analysed. Therefore, at this stage, the *Activity Notation* (see Figure 3) was introduced to aid the process of breaking down the situation's activity triangle system into smaller manageable units or sub-activity triangles.

Actors (Doers)		**Mediator**		**Objective** (Purpose)
Subjects	~	Tools	~	Object
Subjects	~	Rules	~	Object
Subjects	~	Division of Labour	~	Object
Community	~	Tools	~	Object
Community	~	Rules	~	Object
Community	~	Division of Labour	~	Object

Figure 3: Activity Notation

Three *rules-of-thumb* enhance the Activity Notation. The rules-of-thumb state that each combination within the activity notation shall consist of:

1) An 'Actor' represented by the *Subject* or *Community* component of the triangle model.
2) A 'Mediator' represented by the *Tools*, *Rules* or *Division of Labour* component of the triangle.
3) The '*Object'* on which activity is focused.

Each combination within the activity notation represents a complete sub-activity triangle from the main activity system (as shown in Figure 5). For example, it is possible to identify the *Subject-Rules-Object* sub-activity triangle representation whose mediated relationship could be analysed in terms of the application of rules.

5.4 Generate Research Questions

Questions that are specific to a particular combination within the activity notation and also representing a sub-activity triangle are then generated. The questions generated can be general in nature, or they could be specific to a particular situation as shown in section 6.5. Examples of general questions that could be generated based on the described approach are given below.

- What *Tools* does the *Subjects* use to achieve their *Objective* and how?
- What *Rules* affect the way the *Subjects* achieve the *Objective* and how?
- How does the *Division of Labour* influence the way the *Subjects* satisfy their *Objective*?
- How do the *Tools* in use affect the way the C*ommunity* achieves the *Objective*?
- What *Rules* affect the way the C*ommunity* satisfies their *Objective* and how?
- How does the *Division of Labour* affect the way the C*ommunity* achieves the *Objective*?

5.5 Conduct a detailed investigation

A detailed investigation of the situation being examined is then conducted using the questions generated in section 5.4. These questions are used as pointers to what to look for during observational studies, also in questionnaires and interviews as triggers to help decide on what questions to ask.

5.6 Interpret Findings

In order to make sense of what is happening within the activity system, data gathered can be analysed and interpreted in terms of AT's notion of *contradictions*. According to Kuutti (1996), contradictions come to light through problems or breakdowns *within* and *between* activity systems. Engeström (1987) emphasises the importance of contradictions in understanding how an activity system works. He argues that contradictions help to identify problematic areas whose investigation is necessary for the purpose of understanding what is happening in an activity system. The questions generated in section 5.4 can also help to identify areas of contradiction within the activity system.

6 The Case Study

This case study demonstrates how the methodology was used to gather and analyse data in an organisation.

6.1 About the Organisation

The organisation in question operates in the industrial computing sector. It develops and maintains industrial computing systems for its customers all over the world. Part of this maintenance involves rendering continuous customer support on products sold. The organisation was trying to provide better customer support by encouraging workers to share their knowledge and experiences about resolving customer problems. Management in this organisation had recognised the important role that a computer tool could play in the management and co-ordination of knowledge sharing activities. They commissioned the development of a computer system to support work practices in their organisation.

6.2 Modelling the Organisation's work practices

In order to obtain basic understanding about work practices in this organisation, components of the expanded triangle model (Figure 2) were translated in terms of the organisation's work practices using the Eight-Step-Model. The information gathered is outlined as follows:

The *Activity*

For the purpose of the study, the activity of interest was identified as sharing knowledge about work practices.

The *Object* or *Objective*

The objective or purpose of this activity was to provide better customer support.

Subjects

The subjects involved in this activity were identified as single individuals working on their own, a group of individuals working together in a team setting or a team working in collaboration with another team to provide support on the same product.

Mediators (Tools, Rules, Division of Labour)

The organisation already had in place several mediators to support the activity of sharing knowledge about work. These mediators include the use of a computerised Call Tracking System (CTS) *(Tool)*. The CTS was used to trace and monitor the progress of a call from the first time a case is received from a customer, right up to the time the problem is resolved. Online and paper based manuals *(Tools)* were also used as information resources for staff to refer to when resolving cases. The organisation employed two different product support systems *(Division of Labour)* for resolving cases. These included a fast track system for dealing with pre-paid cases charged on a higher rate and a basic rate system charged at a lower rate. A '3 hour rule' *(Rules)* was introduced for dealing with fast track cases, as these had priority over basic rate cases. Basic rate cases had no fixed duration for resolving them. A database *(Tool)* of frequently asked questions (FAQ) together with answers was being developed as a way of encouraging workers to share their experiences from solving cases. Workers were therefore required to identify and gather suitable questions and answers from their workloads whilst carrying out normal duties so that these could be included in the FAQ database.

In the meantime, the organisation had also introduced the use of a performance rating system *(Rules)* so as to monitor both individual and team

performances against targets. This performance rating system used bar charts *(Tool)* as performance measures. The bar charts showed the total number of problem cases received, the number of cases resolved, the number of cases pending, the number of cases targeted, and also the category of cases showing whether they were priority or basic rate cases. These bar charts were published on a weekly basis and used by management to determine the productivity of an individual for the purpose of promotion. Management also used the bar chart performance measures to determine the productivity of a team for the purposes of allocating responsibilities when deciding which team should support which product. Each team normally specialised in supporting a single product *(Division of Labour)*.

A job rotation system *(Division of Labour)* was in operation to allow workers to familiarise themselves with duties of other teams supporting different products from theirs. There was also a work *cultural norm* of consulting a local unofficial expert within the team when faced with a difficult case. This unofficial local expert would be someone recognised by fellow workers as someone willing to assist once consulted.

6.3 Producing the Organisation's Activity System

The above information was used to produce the activity system of the organisation as shown in Figure 4.

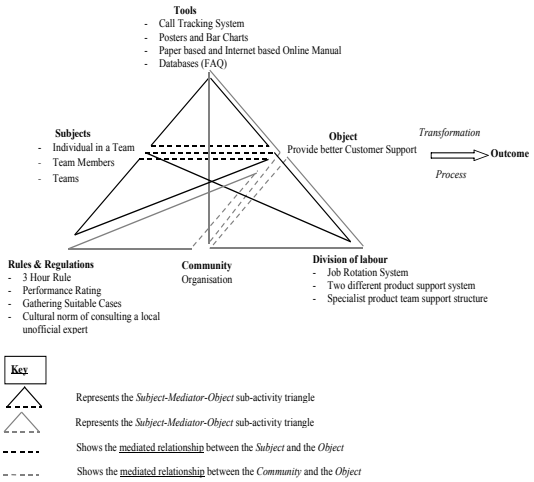

Figure 4: Organisation's Activity System

6.4 Decomposing the Organisation's Activity System

Once the organisation's activity system was produced, the activity notation (Figure 3) was then used to break it down into sub-activity triangles as described in section 5.3.

6.5 Generating Research Questions

Questions that are specific to work practices in this organisation were generated using the method described in section 5.4. Generating specific questions enabled the investigator to obtain meaningful data. The questions generated concerning the provision of better customer support are presented as follows:

- How does the call tracking system helps the team(s) to share knowledge about work?
- How does the rule of identifying and gathering suitable FAQs from cases whilst working affects the way the team share knowledge?
- How does the job rotation system affect the way the team(s) share knowledge about work?
- How does the use of a FAQs database with answers influence the way the organisation provides better customer support?
- How does the organisation's use of a performance rating system influence the way the organisation provides customer support?
- How does the use of a local unofficial expert help the team(s) to share knowledge?

6.6 Detailed investigation of work practices in the Organisation

The specific questions generated in section 6.5 were used to conduct a detailed investigation of work practices in this organisation during observations, in questionnaires and interviews. Qualitative data was gathered and analysed in terms of AT's notion of *contradictions*. Two key relationships were identified as crucial for understanding work practices in this organisation:

- The relationship between team(s) (*Subjects)* and the objective (*Object*) of providing better customer support.
- The relationship between the organisation (*Community)* and the objective (*Object*) of providing better customer support.

These two relationships were then analysed using mediators, namely: *Tools*, *Rules* and *Division of Labour*. When analysing work practices in this organisation, as well as looking at how knowledge sharing was mediated in a work context, the analysis also investigated how the knowledge sharing was hindered through the use of mediators and also other forces in the organisation. The questions generated in section 6.5 were also used to help identify areas of contradiction within the organisation's activity system. For example, by asking the question relating to the organisation's regulation of using a performance rating system, it is possible to identify two areas of contradiction.

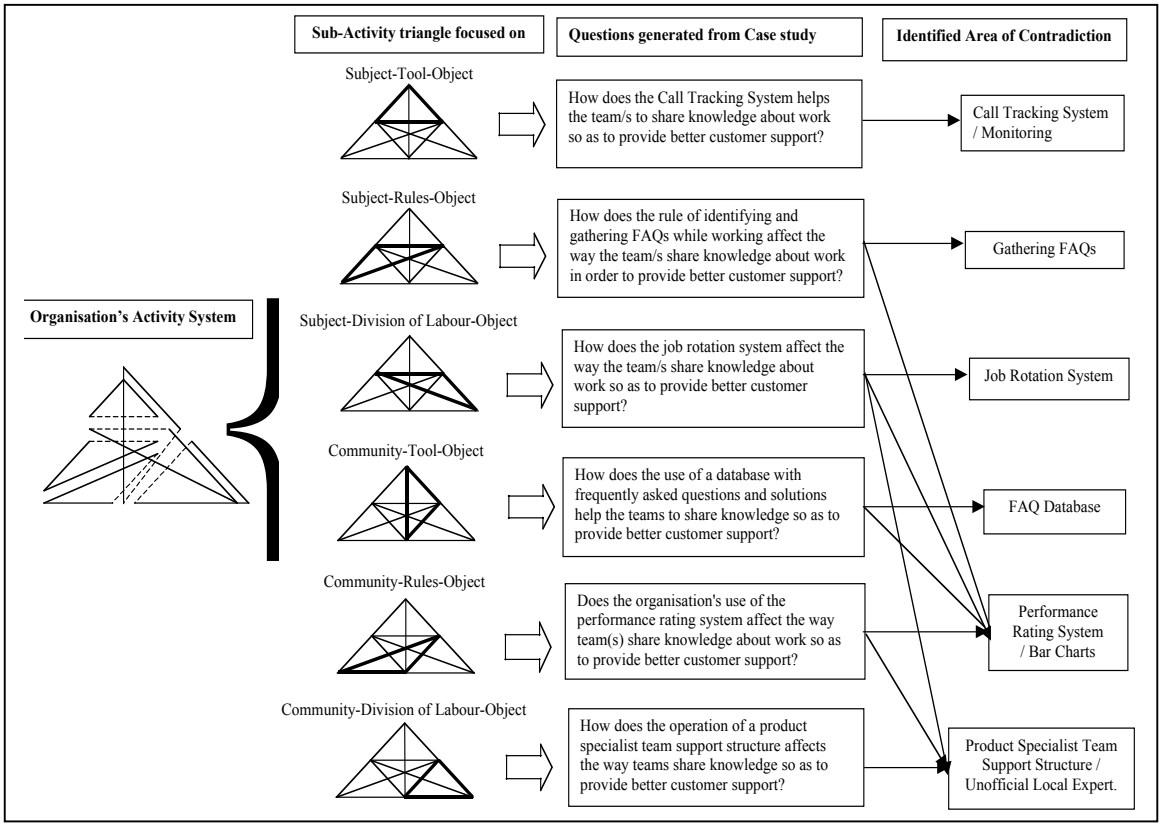

Figure 5: Mapping questions onto activity system

The first results from the use of 'bar charts' whilst the second emerges as a result of the team's work cultural norm of seeking help from a 'local unofficial expert'. Figure 5 shows the mapping between the sub-activity triangles, the generated questions and the potential areas of contradiction. Identified contradictions are discussed in detail in the findings section 6.6.

6.7 Interpreting Findings

The organisation's monitoring of both individuals and team performance through the use of weekly bar charts created a competitive work culture. In this culture, workers were concentrating more on improving their own performance ratings which meant resolving as many cases as possible. Therefore, the organisation's requirement that workers identify and gather FAQs for the database was seen by workers as a 'side-track' that would slow down the internal activity of resolving many cases in order to improve personal performance ratings. This situation created internal contradictions *within* the 'Rules' making sub-activity system as it was difficult to find a suitable compromise between working efficiently to improve personal ratings and finding time to reflect on work performances in order to gather suitable FAQs for the database.

More contradictions were identified *between* the 'Division of Labour' and Subjects' sub-activity systems as a result of the organisation's operation of a job rotation system. The job rotation system required workers to move around to other teams that were supporting completely different products. Different teams had different team work cultures. The job rotation system was introduced in the auspices of familiarising workers with other duties as a way of sharing knowledge that presumably would lead to better customer support. The analysis showed that this job rotation disturbed the team social and work culture through the frequent re-organisation and re-allocation of responsibilities. Teams were forced to accommodate people who joined or left the team. In situations where the unofficial local expert was suddenly moved to another team, the system introduced problems for them to 'fit in' with the new team. Even if the unofficial expert did fit in, there was no guarantee that he or she would command the same recognition of expertise. The competitive work culture also seemed to discourage some local unofficial experts from spending too much time helping others. The local unofficial experts felt that they needed to concentrate on improving their own performance ratings by resolving as many cases as quickly as possible.

7 Conclusion

We have made a case for the operationalisation of AT concepts for the purpose of guiding computer system design. In so doing, we have argued for a structured and replicable AT based methodology to support the requirements capture stage of the design process. In this paper we have proposed such a methodology and systematically outlined the development procedure for the methodology. We have also demonstrated using a case study, the means by which the proposed methodology can be applied to:

- Model the situation being investigated in terms of AT using the 8-step model by translating the various components of Engeström's activity triangle representation, thereafter to produce an activity system of the situation being examined.
- Capture user requirements and communicate these requirements to computer systems developers using the produced activity triangle system of the situation being examined.
- Decompose the produced activity system of the situation being examined using the activity notations and rules-of-thumb so as to reduce complexity by introducing smaller manageable units or sub-activity systems to work with.
- Generate research questions for use during the data gathering process as in interviews, questionnaires, and observations.
- Interpret findings by analysing and identifying possible contradictions in relationship *within* and *between* the various sub-activity systems that together make up the main activity system.
- Show the mapping between the questions generated and the activity triangle model of the situation being examined, vice versa.

In doing so, the paper has presented and demonstrated the application of a systematic AT based methodology for guiding computer system design.

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