Practice-centred e-Health System Design for Cross-Boundary Clinical Decision Support

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By

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Declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university, or other institution of learning

Abstract

The idea of cross-boundary clinical decision support has the potential to transform the design of future work environments for e-health through a connected healthcare system that allows for harnessing of information and peer opinion across geographical boundaries for better decision-making. The trouble, however, is that the use of healthcare information in decision-making usually occurs within the context of a complex structure of clinical work practices that is often shaped by a wide range of factors, including organisational culture, local work contexts, socially constructed traditions of actions, experiences and patients' circumstances. They vary across geographical boundaries, and have remained largely unaccounted for in the design of current e-health systems. As a result, achieving the visions of e-health, particularly in relation to cross-boundary clinical decision support, requires a rethinking of key clinical and organisational processes in a manner that accommodates work practice as a fundamental part of how clinicians work and make decisions in the real-world.

This thesis investigates the concept of work practice as a design requirement for cross-boundary clinical decision support systems in e-health. It is argued that the task of enabling informed decision support across geographical boundaries in e-health can be enhanced through an understanding, and a formal characterisation, of work practices in various healthcare work contexts, and a specification of how practice can be used, managed and transformed to suit various clinical problem situations and patients' needs. This research takes a clinical practice-centred approach to inform e-health system design, and draws on the concept of work practice and cultural-historical theory in social science as well as situation awareness in order to describe the local traditions of actions that guide clinicians' work in the real world. It contributes a coherent conceptual architecture comprising a practice-centred awareness model for cross-boundary awareness, a frame-based technique, named PracticeFrame, for formalising and representing work practice for system design, and ContextMorph, for adaptively transforming a suggestion across work boundaries to suit a user's local work context and practices.

An in-depth user-informed requirements capture was used to gain an understanding of clinical work practices for designing e-health system for cross-boundary decision support. A proof of concept prototype, named CaDHealth, which is based on the Brahms work practice modelling tool and includes a work practice visualisation model, named the practice display, was developed and used to conduct user-based evaluation. The evaluation revealed that incorporating practice-centred awareness enhances usefulness, acceptance and user adoption of e-health systems for cross-boundary clinical decision support.

Dedication

To my parents, who set me on course; and my wife, who bolstered me through the journey

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Selected Publications

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Abbreviations

Abbreviation	Meaning
AI	Artificial Intelligence
CBR	Case-based Reasoning
CDS	Clinical Decision Support
CDSS	Clinical Decision Support System
CHT	Cultural-Historical Theory
CPG	Clinical Practice Guideline
CSCW	Computer-Supported Cooperative Work
EBP	Evidence-based Practice
EIS	Enterprise Information System
GP	General Practitioner
GT	Grounded Theory
HCI	Human-Computer Interaction
HIN	Health Information Network
HIS	Health Information System
IS	Information System
PBE	Practice-based Evidence
SAGAT	Situation Awareness Global Assessment Technique
SAW	Situation Awareness
WfMS	Workflow Management System

1 Introduction

We perceive the world, we perceive others and they perceive us. The problem is that those perceptions are not reliable and that lack of reliability has real consequences in the world of work [and work support systems design].

– Paul Thompson and David McHugh, Work Organisations, 2009, p. 262

1.1 Background

Advances in information technology have created a "flat world" (Friedman, 2005) of networked sociality, and generated remarkable shifts in the way people get information and make decisions. Consequently, professionals in various sectors including healthcare, government and engineering have become increasingly attracted to the resultant form of collaboration as a way of leveraging collective intelligence and harnessing expert opinion across organisational, regional[1] and workgroup boundaries for better decision support (Brézillon and Araujo, 2005; Karacapilidis, 2005; 2008; Kock and Nosek, 2005; Stahl, 2006; Sari et al., 2008; Koch, 2008; Kock, 2008; Luzon, 2008).

Not surprisingly, this move has provoked a lot of research attention towards the re-design of our working environments (Sellen et al., 2002; Nof, 2003; Fernando, 2003; Schaffers et al., 2006; Nasirifard, 2007; Turner et al., 2010), particularly in the healthcare sector where knowledge sharing, often in the form of a "second opinion" (Miller, 2010; Mejia 2007, 2010), is both "a necessity and a common practice" (Abidi, 2006, p. 70). In routine healthcare, clinical decision-making transpires in the midst of problem-based "conversational encounters" (Vyas, 2011 p. 1) between clinicians about a clinical case at hand; joint critical appraisal of research evidence, published reviews, a clinical situation, guideline or administrative policy;

[1] In this thesis, regional boundary is used to refer to territorial boundary, i.e. a particular geographical area. As a result, cross-boundary as used in this work refers specifically to cross-geographical and cross-organisational boundaries, as opposed to cross-disciplinary boundary, e.g. boundaries between disciplines in the health domain.

team-based formulation of a care plan or workflow; referrals to a secondary care specialist; and provision of therapeutic or health maintenance information to patients and their care givers (Abidi, 2006). Typically, these intra-organisational decision support activities are orchestrated in an uncharted and informal manner, often occur interactively and extemporaneously (Whittaker et al., 1994; Bardram et al., 2006; Mejia 2007, 2010), but are largely driven by a common ground (Kuziemsky and Varpio, 2010) offered by the clinicians' shared work context and "knowledge-in-practice-in-context" (Gabbay and le May, 2011, p. 64). As e-health envisions a pervasive healthcare environment in which practitioners share knowledge across geographical, regional and workplace boundaries in a way that adapts to user work context, it becomes imperative for research to ascertain whether the same efficiency and seamlessness that has sustained this culture of ad hoc knowledge sharing and decision support in co-located healthcare working environments can transfer easily to cross-boundary decision support in e-health, and to investigate ways in which technology can help in addressing the challenge.

Research in human-computer interaction (Dourish, 2004), social science (Suchman, 1987) and healthcare (Boulus and Bjorn, 2010; Gabbay and le May, 2011) has shown that human work is *contextual* (Kirsh, 2001) in the sense that it depends on *situations* in the environment in which work unfolds (Giunchiglia, 1993). As a result, one of the core premises of context-awareness research in computer science is to design systems with the capability to adapt to specific circumstances and settings of user activity (Dourish, 2004; Kirsch-Pinheiro et al., 2004). Nevertheless, the notion of context usually adopted by predominant system design approaches is limited to some physical aspects, e.g. user and device location (Dey, 2001, Dey et al., 2001), and groupware (Kirsch-Pinheiro et al., 2004; Brézillon et al., 2004). Only a few systems associate the notion of awareness to other concepts. For instance, (Kirsh, 2001) notes that in tracking context of work, we need go beyond the superficial attributes of who and what is where and when, to consider the highly structured amalgam of informational, physical and conceptual resources that comprise "the state of digital resources, people's concepts and mental state, task state, social relations, and the local work culture" (p. 305).

Realising the vision of cross-boundary decision support in e-health, therefore, makes it imperative for system design to incorporate awareness mechanisms that exploit the notion of *work practice* in modelling context of work. The general notion of work practice has been present in such classical fields as cultural-historical psychology since the 1920s both as a way of understanding the structural dynamics that organise people's actions in real-world decision-making and as a source of psychological contents for problem-solving acquired by individuals (Leont'ev, 1978; Vygotsky, 1978; Robbins, 2006; Chaiklin, 2011), but has remained hugely invisible in a majority of requirements engineering and formalisation practices in traditional system design (Karasti, 2001). In their critiques of conventional system design, social scientists (Suchman, 1987; Nardi and Engeström, 1998) have often pointed out that prevailing design approaches portray a remarkable degree of insensitivity to the details of specific settings of system use with much emphasis on technology development whereas "the actual ways in which these technologies are used appear less significant" (Karasti, 2001, p. 15).

Incorporating awareness mechanisms that exploit the notion of work practice in modelling context of work will lead to *a common ground* for cross-boundary decision support based on *awareness* of one another's work contexts, including local work practices, improvisation strategies, institutional agenda and patients' needs based on real-world situations across work environments. Awareness has been shown to enable interactive decision support in the same place work environments (Bardram and Hansen, 2010), since all the information and artifacts necessary for a work process to achieve its objective are embodied within the work context (Nunes et al., 2009). As a result, effective problem-solving and decision becomes largely dependent on a practitioner's awarereness of what happens with available information and work artifacts, and of the changes in the work context. Within computer-supported co-operative work (CSCW) and groupware design, the notion of awareness is central to an extensive body of research that has established how maintaining awareness of one another's working context enables successful problem-solving, and enhances efficient coordination, collaboration and knowledge sharing amongst co-workers (Heath and Luff, 1992; Heath et al., 2002; Schmidt, 2002; Martinez-Carreras et al., 2011). It emphasizes that people who are situated in close physical proximity are more likely to collaborate on projects because of "the power of local ties" (Boh et al., 2007, p. 596), since they share a common work context, and are easily able to engage in "informal conversational encounters" (Vyas, 2011 p. 1).

Existing e-health systems lack sufficient capability to support problem-solving and facilitate clinical decision support based on practice-centred knowledge about a work situation. This provokes a number of challenges for cross-boundary decision support. How do we enable cross-boundary clinical decision support in a manner that allows for the construction of awareness of a clinical work process at the work practice level? Would such approach sufficiently take account of the situated and socially mediated nature of located work practices, clinical encounters, organisational circumstances and patients' specific needs? How do we enable accurate perceptions of work situations across boundaries of workplaces and organisations? How do we enable a suggestion or "second opinion" emanating from a user in a remote organisation to be easily applied to support problem-solving and decision-making in another work context in spite of the lack of shared context of work for supporting cohesive interaction and knowledge sharing between the work settings?

1.2 Proposed Solution

This thesis proposes a practice-centred approach for the design of context-aware e-health systems for cross-boundary clinical decision support. The goal is to explore the concept of work practice as a design requirement for developing cross-boundary clinical decision support systems for e-health. A central argument at the core of the proposed solution is that the incorporation of an awareness mechanism centred on the notion of work practice, which we refer to as *practice-centred awareness (PCA)* would potentially lead to increased awareness of the contexts and situations of clinical work and, consequently, more effective cross-boundary clinical decision support in e-health. The proposed architecture includes a conceptual model of PCA for cross-boundary clinical decision support in e-health, a technique for adapting suggestions for clinical decision support to user's local work context, which we refer to as *ContextMorph*, an implementation of the proposed model, which we refer to as CaDHealth (**C**ontext-**A**ware cross-boundary clinical **D**ecision support system in e-**Health**), and a multi-method approach for evaluating the usability and utility of the approach.

The reality of work is that, in spite of rules, policies and guidelines, people often solve problems and achieve intelligent actions by improvising knowledge, adapting rules, and applying available resources in ways that correspond with their perceptions of the situation and of the possible consequences. Studies have shown this occurs at the work practice level (Clancey et al., 1998) – the level at which work unfolds as a part of "the mundane aspects of complex socially organised activities in everyday settings" (Karasti, 2001, p. 130), including both the smoothly organised routine ways of working and accustomed procedures that have evolved during years and the problematic situations that rise and become handled by practitioners as part and parcel of everyday work practice – rather than at the task (Chandrasekaran, 1990), procedure (Brézillon, 2007) or activity (Geyer et al., 2006; Bardram, 2009) levels. Although these approaches provide a well-defined structure for making sense of work, they lack mechanisms for representing history of interaction, assume a partial or static view of context, and hardly take account of the various ways by which activities subsume and constrain each other. The use of clinical guidelines, for example, which is highly task-specific, organisation-dependent and activity-based, "ignores the sheer breadth and variability of the multifarious considerations the clinician needs to take into account" (Gabbay and le May, 2011, p. 38) as an inherent part of a clinical decision-making process that only becomes apparent at the work practice level. Work practice denotes "lived work" (Button and Harper, 1996, p. 264), since it concerns "work as experienced by those who engage in it" (p. 264), especially how "recognisable categories of work are assembled in the real-time actions and interactions of workers" (p. 264) and how those workers "reconfigure their organisation and tools to bring resources to bear on a given situation" (Clancey et al., 1998).

The proposed solution builds on approaches, languages and tools for modelling work practices for system design have been proposed (Clancey, 2002; Brézillon, 2007; Bordini et al., 2007; Sierhuis et al., 2009) to further uncover the patterns, practices, stereotypes and contexts of specific clinical work settings for the desingn of context-aware e-health systems for cross-boundary clinical decision support. The approach adopts a user-centred approach, and draws upon cultural-historical theory, context modelling and situation awareness techniques for modelling work practice.

1.3 Key Research Questions

This thesis attempts to comprehensively address two research interests: 1) an attempt to sensitise the design of work support systems and environments towards taking account of work practice as a central part of the specification of context of work, and 2) an approach for realising this through the design of a context-aware e-health system for cross-boundary clinical decision support. In what follows, we translate these research issues into a single precisely defined research question that defines the primary contribution of this work.

To begin, an attempt to sensitise the design of work environments and systems towards accommodating work practice as a central part of the specification of context of work (Kirsh, 2001) echoes established lines of research in the social sciences (Schön, 1983; Suchman, 1987; Nonaka and Takeuchi, 1995; Luff et al., 2000; Karasti, 2001; Schatzki, 2010), healthcare (Montgomery, 2006; lé May, 2009; Harrison et al., 2010; Gabbay and lé May, 2011), HCI (Button and Harper, 1996; Büscher et al., 2001; Dourish, 2004; Clancey, 2006) and decision support systems (Brézillon, 2007; Bucur et al., 2006; Burstein et al., 2010), which argue that work practices are a fundamental part of the ways people work. As such, approaches for designing computational systems for (cross-boundary) decision support should take account of work practices as the structural dynamics that organise people's actions in the real-world (Robinson, 1993; Button and Harper, 1996; Büscher et al., 2001; Chaiklin, 2007; Burstein et al., 2010). However, marrying this understanding to the task of designing computational systems with the capability to gain awareness of work situations across organisational, regional and geographical boundaries for effective cross-boundary decision support is yet to be fully investigated. The ultimate goal, coming from a systems design perspective, is highly crucial for the design of systems that are more usable to humans.

In seeking to address this challenge, we have arrived at a number of questions: Can an understanding of the work context and situation of a remote individual, from the perspective of their work practices, enable a degree of awareness that is sufficiently seamless to facilitate effective cross-boundary decision support? Can we construct a work context model capable of computer-based representations of the wide range of factors that could be used to characterise a work situation at the work practice level? Can we design systems capable of supporting decision-making based on such practice-centred knowledge? And finally, can PCA increase the usability and utility of cross-boundary decision support systems? These questions come with a number of implicit assumptions that we need to expose. The assumptions, particularly when considered in relation to the wide range of factors that constitute work practice (e.g. in healthcare, Gabbay and le May, 2011), centre around underlying questions of the feasibility, practicality and attractiveness of designing systems for cross-boundary awareness and decision support from a practice-centred perspective. In more pragmatic terms, they border on issues of how to capture, represent and prototype work practice, and evaluate a practice-centred system.

With a mind set on improving the design of e-health systems for cross-boundary awareness and decision support, we hypothesize that *the task of enabling cross-boundary clinical decision support in e-health, can be addressed, with acceptable results, through an understanding, and a formal characterisation, of the types and dimensions of context in various e-health work settings and a specification of how context can be used, managed and transformed to suit various clinical problem-solving situations.* In investigating this, we aim to examine and model context from the point of view of practice, i.e. the needs and products around which people reconfigure their organisations and tools in order to bring resources to bear on a given work situation (Clancey et al., 1998). This approach to investigation context resonates with recent research efforts at expanding the definition of context from physical attributes to include organisational, human and device characteristics such as workplace-specific factors, regional policies, device availabilities, prevailing circumstances, and user-specific factors, profiles and preferences (Dey, 2001; Morán and Dourish, 2001; Feng et al., 2009; Nunes et al., 2009; Nwiabu et al., 2011). Logically, to increase the realism of work practice and PCA models and to design effective cross-boundary decision systems for e-health, one needs to account for the structural dynamics that shape people's actions and activities during work (Chaiklin, 2011).

1.4 Aim and Objectives

The aim of this thesis is to develop a framework *for cross-boundary awareness and clinical decision support in e-health that accommodates work practice as a fundamental requirement of e-health system design.* In order to achieve this aim of taking a practice-centred approach to e-health systems design, this thesis has the following three objectives:

- To conduct an in-depth study aimed to understand and formalise clinical work practice to inform the design of e-health systems for cross-boundary decision support,

- To develop a comprehensive framework and system architecture for cross-boundary clinical decision support in e-health that takes account of clinical work practice as a fundamental way part of how clinicians work and make decisions in the real-world, and
- To validate and evaluate the proposed architecture using a proof of concept prototype in order to assess its acceptability, usability and usefulness from the perspective of potential users.

1.5 Scope and Methodology

In literature, there exist two views of context that have predominantly influenced research investigations in context-aware systems design, viz: a view of context as put forward by the positivist engineering tradition and a view of context as espoused by the phenomenological social tradition (Dourish, 2004). The former is a technical notion, and defines the problem of context-aware system design as one of encoding and representing context as changes or cues in a computational environment, often captured using sensor technologies. It is the prevalent approach in mainstream context-aware computing research (Dey, 2001), and offers system developers new ways to conceptualise human action and the relationship between that action and computational systems to support it (Dourish, 2004, p. 20). Using this approach, one is fundamentally guided by the question: what is context and how can it be encoded? On the other hand, the latter view is a notion drawn from social science, which draws analytic attention to certain aspects of social settings (Nardi, 1996; Goldkuhl and Röstlinger, 2006; Anderson, 2007). This approach assumes an interactional model of context, and argues that the representational stance of the positivist engineering tradition, which views context as "a stable feature of the world, independent of the actions of individuals" (Dourish, 2004, p. 22), is a misunderstanding of the nature and role of contextuality in shaping human actions in the real-world.

In this thesis, we apply the phenomenological social tradition approach to developing a PCA model for the design of cross-boundary clinical decision support systems for e-health. By primarily using user-centred methods, this thesis addresses the research question in Section 1.3 by investigating how we can design e-health systems for cross-boundary clinical decision support that accommodates the work practices that are a fundamental part of the ways clinicians work (Gabbay and lé May, 2011). The goal is to enable clinicians working independently across organisational and regional boundaries to provide suggestions to support one another's decision-making in a manner that fits within the user's local work context, social settings and practices and adapts to their problem requirements and patient's needs.

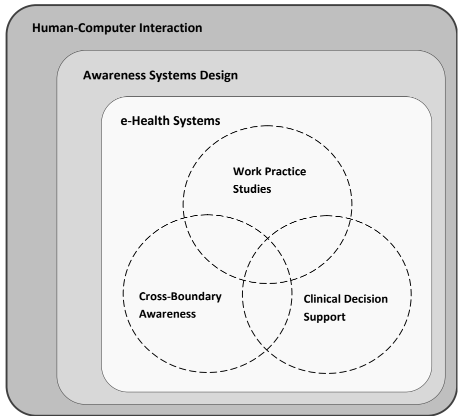

Figure 1.1: Overview of the thesis components

In this research, we have followed primarily a user-centred methodology, and the work we have done includes the following.

- User-centred study of (clinical) work practices: We have conducted a user-centred study of clinical work practices across three countries, namely the UK, the UAE and Nigeria using a mixed method approach (Creswell and Plano Clark, 2007), including grounded theory (Glaser and Strauss, 1967) and a novel technique, which we refer to as *practice probe*. The goal is to provide an empirical basis for developing the concept of PCA, and to identify design requirements to inform the development of technological support for cross-boundary awareness and decision support in e-health.
- Development of conceptual architecture: Based on the results of the study, we outlined a set of design insights to help designers to incorporate mechanisms that improve the design of e-health systems for cross-boundary awareness and decision support at the work practice, and proposed a conceptual model for PCA.
- Fomalisation and prototyping: We developed a formalisation of the PCA model, and an approach for representing work practice known as *PracticeFrame*. An instance of the PCA model has been implemented as the CaDHealth prototype with a visualisation

mechanism for PCA for cross-boundary decision support, which we refer to as *the practice display*.

- Evaluation: We have used a multi-method approach to evaluate the prototype developed in the previous phases. The approach included experimentation, questionnaire and interview techniques, and the (work) situation awareness evaluation technique (Endsley and Garland, 2000).

This research is at the intersection of computer science and social science, and speaks to the relationship between the two by combining social theory, user-centred study and system design. The work is framed within the context of human-computer interaction (Markopoulos and Mackay, 2009), and has drawn upon work practice studies to develop a model for cross-boundary awareness for the purpose of improving the design of e-health systems, specifically for distributed (cross-boundary) clinical decision support (see Figure 1.1). Throughout the work, our perspective has been that of the computer scientist and user-centred designer.

1.6 Contributions

The central focus of this thesis is to investigate the concept of work practice as a design requirement for developing context-aware e-health systems for cross-boundary clinical decision support. By analyzing and applying the notion of work practice in creating a PCA model for cross-boundary decision support, this work contributes to the research areas of user-centred e-health and work support systems design, and, more generally, to the fields of distributed decision support, awareness systems and human-computer interaction (HCI). We note that the idea of applying social science concepts to building context-aware systems is a subject of enormous and still ongoing research involving a wide range of communities in computer and social sciences (Robinson, 1993; Button and Harper, 1996; Nardi, 1996; Schatzki, 2010; Suchman et al., 1999; Schmidt, 2000; Luff et al., 2000; Dayton, 2000; Dourish, 2004; Gay and Hembrooke, 2004; Clancey, 2006; Geyer et al., 2006; Bucur et al., 2006; Goldkuhl and Röstlinger, 2006; Schmidt et al., 2007; Chaiklin, 2007; Bordini et al., 2007; Riemer and Haines, 2008; Allert and Richter, 2008; Anya et al., 2010; Brézillon, 2011; Szymanski et al., 2011; Tawfik et al., 2012). As such, the positions and conceptual definitions developed in this work may be treated as "working definitions or hypotheses" for serving the current purpose rather than claims of universal nature. We outline below the three key scientific contributions of this work.

- We identify and define PCA as a design requirement for cross-boundary clinical decision support systems in e-health. Research in HCI, computer-supported co-operative work (CSCW), informatics and work practice modelling has previously recognised the importance of work practice for system design, but the nature and mechanics of how work practices shape problem-solving and decision-making in various real-world clinical work situations have not been articulated. Related work has focused on activity, and tends to treat practice as a background concept (Geyer, 2006; Bardram, 2009; Bardram et al., 2012). By identifying and defining work practice as a key part of the way people work, this thesis provides, for system designers, an alternative view on decision-making in organisation.
- We propose a conceptual architecture based on the concept of work practice for the design of context-aware e-health systems for cross-boundary clinical decision support. A novelty of the architecture is that it models work context using a holistic approach that makes a necessary separation between the three means by which people acquire the ability to work within a work practice – the ontological work practice, the stereotyped work practice, and the situated work practice. The architecture includes two techniques for formally representing work practices called *PracticeFrame*, and for transforming or "morphing" work practices for cross-boundary decision support called *ContextMorph*.
- We present an approach for enhancing the usability and usefulness of cross-boundary clinical decision support systems through the incorporation of PCA information in the form of visualisation display – the practice display. The approach puts intuitions about the importance of PCA on an empirical footing, increases knowledge about how PCA support could be made effective, and contributes to the design of more usable pervasive decision support systems in e-health by reducing the need for explicit input, since PCA information is generated by the system as a result of a deep-seated practice-centred understanding of a work situation.

This work includes a number of other minor contributions. First, we introduce *a technique for capturing and eliciting work practice information for system design*, which we refer to as practice probes as well as *a frame-based model (*McCarthy and Hayes, 1968*) for representing work practice*, which we refer to PracticeFrame. Second, we identify *four modes of cross-boundary decision support for e-health*, which could apply to cross-boundary decision support in other fields such as e-business and manufacturing. Third, this study increases *understanding about the tension between designing decision support systems for face-to-face interaction and designing for cross-boundary collaboration* among individuals working independently, and highlighted the role of work practice awareness in achieving this. These contributions are discussed further in the remaining part of this thesis.

2

e-Health and the Problem of Cross-Boundary Clinical Decision Support

Human experts are not systems of rules, they are libraries of experiences.
– Christopher Riesbeck and Roger Schank, Inside Case-based Reasoning, 1989, p. 15

2.1 Introduction

In this chapter, a number of background issues related to the analysis of our research problem, namely how to design e-health systems for cross-boundary clinical decision support, are covered. In particular, the three foundational concerns of this work – cross-boundary clinical decision support in e-health, the nature of clinical work, and the notion of awareness – which will set the framework for, and delimit the arguments encompassed by, later discussions in the thesis, are explored. It is shown, through a critical review of existing literature, that a competent and accountable use of a system in a hospital is inseparable from a body of local work practices (Chaiklin, 2011; Gabbay and le May, 2011; Schatzki, 1996; Button and Harper, 1996; Brézillon, 2007; Allert and Richter, 2008; Tawfik et al., 2012) that go beyond clinical workflow representations (Lawrence, 1997; Essex, 2000; Barretto, 2005; Lee et al., 2010; Huser et al., 2011), and through which an awareness of real-world clinical contexts, implicit local work structures, constraints and specific patient-centred needs could be constructed to facilitate effective cross-boundary clinical decision support. Our goal is to present a theoretical basis for the operationalisation of our notion of PCA for cross-boundary clinical decision support in e-health.

2.2 Clinical Decision Support

The use of computers in healthcare is arguably one of "the oldest" applications of information technology. Efforts to automate aspects of healthcare began in earnest as far back as late 1950s (Shortliffe et al., 1973; Musen et al., 2000; Greenes, 2007; Berner and La Lande, 2007). Major incentives for pursuing the use of computers in healthcare were compelling, and chief among them was decision support, which, according to (Shortliffe, 2006), lies at the heart of healthcare informatics. Early intentions were even more ambitious, and included building computer programs that could simulate the decision-making ability of a human expert (Shortliffe et al., 1973).

Rather than "replacing clinical expertise", later efforts were focused on assisting clinicians at the point of care[2]. As a result, there has been a remarkable shift towards programs that can assist in decision-making in real-world clinical contexts. These programs incorporate knowledge models that manipulate guidelines and data in order to simplify access to information needed to make critical decisions by providing reminders and alerts in a clinical encounter, assisting in establishing a diagnosis, recommending appropriate prescription orders, helping busy clinicians avoid errors, and improve overall efficiency in healthcare. However notwithstanding a number of convincing demonstrations of effectiveness in particular cases, “the adoption of CDS [in healthcare] has proceeded at a snail’s pace” (Greenes, 2007, p. xi; Sittig et al., 2008).

2.2.1 Clinical Decision Support versus Clinical Work Process

A review of literature across work practice studies (Button and Harper, 1996; Luff et al., 2000; Büscher et al., 2001; Baxter and Lyytinen, 2005; Nunes et al., 2009; Szymanski and Jack, 2011), clinical reasoning and decision support (Shortliffe, 2006; Benner et al., 2008; Gabbay and le May, 2011), context-based awareness (Dourish, 2004; Bardram and Hansen, 2010), and social aspects of HCI and IS design (Suchman, 1987; Winograd and Flores, 1987) reveals a number of reasons. However, upon reflection, two stand out prominently, and are particularly pertinent to the concerns that we seek to address in this research work. On one hand, research in CDS has (and quite understandably too) been influenced by rule-based paradigm of the first generation CDS systems, such as MYCIN (Shortliffe et al., 1973), even though CDS architecture has since evolved to its current state-of-the-art service-oriented

[2] The early goal of developing CDSSs that can function at the level of human expertise was regarded as one of the three myths of CDSSs. At the 2006 Conference on Medical Thinking held at University College, London Ted Shortliffe challenged the assumption, among others, noting that there is tremendous variation in practice, even among “experts”, which means that expertise can only be fully understood in relation to context of work (Shortliffe, 2006).

model (Wright and Sittig, 2008). The rule-based approach, besides being a core offshoot of the then-dominant "plan-based" paradigm in HCI and AI, derives heavily from prevailing scientific view and conceptualisations of clinical work as consisting of formal, protocol-driven and evidence-based procedures (Gabbay and le May, 2011).

On the other hand, clinicians often view themselves as "experts" in their own particular subject domains, keep up with the literature, apply tacit experiences to guide their actions, and do not, as a result, feel a compelling need for "rule-based" computers to make major recommendations (Greenes, 2007, p. xiii). This is because clinical work "in practice" is not "rule-based", but, rather, involves a good degree of "non-rule-based" actions and improvisation techniques. Several writers, including (Schön, 1983; Suchman, 1987; Riesbeck and Schank, 1989; Eraut, 1994; Fish and Coles, 1998; de Camargo and Coeli, 2006; Gabbay and le May, 2011), have pointed out that experts are hardly "systems of rules", but are, instead, constantly seeking to construct solutions based on local circumstances, organisational culture, experiences, tacit guidelines, and professional artistry. Schön (1983) notes that there exists a huge "gap between formal professional knowledge and the demands of real-world practice" (p. 45), arguing that many of the problems that clinical practitioners face are so complex and often indeterminate that no clear solution can be arrived at based on abstract rules. Gawande (2002) argues that the gap, within which clinical decisions occur, is located between what he calls "the simplicities of science" and "the complexities of individual lives", noting that it is there that one finds the moments of medicine, and indeed clinical decision making. He referred to this moment as that "in which [a clinician] can see and begin to think about the working of things as they are" (p.7). According to Gawande, this gap persists because:

> We look for medicine to be an orderly field of knowledge and procedure. But it is not. It is an imperfect science, an enterprise of constantly changing knowledge, uncertain information, fallible individuals ... As pervasive as medicine has become in modern life, it remains mostly hidden and often misunderstood. We have taken it to be more perfect than it is and less ordinary than it can be. (pp. 7-8)

A similar notion is highlighted in (Fish and Cole, 1998), who construct two views of professional practice, which they refer to as "technical rational" and "professional artistry". They note that technical rational thinking prevails where rules and norms apply, but begins to fade and give way to professional artistry, as soon as the work context starts to embrace uncertainty and “the moments of medicine” begins to hold sway. In their ethnographic study of clinical practices in the UK, (Gabbay and le May, 2011) observe that, during such moments, most clinicians find it very difficult to explain their actions based on any known rules. They concluded that clinical decision-making “in practice” involves what they call “clinical mindlines” – a set of internalized, tacit-based and collectively reinforced guidelines that serve as the clinicians’ “knowledge-in-practice-in-context – which emphasizes the fact that it is context and practice, rather than rules, that dynamically guide actions during clinical decision making.

These studies underwrite a common emphasis – namely that there is a mismatch between the fundamental approach in the design of CDS, which is *dominantly protocol-based*, and the experience of real-world clinical problem-solving and decision making, which is *prevalently practice-centred*. However, in as much as there is a *gap* between protocol and practice, i.e. where the moments of clinical decision-making occur; there is also a *bond* between them that uniquely and artistically guides actions of clinicians during decision making. This interplay between practice and protocol is well highlighted in many studies, including (Greenes, 2007; Gawande, 2002; Fish and Cole, 1998; Suchman, 1987). Gabbay and le May (2011), for example note that such interplay:

> [U]sually involve an element of *craft*, [emphasis in original] which cannot succeed without some degree of skilled improvisation that *builds on any original theory-based plan of action.* [emphasis not in original] (p. 61)

Rules, according to the authors, provide the foundation upon which improvisational actions are built. The argument that improvisation builds on theories and plans has also been at the core of Suchman’s situated action model. Plans, she argues, comprise the "artifact of our *reasoning about* action, not ... the generative *mechanism* of action" (Suchman, 1987, p. 39, emphasis in original). Gawande (2002, p. 7) points out that science and rule-based procedures are as much as “habit, intuition, and sometimes plain old guessing”, equally involved in clinical work. The underlying argument, here, is that while plans and formal theory provide a pre-designed arrangement and the basis for the take-off of a clinical work process, *practice-centred actions*, in tune with ad hoc circumstances and local contingencies, shape how the given task actually gets accomplished. Recently, a number of research efforts in CDS have investigated design approaches that take cognisance of this dichotomy and bond between plans and practice. However, as we move to ensuring that "optimal, usable and effective CDS is widely available … where and when … to make healthcare decisions" (Osheroff et al., 2007, p. 141), it becomes increasingly imperative that these challenges be addressed.

2.2.2 Clinical Decision Support versus Clinical Workflows

Another key aspect of CDS was integration with routine workflow (Shortliffe, 2006). The focus was to generate case specific advice out of a bundle of a medical knowledge base, patient data and an inference engine, consisting of rules and guidelines. Not surprisingly, this led to a re-definition, among researchers and practitioners, of the notion of CDS as broadly "providing clinicians or patients with computer-generated clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care" (Osheroff et al., 2007). In what follows, we discuss a number of guideline-related concepts that represent those that are particularly relevant to this work.

Clinical guidelines derive from the much broader concept of workflow. The WfMC[3] defines workflow as "the automation of procedures [in whole or part] where documents, information or tasks are passed between participants according to a defined set of rules" (Hollingsworth, 1995, p. 6). Workflow is often associated with business process modelling, which is concerned with the assessment, analysis and (re-) design of workflows and task processes of an organisation with a focus on operational procedures. Often, an organisation's workflow includes the set of processes that need to be accomplished as well as the set of people or other resources available for performing those processes and the interactions among them (Cain and Haque, 2008, p. 217). Research in workflow modelling is mostly concerned with the central question of how to incorporate flexibility into an organisation's operational procedures with a view to formally and procedurally representing the complexity of a work situation, and cater for changes that occur in work practices. This raises a lot of issues (Adams et al., 2003); workflows place huge emphasis on the flow paradigm, and as such are traditionally applied in fields such as order processing, document management, travel and insurance claims.

[3] A global coalition of adopters, developers, consultants, analysts, as well as university and research groups engaged in defining standards for the interoperability of workflows and business process models. For more information, visit http://www.wfmc.org/

Clinical practice guidelines (CPG) are "a set of schematic plans for management of patients who have a particular clinical condition" (Miksch et al., 1997) that typically comprise a locally standardised algorithm (Barretto, 2005). Pathways are institution-specific and process-oriented, and comprise set of procedures and outcome target for managing the overall care of a specific type of patient (Barretto, 2005, p. 36) and are usually utilised by a multidisciplinary team with a focus on co-ordination of care. Clinical guidelines are, often, based on generic clinical evidence; while pathways tend to be patient-specific and usually incorporate other non-clinical aspects of care, such cost of care, etc. The National Institute for Health and Clinical Excellence (NICE), UK observe that clinical guidelines are based on the best available evidence with the aim of assisting clinicians in their work, but they do not replace the clinicians' knowledge and skills[4]. Protocols are developed subject to organisational policies and are often based on evidence in order to define the manner in which certain classes of patients must be evaluated or treated. As a result, are often preferred when there is little time to make decisions and little data available to base decisions on (Barretto, 2005, p. 31).

One of the major roles of workflows in CDS is to provide the framework or skeleton upon which the logic of CDS is built. A number of researches have sought to support workflow in CDS, including the UK-based PRO*forma* (Humber et al., 2001) and Map of Medicine (Stein, 2006), the University of Pavia's careflow (Stefanelli, 2002), the Guideline Interchange Format – GLIF (Boxwala et al., 2004) and Asbru (Shahar et al., 1998; Votruba et al., 2004). The PRO*forma* approach is founded on an executable process modelling language and grounded in a logical model of decision-making and plan enactment. Decisions are defined in terms of a set of options with an argumentation mechanism to choose between alternatives (Lacson, 2000, p. 33). PRO*forma* has been used successfully to build and deploy a range of clinical decision support applications (Sutton and Fox, 2003), and is increasingly being applied to others areas of healthcare[5]. However, while PRO*forma* languages permit the description of "Task Network Models" (Sutton et al., 2006), and are potentially effective in modelling the flow of decision making, they lack the capability to model the higher levels of

[4] http://guidance.nice.org.uk/CG

[5] For example, the scope of PRO*forma*-integrated guideline modelling methods and technologies is expanding into Workflow Management Systems (WfMS). Such increase in application is, part, a result of the fact that it is one of a number of recent proposals for representing clinical protocols and guidelines in a machine-executable format, see www.openclinical.org

inter-task coordination or to sufficiently account for other contextual or practice-related factors that influence decision-making in a practical context. Map of Medicine is a care pathway tool, a kind of care map, with the aim of “presenting pathways of best practice for conditions that are not normally seen in general practice”. As a clinical process model, it empowers healthcare professionals to "localise" healthcare product, and "facilitates standardisation of practice and minimisation of risk of variation in patient treatment across the healthcare system whilst leaving enough flexibility so as not to stifle innovation" (Stein, 2006, p. 1196). Map of Medicine includes a graphical representation tool that ensures that “clinical thinking and process is pared down to digestible chunks” (Stein, 2006, p. 1196); however, the concept remains to be fully evaluated.

Rather than focusing just on descriptions of clinical work activities in a manner that allows for the definition of best practice for patient management; careflow focuses on the behavioural aspects of clinical work with regard to a possible support of their execution through advanced ICT (Stefanelli, 2002). In that sense, careflow systems are patient-centred forms of workflows by seeking to model a workflow within a specific clinical domain and case (Panzarasa et al., 2002). Stefanelli (2002) reports that both intra- and inter-organisational implementations of careflow systems exist. Inter-organisational models highlight the growing need for cross-boundary collaboration and "second opinion" support among clinicians, and "offers healthcare organisations the opportunity to re-shape [their] healthcare processes beyond the boundaries of their own organisations" (Stefanelli, 2002). However, inter-organisational careflow is typically subject to conflicting constraints; including the need for coordination in order to optimise flow of care in and between different healthcare organisations as well as how to reconcile differences in organisational procedures and circumstances considering the fact each organisation is essentially autonomous (van der Aalst, 1998). One can, therefore, infer that part of the reason for this is the lack of effective support for practice-related issues that affect clinical decisions in different work settings.

Two other workflow-based specifications – GLIF and Asbru support clinical decision-making through sharing of computer-interpretable clinical guidelines across different medical institutions, settings and system platforms[6] and explicit representation of CPG intentions, patient states and prescribed actions respectively. GLIF leverages standards developed in the HL7 and defines an ontology for representing medical concepts, data and guidelines, and enables encoding of a CPG at three levels: a conceptual flowchart, a computable specification that can be verified for logical consistency and completeness, and an implementable specification that is intended to be incorporated into particular institutional information systems (Boxwala et al., 2004). The decision model in GLIF supports a hierarchy of decision step classes, which includes case steps and choice steps. The case step can be automatically executed, whereas the choice step is ideal where multiple decisions for consecutive options have to be made by the user and cannot be automated, and is particularly flexible in allowing for ways to decide between competing alternatives in a guideline (Lacson, 2000, p. 39-40). Asbru is a task-specific and include temporal patterns (Shahar et al., 1998; Lacson, 2000, p. 34). Its central goal is to embody clinical guidelines and protocols as time-oriented skeletal plans (Shahar et al., 1998; Seyfang et al., 2009). Unlike other guidelines, which are largely rule and algorithm based, Asbru supports the application of a CPG in practice by enabling the intentions and goals of a CPG as well as the temporal dimensions and uncertainties to be defined as an intrinsic part of that CPG.

Though workflow-based approaches have contributed to considerable reduction in sub-optimal care and medical errors (IOM, 2000), and revealed unwarranted practice variations (McPherson et al., 1982; Appleby et al., 2011) among clinical service providers, they have recently come under heavy criticisms because of their inability to relate sufficiently well to real-world clinical contexts. Some of the criticisms appear to raise deepening concerns in view of recent expositions that describe clinical work as activities "taking place in a multidimensional space than as prescription of temporal task sequences" (Robinson, 1993, p. 187). They often fail to capture the social dynamics (e.g. perspectives, negotiation, conflicts and resource availabilities) that arise in the course of care. The primary outcomes of guidelines, protocols and pathways are a sequence of steps encapsulated in textually mediated artefacts, such as manuals and scripts. Gabbay and le May (2011, p. 65) argue that such representations hardly depict clinicians' use of knowledge in real-world clinical contexts,

[6] http://www.openclinical.org/gmm_glif.html

noting that instead of using knowledge in a linear way, clinicians solve problem based on their perception of the social context, of the circumstances and of the possible consequences. The authors contend that in reality “guidelines do not even come close to dealing with all the considerations that a clinician needs to weigh up not as a mere add-on but as an *inherent* part of dealing with clinical problems” (p. 38).

In a study of the use of workflow systems to make sense of activities on the shop floor in the printing industry, (Bowers et al., 1995) note that *there is a high degree of difference between people's indigenous work practices and the order provided by such systems*. They suggest that workflows, in such cases, are seen as technologies for organisational ordering and accountability, rather than tools for supporting work practices. While the potentials of workflow-based technologies and CPGs to coordinate services and improve communication and care management within healthcare processes have been widely acknowledged, the real goal is rarely accomplished in practice primarily because of implementation challenges (Barretto, 2005, p. 9). Part of the challenges derives from the fact that workflows are organisation-specific and mostly involve tightly coupled sequential task execution that hardly plays out well in real-world situations “when things were out of the ordinary” (Gabbay and le May, 2011, p. 94). Studies, such as (Cain and Haque, 2008), point out that clinical workflow-based methods can be easily used to get work done under normal circumstances, but can become difficult under trying circumstances, e.g. "when the ward is full ... [or] ... when the number of small interruptions outweighs the amount of planned work done in a given hour" (p. 217), such that any strict adherence to workflows might mean that the right care is not provided (Kammer et al., 1998; Barretto, 2005, p. 81). Over the years, a number of solutions have been proposed, chief among which is increased coupling between CPG development and situations of real-world clinical practices (Grol, 1993; Lacson, 2000; Seyfang et al., 2009; Gabbay and le May, 2011). For example, Grol (1993) proposes a model for developing guidelines that fit into specific clinical practice situations. The paper identifies two approaches: centralised and decentralised. In the decentralised method, a local group develops guidelines using the literature, regional and local practices and expertise. In the centralised approach, a group of experts within a broader coverage area (e.g. national or international) formulates the CPGs. Increasingly, the trend appears to lean towards CPGs that are able to integrate multiple aspects of clinical practice, e.g. formal knowledge and prescribed actions as well as intentions, practice-centred actions, local circumstances, temporalities and patient-centred needs, in order to appropriately address real-world clinical problems. As a result, concepts such as knowledge-rich workflow systems (Gil, 2009) and contextualised scientific workflows (Brézillon, 2011) have been proposed. See (Nutt, 1996) for an overview of the evolution of workflows. What is required are more approaches that not only integrate CDS into existing HISs (Kaur and Wasan, 2010), but also broaden the boundaries of traditional CDS research (Patel and Arocha, 2001) to incorporate practice-level analysis of clinical work processes and decision-making (Brézillon, 2011; Fan et al., 2011; Pace et al., 2010; Allert and Richter, 2008; Dourish, 2004).

2.2.3 From Evidence-based Practice to Practice-based Evidence

Evidence-based Practice (EBP) entails the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996). The practice of EBP impies integrating individual clinical expertise experiences with the best available external clinical evidence obtianed from systematic research. According to the National Library of Medicine[7], cited by (Barretto, 2005, p. 20), EBP follows four steps; namely formulate a clear clinical question from a patient's problem; search the literature for relevant clinical articles; evaluate (critically appraise) the evidence for its validity and usefulness; implement useful findings in clinical practice. The current drive towards EBP, which began to gain ground in clinical practice in the early 1990s, has been fuelled, primarily, by a general appreciation that clinical decisions should be based, to a much greater degree than they have been in the past, on medical knowledge derived from established findings, e.g. research (Muir Gray, 1997). Workflow-based technologies and CPGs are an example of the use of EBP; often, they present a clinician with flowchart-based views on how to properly diagnose illnesses, choose the best testing plan, and select the best treatments and methods of disease prevention (Torphy et al., 2006).

[7] http://www.nlm.nih.gov/index.html

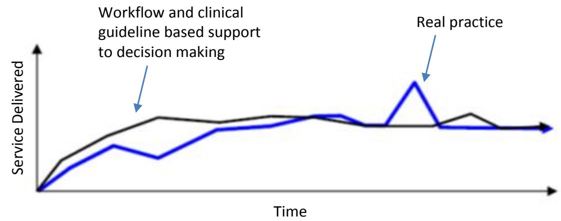

Figure 2.1: Guideline recommendations versus real practice decision making. Often, clinicians are able to deviate from steps recommended in the CPG for unusual and atypical circumstances not covered by the CPG (adapted from Barretto, 2005, p. 29)

Criticisms of the EBP approach led to the emergence of practice-based evidence (PBE). A central argument of the PBE approach is that while too much effort has gone into the design of “idealised models of how clinicians ought to use the best evidence”, e.g. CPGs, the reality of practice is that clinicians so often do not use them (Gabbay and le May, 2011). Essentially, research in PBE seeks to *redress the gap between guideline-based models of care and practice-centred realities of clinical work*. One of the arguments for PBE is well articulated in a study of general practitioners by John Gabbay and Andree le May (2011). The authors observe that clinical decisions are often the result of psychological processes that may involve guidelines and rules inherent in idealised models of care, but also a rich mixture of “complex and competing goal, demands and local circumstances and systems” that are “far more suited to practice than guidelines or protocols or the clear steps that are traditionally associated with the linear model of evidence-based practice” (p. 60). Other works, such as (Shahar et al., 1998; Lacson, 2000; Stefanelli, 2002; Doust and Del Mar, 2004; Seyfang et al., 2009; Bardram and Hansen, 2010, 2010a) report, from varying perspectives, the influence of context of work on clinical work and the insufficiency of reliance on abstract guidelines. Uncertainties about the effects of treatments and clinical decisions are inevitable (Doust and Del Mar, 2004, p. 475), and while CPGs provide the guiding map required to navigate through those uncertainties, reducing patient care to algorithmic steps of binary (yes/no) decisions amounts to gross injustice to the complexity of medicine and the non-trivial parallel and iterative thought processes inherent in clinical decision-making (Woolf et al., 1999, p. 530). Figure 2.1 depicts the trend in the use of CPGs and EBP versus practice-centred approaches in supporting clinical decisions.

Several CDS models have been proposed as viable approaches to this problem. One that has increasingly gained ground is the integrated approach. Figure 2.2 depicts a model of such approach that integrates formal knowledge, local rules and organisational guidelines and work practice-centred approaches. Stefanelli (2002, p. 1) rightly notes that clinical decisions should combine three factors; scientific evidence, socio-ethical values, and resources, e.g. economic and local work context-related factors (Grol, 1993; Doust and Del Mar, 2004; Gabbay and le May, 2011). The goal of the movement to PBE is to close the gap between scientific evidence (EBP) and clinical practice (PBE), which, as shrewdly noted by (Peek, 2011), remains one of the greatest challenges in today's healthcare delivery.

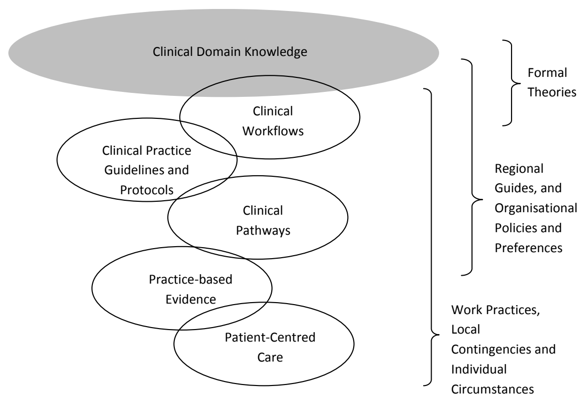

Figure 2.2: Conceptualisation of the work practice-based approach as an integration of formal knowledge, local factors and organisational guidelines

2.3 e-Health and Cross-Boundary Clinical Decision Support

Since its first appearances in the scientific literature in 1999 (Della, 2001; Iakovidis et al., 2004), the sub-discipline of e-health has had, as one of its core goals, the challenge of developing environments to support information and knowledge exchange among clinical professionals across boundaries of workplaces and regional health information networks (Silber, 2004; Tsiknakis et al., 2005; Tan, 2005; IANIS, 2007). In its groundbreaking report (IOM, 2001) acknowledges the need for a connected healthcare system based on self-organising subsystems that takes cognisance of local practices, tailored towards patients' needs, and, at the same time, maintains a shared purpose and standard of care. It has been argued that local adaptation, innovation and initiative (Tsiknakis et al., 2005) as well as support for patient safety and patient-centredness (IOM, 2000; Stewart, 2001) constitute essential ingredients to achieving this goal of a successful e-health infrastructure, where the subsystems follow "simple rules adapted to local circumstances" (Tsiknakis et al., 2005, p. 300). Healthcare work unfolds within a diversity of contexts and actors; and, as such, realising the degree of adaptive cross-boundary decision support required in e-health calls for approaches that seek to address the human and organisational factors that are part of the context of healthcare service delivery. This provokes a number of research challenges, namely: how do we define the context of clinical work in terms of human and organisational factors? How do we bridge the gap between two contexts of clinical work in order to enable adaptive cross-boundary decision support among clinical practitioners? While we defer our approach to addressing these issues to later chapters, we seek to understand, in this section, how earlier research efforts have sought to address them.

2.3.1 The Case for e-Health and Cross-Boundary e-Health

Applying IT to healthcare commenced as far back as the 1960s under various labels including "computers in healthcare", "medical informatics", "health informatics", "telemedicine" and "health telematics". However, unlike earlier attempts, e-health has been called a "revolution" (Silber, 2004), which does not just stop at the general idea of "improving healthcare through the use of ICT", but also goes further to seek to "create ambient intelligence for healthcare professionals" (Iakovidis et al., 2004, p. vi) and to deliver across boundaries of clinical practice "responsive healthcare tailored to the needs of the citizen" (Silber, 2004, p. 3). From this perspective, the notion of e-health conjures up a reference to the idea of tele-expertise – one of the five key applications of telemedicine with a focus on prevention, diagnosis and collaborative practice (Perednia and Allen, 1995; Silber, 2004, p. 15; Latifi, 2008; Househ et al., 2009). While telemedicine places emphasis on the application of IT technologies (e.g. virtual reality) to healthcare through such notions as virtual e-hospital (Latifi, 2008, p. 3), tele-surgery, tele-conferencing and remote electronic clinical consultation (Perednia and Allen, 1995; Househ et al., 2009), e-health tends to prioritise the sharing of clinical information and services rather than the functions of technologies, and emphasises collaborative and adaptive knowledge sharing for improved healthcare. This focus is aptly captured by (Silber, 2004) emphasizing that healthcare teams across cultural and national contexts can use e-health for patient management, and can engage in "electronic messaging between the hospital and other healthcare actors for communication of clinical and administrative data, and telemedicine and second opinions, in any specialty" (p. 4).

Not surprisingly however, e-health, like similar concepts (or buzzwords) that have emerged in ICT, over the last three decades, is beleaguered by the lack of a widely agreed-upon definition[8]. In a systematic review of 51 published definitions of e-health, (Oh et al., 2005) note that there is a glaring lack of consensus among e-health researchers and practitioners on what the concept actually means. The term tends to be defined with regard to a series of characteristics specified at varying levels of detail and generality (Silber, 2004). While several authors have adopted a broad sense approach to the definition of e-health, often slackly equating it to any form of "Internet-related healthcare activities" (Iakovidis et al., 2004; Latifi, 2008)[9], a definition that strikes an interesting note with the challenges we seek to address in this work view e-health as "a new way of working, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology" (Eysenbach, 2001). This is because of its indirect reference to the notion of cross-boundary e-health (Anya et al., 2011). Though less established in e-health and health information systems literature, cross-boundary e-health emphasises collaboration and distributed knowledge sharing and decision support among clinical practitioners working across organisational, regional and national borders. Silber (2004) observes that one of the common denominators for moving forward the case for e-health is that professionals need to "engage in informal networking with colleagues in other countries" (p. 25) in a manner that appropriately informs each other's practice, and takes cognisance of local work circumstances and patients' needs.

In this thesis, we use the term "cross-boundary e-health" to refer to *the open, interoperable and patient-centred exchange of knowledge, expertise and services among healthcare professionals, patients and/or systems in an e-health environment*. It is open and interoperable

[8] However, efforts have started towards establishing a generally acceptable notion of e-health at both conceptual and implementation levels. The World Health Organisation has established various e-health initiatives, such as the WHO Global Observatory for eHealth (GOe) which aims "to provide Member States with strategic information and guidance on effective practices, policies and standards in eHealth". For more, visit http://www.openclinical.org/e-Health.html, http://www.who.int/kms/initiatives/ehealth/en/, and http://www.who.int/ehscg/en/

[9] See also publications of the Journal of Medical Internet Research from vol. 1, 1999 to date – http://www.jmir.org/

because exchange of services adheres to standards of protocol that take into cognisance the circumstances of users local clinical contexts in order to move care from single solutions to collective knowledge and "clinical mindlines" cultivated with "contextual adroitness" (Gabbay and le May, 2011, p. 85). The American (IOM, 2001) report observes that if care is to move beyond single solutions crafted by individual clinicians, "it will require an accurate understanding of patient needs so that standard processes can be provided and individual solutions crafted as appropriate". (p. 157) The notion of cross-boundary e-health draws on the idea of "second opinions" (Silber, 2004, p. 4; EU Information Society, 2010, p. 21) in medicine, and aims to create within a global healthcare infrastructure, a knowledge network or communities of practice (Wenger, 1998) that allows clinicians to "loosely" share knowledge to support one another's decision in manner that takes cognisance of the differences in local contexts of work, available tools and patients' needs between the clinicians. Cross-boundary e-health involve the socio-cultural and organisational aspects of work (Schein, 2004; Robbins, 2007) as well as the psychology of knowledge transfer (Szulanski, 2000), since it is concerned with ways by which a clinician or a community of clinicians in one work setting (e.g. a clinical team, a hospital or a geographical region) is affected by the experience of another clinician or a community of clinicians in a different work setting. It evokes similar concerns and challenges inherent in the design of future decision support technologies (Karacapilidis, 2006), chief among is how to bridge the socio-technical gaps in decision support systems (Respício et al., 2010).

In e-health, cross-boundary decision support as well as "interoperability is both a pre-requisite and a facilitator" for facilitating deployment across professional, cultural, organisational and technical boundaries and stimulates profound changes in the way we understand partnerships for making the global shared vision happen. ((EU, 2010, p. 26). However, one of the challenges in cross-boundary decision support remains how to bridge the gap between various clinical work contexts, which is required to create the kind of seamless suggestion sharing or "second opinion services" (Silber, 2004, p. 4; EU, 2010, p. 21) that obtains in intra-hospital work settings (e.g. during wards rounds and multi-disciplinary team meetings). In such settings, clinicians often reach better decisions by combining available domain information with their practice-based knowledge in ways that are largely driven by their common work context. As a number of studies in CSCW, HCI and HIS (Mejia et al., 2007, 2010; Bardram and Hansen, 2010; Bossen, 2002) have revealed, in co-located hospitals, clinicians are constantly engaged in informal interactions and cooperative problem-solving aimed at deriving more effective treatments for their patients based on available expertise, local resources and patients' circumstances. Similar structures of interpersonal interactions and collaborative problem-solving are equally found to be vital to the success of projects in software development and in traditional organisational work settings (Kraut et al., 1990; Turner and Kraut, 1992; Whittaker et al., 1994; Azudin et al., 2009; Jarrahi and Sawyer, 2010). In a broader organisational sense, knowledge sharing across organisational and workplace boundaries aimed to inform practice has, over the last decade, been a dominant feature of contemporary work (Argote et al., 2000; van der Vegt et al., 2003; Röll, 2004; Marouf, 2007; van Wijk et al., 2008; Oborn et al., 2010) – most probably in pursuance of the noble ideals of ICT-enabled globalisation (as equally enunciated in e-health). Studies of the problem of knowledge sharing across community boundaries and multiple work sites of multi-national companies identify enormous challenges and requirements to be considered in real-world cross-boundary knowledge sharing situations (Swan, 2001; Novak, 2007; Wenger, 1998; Bonifacio et al., 2002).

In e-health, however, such context-enabled common grounds for knowledge sharing hardly exist and there is little understanding about how technology could enable interactive cross-boundary decision support in such a distributed health infrastructure. Existing approaches lack the capability for a shared cognitive and social context against which remotely distributed clinicians, with no common work context, can construct a shared meaning of information and understanding of practices (Lave and Wenger, 1991). e-Health is not only about computer applications but also about "cognitive, information processing and communication tasks of clinical practice" (Iakovidis et al., 2004, p. vi) and work context. By attempting to model context in terms of human and organisational factors, the approach taken in this research seeks to address that challenge. As noted by (Househ et al., 2009, p. e11), understanding how socio-cultural interactions impact knowledge exchange in a distributed environment, such as e-health, represents an opportunity to enhance how such activities are carried out.

As more technologies emerge that can potentially enable distributed professionals to leverage collective intelligence and social creativity across organisational, regional and workgroup boundaries for improved decision making, it becomes pertinent to investigate the possibility of building models of informal intra-hospital knowledge sharing and decision support to serve e-health. What level of interoperability can, and should be, supported? Can such a model adequately support effective knowledge sharing given the, often, huge differences in users' work contexts? To what extent can low-level workflow-independent practices that enable informal interactions in collocated settings be captured within such a model? And what form of knowledge would be most effective: explicit or tacit, declarative or procedural, generic or specific, individual or collective, value-neutral or value-laden, context-free or context-bound? What minimum amount of patient information will be safely incorporated in the shared knowledge?

2.3.2 Context-Awareness and Cross-boundary e-Health Decision Support

As research in e-health continues to develop, there is an increasing understanding that e-health technologies and CDSSs "need to be cognisant of the contextual aspects of the environments in which … decisional processes unfold" (Burstein and Holsapple, 2008, p. 221). As a result, numerous research efforts, for example in the areas of context modelling for decision support (Burstein et al., 2010; Grigsby et al., 2010) and pervasive computing in healthcare (Borriello et al., 2007; Bardram, 2009), have focused on how to relate the applicability of such systems to varying contexts of clinical work. See (Bricon-Souf and Newman, 2007) for a review of context-awareness in healthcare. However, as astutely pointed out by Paul Dourish in his seminal paper (2004, p. 19), "considerable confusion surrounds the notion of ''context''—what it means, what it includes and what role it plays" in interactive and decision support systems. A survey of research papers that focus on context across sub-disciplines of computer science indicates that there is no single definition of the term[10]. Various definitions of context and varying notions of what context should include appear in several literature sources (Dey and Abowd, 2000; Winograd, 2001; Dourish, 2004; Kirsch-Pinheiro et al., 2004; Turner, 2006; Porzel, 2011), and do reflect, to a large extent, the authors' approaches and perspectives. For example, (Kirsh, 2001) asserts that context "is a highly structured amalgam of informational, physical, and conceptual resources that go beyond the simple facts of who or what is where and when to include the state of digital

[10] See, among others, LNAI subseries of LNCS series focusing variously on modeling, using and retrieval of context, published by Springer since 1999 – volumes 1688, 2680, 3554, 4635 and 3946.

resources, people's concepts and mental state, task state, social relations, and the local work culture" (p. 306). This definition relates well to the notion of context as a collection of relevant conditions, conceptual and observational elements of real-world environments "that make a situation unique and comprehensible" (Pomerol and Brézillon, 2001), and for which an awareness of work within a specific situation can be constructed for e-health and cross-boundary decision support.

In our review of research work on context-aware systems for decision support and clinical applications, we noticed that most approaches appear to limit the notion of context to physical entities, such as location, time or device, and are often focused on how to capture context (perhaps using sensor technologies), and encode and represent context information. The problem with such approaches is that there exist within any work situation "numerous interacting factors that people do not even pay attention to on a conscious level, and many of which are outside the ability of machine input devices to capture" (Degler and Battle, 2000), but which nevertheless constitute context. Other approaches focus on content adaption, mostly multimedia and information content. They usually take into account the physical context or technical capabilities of a client device, e.g. a mobile phone, or the information needs of a user, e.g. a clinician, and seek to enrich or transform the original content in a way that would suit the user or device (Grimshaw et al., 1997; Dey et al., 2001; Schilit et al., 2002; Muñoz et al., 2003). The real challenge of context-awareness in healthcare decision support lies in the fact that healthcare takes places in a highly dynamic environment that relates not only to location and time, but also to complex organisational, socio-cultural, activity-related and contingent features of a situation, which any decision support system must not fail to take into account (Harrison et al., 2007).

With the increased research efforts, arguably following Mark Weiser's landmark publication (1991), research studies that seek to explore other aspects of context, or what (Dourish, 2004) refers to "context as an interactional problem", have begun to emerge (Moran and Dourish, 2001; Bardram et al., 2006; Bettini et al., 2010; Bardram and Hansen, 2010; Brézillon, 2011). The goal was to develop models of awareness of context that are based not only on location, time and device, but also on the social, cultural and organisational aspects of the user. Dourish (2001) argues that research in context-awareness ought to incorporate "work on sociological investigations of the organization of interactive behaviour", noting that context as "the organizational and cultural context as much as the physical context – plays a critical role in shaping action, and also in providing people with the means to interpret and understand action". The meaning of action, thus becomes experientially and "interactionally determined ... as actions and utterances gain their meaning and intelligibility from the way in which they figure as part of a larger pattern of activity". Reviewing context-awareness in healthcare, (Bricon-Souf and Newman, 2007) note that because of the complexity of the features of context, current research lacks a consensus as to the most appropriate models or attributes to include in context-awareness. They suggest that research in context-aware healthcare should increasingly draw upon different disciplines for deeper analysis of the inherent sociotechnical nature of context-aware applications in healthcare.

Most researchers investigating context from the perspective of socio-technical design draw from theories of activity and social behaviour in the social sciences (Kuutti et al., 1991; Fjuk et al., 1997; Engeström, 2000; Dourish, 2001; Kaenampornpan and O'Neil, 2005; Kofod-Petersen and Cassens, 2006; Favela et al., 2007; Forlizzi, 2007; Feng et al., 2009; Brézillon, 2011). Though considerable progress has been made, the task of building effective computational models of human social interaction remains a huge challenge. Moreover, there are only a few works that associate the notion of context to a knowledge level analysis (Newell, 1981) of human work (Kofod-Petersen and Cassens, 2006). In this research work, we seek to explore a context-based awareness mechanism that delivers information to clinicians in a manner that considers not only changes in the user's situational environment, but also the operative social processes surrounding their everyday interaction within the environment as well as concepts and rules of their domain of work. The goal is to be able to "use the context in order to discriminate or elaborate the meaning of the user's activity" (Dourish, 2004, p. 25). We posit that the link between concepts and meaning of an action, on one hand, and the real-world contingencies of using the same action in problem-solving and decision making, on the other hand, can be found in the concept of practice. Such an approach will help equip a decision maker, e.g. in cross-boundary e-health and real time decision support environments, with full information about the situation of care for effective context-aware decision support.

2.3.3 Approaches to Boundaries and Boundary Crossing

John Wennberg and his colleagues were among the first to point out, more than three decades ago, that there is a significant amount of variation in clinical practices[11] across geographical boundaries, even though they all treat clinically similar patients (McPherson et al., 1982). In a study examining the incidence of common surgical procedures across hospital sites in the US, UK, and Norway, the authors note that the degree of variation appeared to be more characteristic of the procedure than of the country in which it was performed. Though, all three sample zones in the study are technologically developed countries, which could have accounted for the observed little relation between methods of organising and financing care and the intrinsic variability in the incidence of common surgical procedures; the study, however, highlighted the critical role of “locale” (Fitzpatrick, 1998) in delineating boundaries of clinical practices and healthcare delivery.

Over the years, a rapidly growing body of research from several distinct lines of investigation (Barnes et al., 1985; Brennan et al., 1991; Fiscella et al., 2000; Ozen et al., 2004; Gibbons, 2008; Harrison et al., 2010; Gabbay and le May, 2011; Appleby et al., 2011) have coalesced to corroborate Wennberg’s findings of differential healthcare delivery and non-random distribution of practice patterns across boundaries of geography and local work context. While acknowledging that both the causes and solutions of variations in healthcare are likely to be complex, multifaceted, and interrelated, (Gibbons, 2008) notes that the true measure of the future impact of ICT on healthcare lies on the design of e-health solutions that would "go far beyond mere information sharing between patients, providers, and healthcare systems, to enabling clinical research and experiential medicobehavioural interventions not currently conceivable" (p. 159). The key to realising that, he recommends, lies in increased integration between the ICT fields, on one hand, and the socio-behavioral, cultural-historical and population sciences, on the other. By definition, ICT is a global and cross-boundary phenomenon; while socio-behavioral and cultural-historical issues are intra-boundary and largely exist within a local clinical work envrionment. We suggest that any productive

[11] John Wennberg used the term unwarranted variation (or geographic variation) to describe these differences, probably because they found out that the differences "cannot be explained by illness, medical need, or the dictates of evidence-based medicine", see also (Appleby et al., 2011). However, recent evidence has shown that a substantial amount of variations in healthcare are down to differences in patients' needs and perspectives as well as local resources and practices (Gabbay and le May, 2011).

marriage between the two need to draw substantially from the notion of boundary as enunciated in Star and Griesemer's concept of boundary objects (1989). Such an understanding will enable us to provide answers to such questions as: What constitute the boundaries in cross-boundary e-health? What forms do they take – physical, technological, social, psychological, economic, cultural, organisational or professional? Where do the boundaries actually lie within an e-health space? Are they theoretical or do they exist in practice? What effect would they have on distributed clinical decision support in e-health?

Boundaries – demarcation lines between different cultures, world views, identities, enterprises and fields of practice (Zdunczyk, 2006) exist because there are inherent differences in human identities, conditions and organisational perceptions and approaches (Gabbay and le May 2011). Boundaries have often been defined as stable lines of distinction (Kerosuo, 2006, p. 71; Kajamaa, 2011, p. 362) and "edges" of communities of practice (Wenger, 1998, p. 119), which are necessary for the structuring and management of the activities of an organisation. The notion of boundaries points to differences and distinctions that people create, as a result of certain circumstances and conditions, while participating in activities across a wide range of social phenomena, organizations, and institutions (Kerosuo, 2006). Boundaries may exist at the level of workgroups, communities of practice, institutions or regions, and their nature can vary from fluid lines of distinction to complex discontinuities between separate worlds of practice (Hernes, 2003; Kajamaa, 2011). Local clinical practices, contexts, and patients' perspectives and circumstances provide spaces for the development of local understandings, knowledge, and learning in hospitals (Wenger et al., 2009). Boundaries are interwoven with peripheries that signal a community's point of contact with the rest of the world; they may enable or hinder the transfer of meanings across those peripheries (Wenger, 1998, p. 120). According to (Star and Griesemer, 1989), boundary objects denote:

> objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites ... They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation." (p. 393).

Boundary objects allow for practice-centredness by being "strongly structured in individual-site use", and at the same time, allow for transferability of meaning by being "weakly structured in common use". Boundaries can take both concrete (e.g. as artefacts. documents and locations) and abstract forms (e.g. as actions and practices). The notion of boundary-shaking practices has been referred to in (Balogun et al., 2005; Anderson, 2007; Akoumianakis et al., 2009).

In the past two decades, the notion of “boundaries” and related concepts, such as boundary object (Star and Griesemer, 1989), boundary crossing, boundary breaking (Kajamaa, 2011), and boundary spanning (Gasson, 2005, 2005a) have increasingly become intriguing research foci in IS, HCI, organisational studies and management. For example, such approaches are commonly used in IS research to investigate expertise collaboration, sensemaking and knowledge sharing across organisational boundaries (Gasson, 2005a; Kerosuo, 2006). Kajamaa (2011) applied the notion of boundary to a study of collaboration in frontline hospital work, and observes that boundary in the hospital was particularly solid making collaboration effort conflictual. However, boundaries can be quite challenging to cross (Carlile, 2004); practices can be fluid, and objects can take on different forms and uses depending on work circumstances. Several studies have applied the idea of brokers as mediators in boundary cross (Kajamaa, 2011, p. 363). However, more studies on boundary and boundary dynamics are still required to understand and model the complex nature of clinical work environments and their varying conditions (Carlile, 2004), and to analyse interactions between and across boundaries.

2.3.4 Overview of Clinical Decision Support Tools

Over the past 40 years or more of the history of computers in healthcare, a large number of computer-based clinical decision support systems and tools have been developed and their usefulness evaluated (Shortliffe et al., 1973; Greenes, 2007; Berner and Lande, 2007; Berner, 2009). Though the overarching objective of helping health professionals make clinical decisions (Shortliffe, 2006) has remained relatively constant in these applications, various techniques and approaches, which reflect such issues as variations in clinical practices, advances in IT or findings of research investigations (IOM, 2000), have been adopted. Recently a number of e-health applications have equally been developed with the potential to support clinical decisions (Iakovidis et al., 2004), and have been used for a variety of purposes, ranging from improving quality and efficiency of care to seeking “second opinions” and enhancing safety (Wright and Sittig, 2008).

Early approaches to the design of CDSS derived heavily from research into the use of artificial intelligence in medicine, and mostly incorporated rule-based techniques (Shortliffe et al., 1973; Berner and La Lande, 2007; Berner, 2009). Notable among this generation of CDSSs is the MYCIN, developed at Stanford University, and consisting of a fairly simple inference engine and a knowledge base of about 600 rules. The aim then was to replace human experts and to support diagnosis by seeking to “simulate human thinking” (Berner and La Lande, 2007, p. 4; Shortliffe et al., 1973). As the medical informatics community gained experience with prototype expert systems, however, this enthusiasm began to wane, giving way to the less ambitious, but more realistic, goal of assisting clinicians in their own decision-making. This gave rise to the use of knowledge-based and data mining techniques, and resulted in a categorisation scheme for CDSS based on whether they are knowledge-based systems and nonknowledge-based systems that employ machine learning and other statistical pattern recognition approaches (Berner and La Lande, 2007). Computer programs that applied these approaches include DXplain and Iliad. They have been designed to consider historical and physical examination findings, laboratory and test results, and to create a list of diagnoses to explain those findings. The systems performed remarkably well, and were based on large searchable database that related the presence or absence of findings with diseases and other conditions. However, their inability to relate to a clinician's context of work meant that their broad use in clinical care was limited.

Another categorisation scheme is based on the timing at which the system provides support. This categorisation was the focus of the work of Metzger and his colleagues. According to their framework, CDSSs can be classified as tools that bring relevant clinical knowledge to the point of care, tools that assist in managing individual patient, and tools that apply care advice across a population of patients; whether such tools provide support before, during, or after care; or whether they provide support actively, e.g. as alerts, or passively, e.g. in response to clinician input or patient-specific information (Metzger and MacDonald, 2002). A chorological evolution of CDSSs as a four-phase model, which include standalone decision support systems, decision support integrated into clinical systems, standards for sharing clinical decision support content and service models for decision support is presented in (Wright and Sittig, 2008). The four phases, covering the period 1961–2007, "show evolving and increasingly sophisticated attempts to ease integrating decision support systems into clinical workflows and other clinical systems" (Wright and Sittig, 2008, p. 641) such as electronic health records and computerised provider order entry systems, but largely ignores the role of clinical practice information, local work environment and social learning systems in decision making.

Not long ago, the Web and related digital technologies have spawned the burgeoning of information revolution that have heavily affected healthcare, and led to a re-thinking of the design of CDSSs and e-health applications. A central goal of developers of this era of CDSSs is not only to develop systems that deliver required information that are "intelligently filtered or presented at appropriate times" (Osheroff et al., 2007), but also that could be integrated with the healthcare's social and organisational dynamics. Such systems "naturally" form part of the organisation's social practice (Schatzki, 1996; Chaiklin, 2007). Underlying this goal are two issues: 1) to support knowledge sharing and social collaboration among clinicians across boundaries of practice, and 2) to make CDSSs more usable by integrating them into existing medical practices and organisational infrastructure (Nerlich and Schaechinger, 2003) as well as tailoring their design towards the clinicians' socio-cultural ways of doing things (Dourish, 2004) and prevailing clinical situations. In making *The Case for eHealth*, Denise Silber observes that an emergent goal in the design of CDS and e-health systems, which is equally well evident in recent research findings (Ahern, 2007), is to enable "professionals ... to collaborate efficiently across boundaries, whether local, regional, national, or worldwide" (2004, p. 8). In their rank-ordered list of grand challenges in CDS, (Sittig et al., 2008) identify as paramount the need for an architecture for sharing executable CDS modules and services, and to improve human-computer interface of CDSSs so as to increase the capabilities for practice-level support. Several initiatives[12] have recently emerged from numerous local, regional and national governments and organisations, which encourage healthcare providers to implement state of the art clinical information systems, targeting varying clinical situations and practices from single clinician practices to large integrated delivery networks (Tsiknakis

[12] http://www.ehealthinitiative.org/

et al., 2005; Osheroff et al., 2007; Kaur and Wasan, 2010). Other issues, particularly relevant in the design of cross-boundary EIS, include variations in clinical practices between hospitals and regions. Martinez et al. (2005) found that differences in needs and conditions of primary healthcare between developing and industrialised countries lead to the use of different solutions and approaches by different stakeholders, while (Chen and Akay, 2011) observe that "varying needs of developing countries" influence the type of electronic medical records and primary healthcare systems in use there.

It has been argued that realising the vision of CDSSs that would enable the e-health vision of cross boundary decision support (Novak, 2007) requires increased research for more in-depth understanding of work practices and clinical processes in relation to users' local work contexts and varying patients' situations. This calls for the development of workplace-specific health information systems and context-appropriate tools (Unertl, 2009) that are integrated into the global HIN. To achieve this, two major challenges become prominent: how to construct generic models of work practices given the significant variations in what are defined as work practices in different areas. Will work practices be modelled as context or content in relation to task execution? How will the models be integrated into existing EIS and WfMS both for inter-organisational workflow integration and e.g. ensure minimised error and coordination load (Cheng et al., 2003)?

Healthcare depends on informatics (Silber, 2004, p. 4) that is strongly tied to local work processes, practices and circumstances. Despite the role of the concept of practice in explicating work processes in different contexts, e.g. in healthcare, (Gabbay and le May, 2011), it still attracts very little research attention as an approach to the design of CDSSs and e-health applications. As a result, this research appears relevant in the face of emerging trends in integrated HINs and EIS (Xu, 2011), recent advances in e-collaboration (Karacapilidis, 2005, 2006) and the increasing need among professionals in healthcare and elsewhere (Sari, 2008; Xu, 2011) to leverage collective intelligence and social creativity across work boundaries for improved decision-making and, does have enormous implications for the design and adoption of future CDS technologies for e-health.

2.4 The Nature of Clinical Work

Empirical and theoretical work over the past few decades has shown that the nature of clinical work is not just a matter of applying clinical science and following formal rules and procedures. It involves a considerable degree of what (Gabbay and le May, 2011, p. 39) refer to as "guided complexity". Guided complexity implies that a large part of clinical work remains "underdetermined until realised in situ" (Robinson, 1993, p. 189), and does bring to the fore the severe limits of the use of workflows only to represent clinical work. Recently, attempts to understand the real nature of clinical work have led designers of systems for supporting clinical work to adopt techniques and approaches for investigating the wider concept of work from such fields as the social sciences (e.g. Garfinkel, 1967; Bourdieu, 1977; Giddens, 1984; Schön, 1983; Geertz, 1983; Suchman, 1987; Orlikowski, 2002; Schein, 2004; Gabbay and le May, 2011). These investigations have revealed a couple of issues, notably that: 1) work has a dual nature, and 2) understanding work as enacted in the real-world requires representational formalisms that go well beyond what is offered by workflow-based approaches.

In *Making Work Visible*, Lucy Suchman argues that a major challenge for researchers engaged in understanding work processes, in such fields as workflow modelling, business process reengineering and information systems design, is to conceptualise “the intimate relations between work, representations and the politics of organisations” (Suchman, 1995, p. 58). Several studies in organisatonal science, psychology, CSCW and information systems have developed general frameworks and specific analyses of relations between work, technology and organisation (Hughes et al., 1993; Luff et al., 2000). In particular, a number of central concerns become obvious 1) the significant, but, often, subtle differences between normative accounts of work practices and the realities of how work actually gets done ‘in practice’ (Suchman, 1987), 2) the politics surrounding what aspects of work, knowledges and experiences are to be included in a representation, and 3) the implications of making them visible (Suchman, 1995).

In this section, we will take the view that existing formalisms for representing work largely adopt formal approaches, e.g. in workflow modelling and business process reengineering, which do not sufficiently reflect the complexities of the practical contingencies of work practices, including the inherent capabilities of the human actor (Bannon, 1995) and the historically-developed traditions of actions of the communities of practice around such work (Chaiklin, 2011). We will argue that one of the reasons for this is the challenge of managing the complexity that could possibly emerge out of a representation that tries to encapsulate both formal work processes as well as the intricate and contingent realities of practice in the real-world, and the inability to properly conceptualise "the intimate relations" between entities in a workplace, which (Suchman, 1995, p. 58) refers to. In order to manage the possibly emergent complexity, we will argue, along the line of (Suchman, 1995), that representations of work ought to be interpretations that are designed to serve particular interests and purposes; a perspective that resonates with Star and Strauss's (1999, p.10) crucial point that what needs asking is what exactly work is, and to whom it might (or should) be visible or invisible.

2.4.1 Duality of Work

The duality of work refers to the notion that problem-solving and decision-making in complex work settings are characterised by a dual nature (Fitzpatrick, 1998, p. 24; Færgemann et al., 2005). Fitzpatrick (1998, p. 24) note that the concept tends to highlight the complexities of work, as captured in the differences between work specifications and actual work routines, and the interdependencies between different actors and entities within a work structure, rather than their distinctiveness. The notion of duality of work is informed by a number of influential strands of theories in social science and anthropology (Giddens, 1984; Bourdieu, 1977; Turner 1994; Reckwitz 2002; Chaiklin, 2011), and is empirically anchored on the findings of a number of ethnographically-informed and user-centred investigations of problem-solving and decision-making in the real-world.

In her widely cited work, (Suchman, 1987) observes that work – purposeful actions and intelligent behaviour – is essentially realised in the interplay between plans and situated action. Her work questioned the prevailing cognitive science focus on planned action model and rationalistic thinking (see Section 2.3.4.2), insisting that since, in real life, "the circumstances of our actions are never fully anticipated and are continuously changing around us. ... our actions, while systematic, are never planned in the strong sense that cognitive science would have it. Rather, plans are best viewed as a weak resource for what is primarily *ad hoc* activity" (p. ix). Suchman further observes that the role of plans and situated action in work processes are distinct and mutually supportive in that:

> Plans are resources for situated action, but do not in any strong sense determine its course. While plans presuppose the embodied practices and changing circumstances of situated action, the efficiency of plans as representations comes precisely from the fact that they do not represent those practices and circumstances in all of their concrete detail. (p. 52)

In a related sense, (Strauss, 1993) portrays, in his theory of action, the relationship between action, i.e. work – or to use the gerund he prefers, acting, or even better, interacting, and context, i.e. the situations of acting. He distinguishes between interactional processes, such as negotiation around the work to be performed, and situational properties, such as division of labour, resources and institutional mandates that give form, direction and, to some extent, fate to activity and are part and parcel of the articulation of lines of action and the performance of work.

Star and Strauss (1999) talk about visible and invisible work as a way of referring to formal task descriptions and explicit work processes on the one hand, and informal tasks and “behind the scenes” work on the other. The notion of visible and invisible work is also evident in the works of (Suchman, 1987; Robinson, 1991; Schmidt and Bannon, 1992; Fjuk et al., 1997; Bowker et al., 1997). Related to the notion of visibility and invisibility is the distinction is between formal and informal work activities (Perin, 1991; Kreifelts et al., 1991; Rodden and Schmidt, 1992). Formal work activities concern the visible aspects of work performance (Star and Strauss, 1999). For example, a workflow model, such as a clinical guideline, denotes the formal sequence of activities needed to get a task done. Informal activities, on the other hand, are concerned with the "conversations about work" (Fitzpatrick, 1998, p. 24), i.e. the casual and ad hoc interactions, lightweight communication and practice-based activities that often fall outside of formal workflow processes and organisational routines (Mejía, 2007; Morán et al., 2010), but are, nevertheless, vital to work and do remain a common occurrence for almost all work processes (Adams et al., 2003).

Brézillon (2007, 2011) has highlighted a related notion – that of the distinction between procedures and practices A procedure refers to an abstract specification of problem-solving sequences that, often, relies heavily on organisational policy and strategy; a practice, on the other hand, is the way in which an employee has decided to adapt the procedure relying on personal elements and peculiar problem circumstances (Brezillon, 2011). In a similar vein, (Robinson, 1991, 1993) introduces the concept of double-level language to denote the double level nature of work where work is carried out at both a formal and a cultural level that inform and shape each other. The formal level is highly restrictive and thus ensures order, supports explicit communication, and "provides a common reference point for participants . . . a sort of "external world" that can be pointed at, and whose behaviour is rule-governed and predictable" (Robinson, 1991, p. 43). The cultural level involves subjectivities and supports implicit communication; "understanding, interpreting, and changing "items" at the formal level was mediated by conversation at the "cultural" level" (p. 42). The notion of double level language is "intended to catch the idea that implicit, often indirect communication (through artefacts) and explicit communication (speech, ad hoc notes) are ... complementary and mutually supportive" (Robinson, 1993, p. 196). Robinson argues that "the formal level is meaningless without interpretation, and the cultural level is vacuous without being grounded" (Robinson, 1991, p. 43). Schmidt and Bannon (1992) talk about primary and secondary work. Primary work denotes the carrying out of core tasks, whereas secondary work arises to deal with the interdependencies between multiple actors who need to interact with available artefacts and with one another through a common field of work. A similar notion – that of local and global dimensions of work – appears in (Færgemann et al., 2005). Investigating articulation work, the authors argue that such work, particularly in large-scale settings, is characterised by a dual nature; the local dimension represents articulation handled internally in a local work arrangement, whereas articulation activities undertaken across boundaries of local work arrangements are handled within the global dimension.

Each approach to the duality of work underscores a certain emphasis as the other, but in a slightly different tone. At the core of the approaches is the revelation that work (i.e. ideal work) consists of both a formally defined model (plans, workflows, clinical guidelines, procedure definitions etc.) that forms the basis upon which the (actual) work, as realised in situ, emerges out of the interactions between the actors, their environment, work context and available tools and resources. Fitzpatrick (1998) notes that though the basic dichotomy between the different dualities of work, as noted in (Jirotka et al., 1992), "is hard to sustain" in practice, the distinction has proven "a useful tool to heighten awareness of less visible activities, and as a reaction to "tame" rationalistic approaches to the conceptualisation of work" (p. 25). We posit that computer-based representations of work need to embody the duality of work in order to facilitate more informed cross-boundary decision support in e-health. The dual nature of work provides the much needed balance between an understanding of practice as the details of how people actually work and formal procedures or "organisational rulebooks" (Dourish, 2004, p. 25) as specifications of how people ought to work.

2.4.2 Representations of Work

Early approaches for representing work were heavily shaped by what (Winograd and Flores, 1987) termed “a rationalistic tradition”. Based on the notion of a rationalistic tradition, the authors note that the series of steps that one would take to solve a problem whose solution one cares about would include:

> Characterise the situation in terms of identifiable objects with well-defined properties. Find general rules that apply to situations in terms of those objects and properties. Apply the rules logically to the situation of concern, drawing conclusions about what should be done. (p. 14-15)

The key assumptions of the rationalistic approach are that the essential aspects of thought can be captured in a formal symbolic representation and applied to models of system design (Winograd, 2006). The rationalistic paradigm has, for years, pervaded the fields of AI, computer-aided problem-solving and design, and its essence becomes particularly remarkable given the large body of literature dedicated to algorithms, notation-based programming, workflow modeling (e.g. clinical workflows) and business process engineering. First, cognitively informed approaches were proposed as a way of analysing and representing tasks beyond what were offered by rationalistic thinking. Such approaches include hierarchical task analysis (Chandrasekaran, 1990; Chandrasekaran et al., 1992), cognitive task analysis (Crandall et al., 2006), and GOMS model (Card et al., 1983). The focus of the approach is to describe physical tasks and cognitive plans, including descriptions of both manual and mental operations and activities, task and element durations, task frequency, task allocation, task complexity, environmental conditions, and any other unique factors involved in or required for one or more people to accomplish a particular work goal. The cognitive approaches have led to deeper understanding of the “user workspace”, and have been applied to a wide range of domains, e.g. healthcare (Huser et al., 2011). However, one of their main drawbacks is the fact that they embody an abstraction of the actual work process; their emphasis on the planned action model rigidly ignores context, e.g. the dynamics of specific settings of problem-solving, and user unpredictability, e.g. individual preferences, organisational issues, and social aspects of work.

The role of context and the influence of specific settings of system use – the absence of which have formed core critiques of rationalistic system design (Suchman, 1987) – have become increasingly recognised as key to defining how humans use computers in problem-solving, emphasizing the nature and representations of work and the multidimensionality of the HCI space. Robinson (1993) has argued that support for work practice is better conceptualised as support for activity taking place in a multidimensional space rather than as prescription of temporal task sequences – as often assumed by the rationalistic and task analysis approaches. The notion of a multidimensional space is more representative of real-world work processes, and denotes, in essence, a means of addressing the drawbacks of the cognitive approaches and the designer's reaction to the need to incorporate context into system design. The author notes that work in the real-world involves a number of issues that can hardly be "anticipated" and accommodated for during design time, and argues for a model of design for anticipated use, which reflects the fact that work itself is underdetermined until realised "in practice". Robinson draws upon Suchman's groundbreaking work on "situated actions" (Suchman, 1987), which has, for over two decades, been a common source for the idea that computer systems should respond to "already-existing human practices" (Chaiklin, 2007, p. 173), which inform the unfolding settings within which they are used (Dourish, 2004). According to Suchman:

> [Situated action] underscores the view that every course of action depends in essential ways upon its material and social circumstances. Rather than attempting to abstract action away from its circumstances and represent it as a rational plan, the approach is to study how people use their circumstances to achieve intelligent action.. (p. 50)

In their analysis of due process in workplaces based on the notion of "articulation work" (Strauss et al., 1985), Gerson and Star (1986) make a similar point "it will always be the case that in any local situation actors "fiddle" or shift requirements in order to get their work done in the face of local contingencies”. (p. 258). Representations depict views of a world of work that can never be complete or permanent. Any description, as such, is a snapshot of historical processes in which differing viewpoints, local contingencies, and multiple interests have been temporarily reconciled. As noted by (Suchman, 2002), the central goal of work practice-centred representations is to explore an understanding of work beyond formal workflows and organisatonal routines for the design of technologies that can be more sensitive to their contexts of use. This approach brings to the fore how to computationally represent and mode the complexities of the real human world (Winograd, 2006, p. 1257). To explore representations of work based on the concept of practices, researchers have acknowledged the need to look beyond domain of computer science. Work that adopt this approach include (Dourish, 2001a, 2004; Brézillon, 2011), and draw largely on social and practice theories.

2.4.3 Methodologies for Understanding Clinical Work

At the core of approaches for understanding clinical work (and work, generally speaking) is the argument for a re-thinking of the status of “representations of work” (Bannon, 1995); a struggle, among researchers, to make work more visible by simplifying the complex and intertwining relationships that has beclouded the space of interaction between people and machines (Winograd and Flores, 1987; Suchman, 1987; Robinson and Bannon, 1991; Sumner et al., 1998; Dourish, 2004; Szymanski and Jack, 2011; Gabbay and le May, 2011); and, quite remarkably crucial, an adoption of the practice-theoretic perspective or, simply, the “practice turn” (Schatzki et al., 2001; Suchman 2002; Pace et al., 2010; Gabbay and le May, 2011). Work typically takes place at particular times, in particular places, and in relation to specific cultural, social and technological circumstances (Kemmis, 2009; Chaiklin, 2011); the linchpin of the practice-centred approach, therefore, is that work analysis and IS design strategies should reflect this. We review the theoretical and empirical approaches that have been applied towards a representation of real-world work beyond formal work processes, which that only denote, according to (Clancey, 2006), “inference[s] applied to facts and heuristics”.

2.4.3.1 Theoretical Approaches

Literature across health and social sciences and, more recently, IS and HCI is suffused with accounts of what (Gabbay and le May, 2011, p. 166) describe as social construction of “clinical reality”. The notion of clinical reality, arguably, highlights the fact that clinical work has a dual nature; i.e. any instance of clinical encounter (May, 2007) is so profoundly and inextricably influenced by prevailing social, organisational and environmental contexts that the encounter becomes remarkably different from any pre-existing theoretical construction of it. We discuss a number of theoretical conceptualisations that make evident the notion of social construction of clinical reality in relation to our concept of practice-centred awareness. The theoretical conceptualisations, among others, attempt to elucidate the hidden practicalities of the "space" within which people work.

The French Philosopher, Pierre Bourdieu (1977) was among the first to seek a deep-seated understanding of human work. In his field study of the Algerian Kabyle people, he develops, around the central concept of the *habitus*, a general account of how human action should be understood in relation to its cultural and social contexts. Bourdieu notes that local (instances of) problems are so complex with inherent "ambiguities and uncertainties of behaviour and situation" that it often requires the "art of the necessary improvisation" (p. 8) to achieve excellence.. The concept of the *habitus* applies reasonably well to clinical problem situations across boundaries; since clinicians, during decision making, often have to engage in actions that go well beyond the "rules" that could be abstracted from any clinical workflow. (Gabbay and le May, 2011) note that:

> To watch a clinician manage a patient competently is to watch much more than the application of a set of rules or guidelines. It is an act of extraordinary sophistication and complexity … (p. 168)

Equally underlying this crucial, but blurred, nexus between clinical action and clinical problem context is the idea of "common sense" and "local knowledge" (Geertz, 1983). Geertz has observed that for all individuals in all cultures, it is "only in isolating what might be called its stylistic features, the marks of attitude that give it its peculiar stamp", such as "natural-ness", "practical-ness", "immethodical-ness" and "accessible-ness", "that common sense … can be transculturally characterised" (p. 85). Gabbay and le May (2011) extends Geertz's concept of common sense to formulate the term "clinical common sense". They observe that:

> When clinicians arrive … at decisions that "just make sense" but which they can't explain …, it is arguable that part of their inarticulacy is due to exactly these attributes of the "clinical common sense" that are the hard-won basis of their professional capital. (p. 168)

Though messy, inconsistent and difficult to articulate, clinical common sense includes what Geertz calls “stylistic features” that makes it a convenient tool, as a “local knowledge”, to support a clinician in navigating the contextualised and “disorderly terrain” (Gabbay, and le May, 2011, p. 168) of their local practices.

In his work focusing on a search for a new foundational approach to HCI, Paul Dourish (2001, 2001a) proposes the concept of embodied interaction. Underlying embodied interaction is the notion of embodiment, which reflects both “a physical presence in the world and a social embedding in a web of practices and purposes”; it is “the property of being manifest in and as a part of the world” (Dourish, 2001a). Dourish's work, which draws heavily on twentieth century philosophical accounts of the phenomenological tradition, argues that the context or setting within which an activity unfolds should not be treated as mere background, but as a fundamental and constitutive component of the activity. If we take, as we do in this work, the view that clinical work practice comprises the context and setting of clinical work, then the concept of embodied interaction becomes not only a “constitutive component” of work, but also provides a set of propensities to guide the decision-making pattern of a clinician, albeit non-rigidly, and to address a wide range of contextual modulators for all likely occasions within a local work environment. The idea of bringing context or practice out of the background resonates equally well with Chaiklin’s (2011) arguments on the crucial role of practice in mediated work environments. The author argues that approaches for analysing work need "consider activity as organised in relation to practice" as a necessary means of scaffolding people’s cognitive capabilities and shaping work in the real-world. Equally related to our concept of practice-centred awareness are Suchman's much cited concept of situation action (1987) and Christina Haas' theory of embodied practice. The pivotal point of Hass' theory, which grew from her years of empirical research on the effects of using the computer to write (Haas, 1996), is that "technologies and other artifacts "encode" the knowledge of a community and allow for certain kinds of cultural activity and not others" (p. 45); thereby impacting on the individuals who use them. Other theories and ideas that have attracted the attention of researchers seeking to understand work “in practice”, most of which, like embodied practice, draw on contemporary Vygotskian studies, include the concept of social situatedness, situated learning, situated cognition, and situated activity (Lave and Wenger, 1991; Hendriks-Jansen, 1996; Lindblom and Ziemke, 2002).

Within the field of healthcare, the ethnographic study of ‘Lawndale’ practice by (Gabbay and le May, 2011), has provided a formidable insight in the nature of clinical work. The authors argue that neither formal domain knowledge nor organisational guidelines as employed by expert clinicians to 'technically' guide heuristics, pattern recognition or categorisation – ‘illness scripts’ (Gabbay and le May, 2011, p. 56) during diagnosis is sufficient to account for the whole of range of issues and variable factors (e.g. lack of precision tools for early detection of breast lumps, or how to manage the psychological trauma of a bereaved patient) that a clinician has to deal with during diagnosis and treatment. The study notes that “clinical reasoning is far more situated and flexible than even the most complex clinical algorithm can express” (Montgomery, 2006), and introduced the concept of “clinical mindlines” to describe the set of internalised, collectively reinforced and tacit guidelines, which are informed by clinicians’ professional training, practical experience and their understanding of local circumstances and systems, and which serve as their “knowledge-in-practice-in-context” (Gabbay and le May, 2011, p. 65) in dealing flexibly with the contingencies of clinical practice. Originating from the field of medical practice, study has brought to the fore the hitherto difficult to acknowledge fact that clinicians often do not follow the “idealised model” of technical medical knowledge (Cabana et al., 1999; Gawande, 2002), but rather choose to draw, as circumstances warrant, from their clinical mindlines to address patients’ needs in varying situations. Arguably, the outcome of the ethnographic study, which is compatible with the result of our user-centred study (see Chapter 4), has provided a fodder for the design of clinical decision support systems based on the correlation between local circumstances and patterns of clinical practice. In a related work, which focuses on unintended and undesired consequences of the use of HIT, (Harrison et al., 2007) proposed the concept of interactive socio-technical analysis aimed to capture common types of interaction and recursive processes within a clinical work setting. The study notes that effective use of technologies in clinical settings requires understanding the gap between HIT design and the healthcare organization’s socio-technical system, including its workflows, culture, social interactions, and technologies (Dayton, 2000; Respício et al., 2010; Burstein et al., 2010).

Many of the ideas considered in this section still appear too under-developed to pass for a theory, and some have been criticised for being over-ambitious or too vague, or for the lack of precision about how the dual dimensions of work exactly interplay in a real-world context for the construction of clinical realities. Nevertheless, most of them do command considerable currency among researchers, and provides a productive framework for conceptualising the idea proposed in this thesis – namely how to design e-health systems for cross-boundary clinical decision support based on the notion of work practice. They have the potential to foster a clinician's awareness of complex clinical situations across boundaries of work settings.

2.4.3.2 User-Centred Methodologies

A high-level concern of investigations of human work, which draws from the cultural-historical tradition, is not to understand the "user" per se, but rather to understand the human mind, or what (Nardi, 1996) refers to as "consciousness", within a work context, i.e., the meaningful, goal-oriented, and socially directed interaction between people and their material environments; and to apply that understanding to inform technology design (Card et al., 1983; Carroll, 1997). A number of user-centred methodologies by which researchers can gain an understanding of work exist. They are most usually multidisciplinary, and often combine both quantitative and qualitative methods; however, they all emphasize the centrality of the user's work context, and have been well employed in numerous studies of clinical practices and decision-making (Gabbay and le May, 2011; Hannan, 1999; Edwards et al., 2006; Ozen et al., 2004; Appleby et al., 2011). In this section, we consider a number of such approaches that can be used to understand and represent clinical work.

In HCI and IS research, the most commonly used of the approaches is ethnography, or the more theoretical approach, ethnomethodology[13] (Garfinkel, 1967), which is originally associated with socio-cultural anthropology (Geertz, 1983). An excellent account of work practice studies employing ethnography, among others, can be found in (Plowman et al., 1995; Luff et al., 2000; Gabbay and le May, 2011). Ethnography is a qualitative, interpretative technique for data collection, which involves the researcher engaging in some degree of immersion and participatory observation of work in its natural setting over a period of time

[13] The terms, ethnography and ethnomethodology are often used synonymously in HCI, CSCW and IS (Dourish, 2007; Dourish and Button, 1998). However, ethnomethodology denotes the more theoretical approach, while ethnography refers to a qualitative methodology. Ethnomethodological ethnography, which seeks "to uncover the moment-by-moment nature of work as it is constituted by the participants" (Fitzpatrick, 1998, p. 17), came into common use in IS design following Suchman's seminal workplace study of photocopier use (1987).

with the aim of providing a "detached" interpretation of people's experiences and engagement with the work. The strength of ethnography lies in its focus on the study of work as it occurs, while, at the same time, enabling the researcher to provide an unbiased account that is devoid of any imposition of preconceived research questions or hypothesis. According to ethnography, people's interaction with technology, their social conduct, exhibits "improvised character", carried on in real-time in the course of their work (Dourish, 2001a). A growing concern about the use of ethnography in HCI and IS research, however, is how to harness suitable, and measurable, design implications out of a, hitherto, sociological and phenomenological form of inquiry (Dourish, 2006). In view of the wide range of forms of ethnographic studies in HCI and IS, (Dourish, 2006) notes that there is still considerable debate over what ethnography means for HCI and IS research and how it can best be employed in design contexts.

A related user-centred (theoretical) approach to understanding clinical work, which works with ethnographic data, is a sociological theory known as symbolic interactionism. A basic assumption of the symbolic interactionist tradition is that people act toward things on the basis of the meanings they ascribe to those things, which arise from within the society itself and out of the processes of interaction between members of society (Blumer, 1969; Cuff et al., 1998). As noted by (Fitzpatrick, 1998), the focus of symbolic interactionism, as such, is "to understand the symbolic meanings that people attach to situations and how these evolve over time through interpretive communicative activity between people" (p. 17). The real challenge from the perspective of cross-boundary decision support is to understand how local settings and circumstances influence variations in problem-solving and decision making, and how different people seek to adapt commonly available resources, e.g. online information, in order to achieve their goals based on the tools they have and the challenges they face.

One approach, which draws extensively from the tradition of symbolic interactionism, is the grounded theory developed by Glaser and Strauss (1967). According to (Strauss and Corbin, 1998), grounded theory is a "qualitative research method that uses a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon." The primary idea behind grounded theory is to inductively generate a theory out of empirical data in contrast to theories acquired by logico-deductive methods. The grounded theory methodology is designed to help researchers produce "conceptually dense" theories (Vyas, 2011, p. 32), which represent the “patterns of action and interaction between and among various types of social units” (Strauss and Corbin, 1998) and which accounts for most of the variations in change over time, context, and behaviour in the studied phenomenon. The aim, in grounded theory, is not to create the "objective truth" but rather to conceptualise "what's going on" on the basis of empirical data.

2.5 The Notion of Awareness

The term “awareness” conveys a broad notion of “taking heed of [the] context” (Schmidt, 2002, p. 286) of something or event, and has been shown to represent a large concept that can be used in different situations (Chalmers, 2002; Schmidt, 2002; Heath et al., 2002; Kirsch-Pinheiro et al., 2004; Vyas, 2011), a times even in contradictory ways (Schmidt, 2002, p. 287). As humans, we have a natural ability to construct and maintain awareness of each other’s activities, context or status, even across boundaries of time, events, work domains, organisations, regions and cultures. Furthermore, we can intelligently draw necessary analogies between disparate activities and contexts so as to adapt knowledge across boundaries to suit specific problem-solving situations and real-time constraints. We do this in part because we are implicitly aware of one another’s operational contexts (Belotti et al., 2005), we have background knowledge of the universe of one another’s working environment and prevailing working patterns (Dey and Abowd, 2000) as well as general knowledge of “perceivable differences” (Rattenbury, 2008, p. 3) among different “activity landscapes” (Kirsh, 2001, p. 305) in the real-world. Research on awareness, which has its root in CSCW, particularly in a number of work place studies (Heath et al., 2002, p. 317), stems largely from a desire to design information systems that can mirror this kind of human capability. Although awareness comes to us so natural that we apply it to daily tasks without needing to think about it, (Gutwin, 1997, p. 12) observes that the nature of awareness is not inherently obvious, and does pose considerable challenges to systems design, particularly from HCI and IS perspectives (Markopoulos and Mackay, 2009; Schraefel et al., 2009; Vyas, 2011).

Over the past twenty years, the idea of awareness has been explored in different ways in literature (Dourish and Bellotti, 1992; Muller et al., 1997; You, 2000). However, the concept fundamentally amounts to “an understanding regarding what others do, where they are, or what they say" (Markopoulos and Mackay, 2009, p. v) in order to enable inferences about the intentions, needs, actions and even emotions of others. Probably one of the most cited definitions of awareness in HCI and CSCW literature is given by Paul Dourish and Victoria Bellotti in their seminal paper (Dourish and Bellotti, 1992) in which they defined awareness as "an understanding of the activities of others, which provides a context for [one's] own activity" (p. 107). The authors use different kinds of displays, e.g., whiteboards, access privileges and alerts about people's activities and status, in order to provide (shared) information with the aim of influencing (i.e., providing a context for) one's own actions. However, by emphasizing that it is "the activities of other people that sets the basis for one's own actions" (Markopoulos and Mackay, 2009, p. 232), the definition appears to suggest that social consciousness and group awareness are the only goals of awareness. Awareness could be constructed for different purposes, including informal interactions, spontaneous connections, collaborative work, development of shared cultures, distributed decision support, enabling intelligent inferences by autonomic systems, and in the context of clinical information systems (Dourish and Bly, 1992; Feng et al., 2009; Gonzalez and Wimisberg, 2007; Abbot and Wallace, 2007; Alsos, 2010). Researchers have arguably proposed that collaboration, social interaction and decision support are enhanced when systems communicate awareness information about the presence, context and activities of others in distributed work environments (Dourish and Bellotti, 1992; Gutwin, 1997; Riemer and Haines, 2009; Markopoulos and Mackay, 2009; Bardram and Hansen, 2010; Vyas, 2011).

In the literature, awareness is conceptualised in two major ways that relate to two different scenarios. The first is in a co-located setting, where participants are working towards achieving a common goal, e.g. in a control room (Heath and Luff, 1992). Secondly in a distributed setting, where participants are remotely attempting to collaborate via some kind of technological support, e.g. in cross-boundary clinical decision support. Vyas (2011) remarks that the two scenarios require different treatments of the term awareness. Whereas the concept and process of constructing awareness appear trivial, and easily taken for granted, in co-located contexts (Riemer and Haines, 2009; Anya et al., 2010; Bardram and Hansen, 2010), in distributed work settings, the process has to be mediated, e.g. by technology or practice, or effectively signaled by users (Riemer and Haines, 2009). In order to design for meaningful cross-boundary decision support in such environments, it becomes imperative to conceptualise effectively what awareness actually means, to derive a mechanism for understanding the numerous aspects of what awareness construction entails, and to decide what aspects of the other’s work – both from theoretical and real-world perspectives – that one needs to be aware of.

The idea of constructing and maintaining awareness of one another’s working context has been explored considerably in literature (Dourish and Bellotti, 1992; Brézillon et al., 2004; Vyas, 2011), and has been applied to a number of real-world settings in such areas as healthcare (Bardram and Hansen, 2010), driving and simulation (Brézillon and Brézillon, 2008), and control and operating rooms (Heath and Luff, 1992). Different forms of awareness have been proposed and explored, including collaboration awareness, peripheral awareness, background awareness, mutual awareness, passive awareness (Dourish and Bly, 1992), workspace awareness (Gutwin, 1997), experience-focused awareness (Vyas, 2011), activity-based awareness (Bardram, 2009), situation awareness (Endsley, 1995) and context-based awareness (Brézillon et al., 2004; Bardram and Hansen, 2010). While the proliferation of forms of awareness is a clear indication that the term “awareness” is found to the equivocal (Schmidt, 2002), the various guises under which the concept has been studied has, nonetheless, contributed to the design of computational models of awareness that are able to explicate the complex array of interdependent and highly contingent circumstances, conditions and actions that are required to understand things and events in the world. Several researchers, such as (Agostini and Prinz, 1996; Schmidt, 2002; Dix, 1997; Gutwin, 1997; You, 2000; Health et al., 2002; Riemer and Haines, 2008; Markopoulos and Mackay, 2009; Vyas, 2011), have reported a number of characteristics of awareness. An analysis of these works, particularly from a practice-centred perspective, suggests that awareness consists of the following basic conceptual features:

- Awareness is determined by work and workplace setting. It is knowledge of the state of the environment, environment being a temporally and spatially bound setting for people interacting within it. It is by the people’s experiences of this interaction.
- Awareness is dynamic, because the environment changes, and thus awareness needs to be kept up to date (You, 2000).

- Maintaining awareness is not the main target of tasks. It is necessary, but not enough. It enables smooth completion of tasks (You, 2000).
- Awareness has a socio-technical dimension, and is important to both social and technical research.
- Awareness is both implied in people's work and an integrated aspect of their practice (Vyas, 2011, p. 17)

We adopt, in this work, a practice-centred approach to the design of awareness models for cross-boundary decision support in e-health. Awareness is an attribute of practical action, and, as such, is constructed as a part of how we work. As rightly noted by (Heath et al., 2002):

> The ways in which individuals accomplish awareness is inextricably embedded in the activities in which they are engaged, and the ways in which those activities necessarily entail particular practices and procedures. (p. 318)

Awareness is purposeful and implied in our activities and practices. It involves not only knowledge about the dynamic and task-oriented, easily observable interactions within a spatially and temporally bounded space, but also knowledge about what influences those interactions and the end to which the interactions are directed. What others will become aware of about our activities is dependent upon the motive for seeking such awareness. Moreover, the awareness is equally dependent upon the activities in which we and the others are engaged in, our domain and organisational context, and how we conduct those activities (i.e. our practice). Awareness captures the social and work contexts of use in CSCW and decision support systems (Gross et al., 2005). Observational studies of complex and knowledge-based problem-solving domains (Luff et al., 2000; Clancey, 2006; Suchman, 1987; Bardram and Hansen, 2010; Gabbay and le May, 2011), have suggested that users often employ practices and procedures that not only fall outside of formal work processes, but were also hardly predictable during system design (Riemer et al., 2007). The real challenge, therefore, is to understand how people effortlessly make practical sense of what other people do, how they are likely to do it (under various circumstances), and what they might need in doing it. It has been suggested that our system design approach need to take into account diverse coordinative practices through which work is routinely and seamlessly integrated (Vyas, 2011, p. 16). These coordinative practices differ from domain to domain, from locality to locality, and from context to context. And as noted by (Luff at al., 2000), a firm grounding of design approaches in the concept of practice is crucial for the design of effective work support systems.

2.6 Summary – Towards a Practice-Centred Perspective

This chapter has discussed the three foundational concerns of this research investigation, namely cross-boundary clinical decision support in e-health, the nature of clinical work, and the notion of awareness, and indicates that as technologies have evolved, so too have the social, practice and culture-related issues with which they are interlinked. It reveals that problem solving and decision making involve “a complex of customs, social situations, personal experience, culture and objects" (Hoshi, 2011, p. 73) that go well beyond clinical workflow representations. Existing CDSSs and e-health systems are often "not successful in realising sustainable innovations in healthcare practices" because their development often disregards the practice-level where the interdependencies between technology, human characteristics, and the socio-economic environment of work (van Gemert-Pijnen et al., 2011) become more obvious. Incorporating practice-level analysis into the whole process of information systems design has remained a challenge (Dourish, 2004; Allert and Richter, 2008; Unertl et al., 2009; Pace et al., 2010; Brézillon, 2011; Fan et al., 2011). As a result, new holistic approaches to the development of e-health technologies are needed, which take into account the complexity of healthcare in terms of the practices and habits of clinicians and the needs and circumstances of patients as an inherent part of clinical decision making. In the rest of this thesis, we show how we have contributed to this line of enquiry by investigating the concept of work practice as a design requirement for e-health systems for cross-boundary clinical decision support. The goal is to adequately support clinical decision-making based on real-world contexts, practices and patients’ needs.

3

Theoretical Frameworks

Without logic, a knowledge representation is vague, with no criteria for determining whether statements are redundant or contradictory. Without ontology, the terms and symbols are ill-defined, confused and confusing. And without computable models, the logic and ontology cannot be implemented in computer programs.

– John S. Sowa, Knowledge Representation, p. xii

3.1 Introduction

Since this research involves the construction of awareness of work at a work practice level, the use of theoretical frameworks to rigorously explore “the precarious relationship between how people work and how the work gets done” (Crawford, 1995, p. 5) in the real-world, and to facilitate adaptive cross-boundary decision support in an e-health environment is going to be an integral part of this thesis. In this chapter, we present a brief review of a number of relevant conceptual and theoretical frameworks for investigating awareness, work practices and context-based decision support. In particular, this chapter discusses the cultural-historical theory (CHT), the theory of work practice, and situation awareness (SAW). The list is a reflection of the main frameworks and techniques that particularly come close to our research goals. The key contribution of this chapter lies in the manner in which a wide range of diverse theories and frameworks are integrated to construct an awareness model that enables a deep-seated understanding of work practices in real-world clinical work settings.

3.2 Underlying Theoretical Perspective

The basic meta-theoretical thought that informs this research work is the practice-theoretic perspective, an emerging and competitive paradigm that seeks to analyse people's behaviour and interaction with technology by means of focusing on "practice" as the key object of research (Chaiklin, 2011; Gabbay and le May, 2011; Pace et al., 2010; Isah, 2008). The practice-theoretic perspective is not a coherent theory per se (Postill, 2010), but rather an analytical perspective within such frameworks as socio-cultural theory, practice theory and cultural-historical psychology, and are able to draw from an assembly of theoretical elements found in the works of Vygotsky, Bourdieu, Leont'ev, Giddens, de Certeau and Garfinkel, and more recently (Suchman, 1987; Fitzpatrick, 1998; Dourish, 2001). The use of theoretical frameworks from the social science discipline to inform research studies in IS, HCI and CSCW is not new[14], and underscores the growing need among researchers in informatics to ground system design in a deep-seated understanding of people's needs and engagement with the real-world situations of their environment (Wenger, 1998; Loo and Lee, 2001; Reddy et al., 2003). In adopting a practice-theoretic perspective, our challenge is to explore how the theoretical frameworks discussed in this chapter would potentially enable the design of technologies for constructing awareness of actual clinical work situations in e-health, to represent that awareness as knowledge and to use the knowledge to adaptively support clinical problem-solving and decision-making across work boundaries. As noted by (Sierhuis and Clancey, 1997), knowledge is arguably embodied in people's work practices, and, as such, can hardly be fully understood outside its context of use (Maguire, 2001).

3.3 The Cultural-Historical Theory

CHT has its roots in early twentieth century work of developmental psychologist, L. S. Vygotsky, and his colleagues in the former Soviet Union (Vygotsky, 1978; Leont'ev, 1978; Raeithel, 1992). The central idea of the Vygotskian concept was to establish a "cultural-historical science" about humans with the aim of providing a unified account of "the nature and development of human behaviour" (Lantolf, 2006, p. 8), and a basis for understanding human practices and praxes, e.g. learning and doing, in the developmental, cultural, historical and environmental contexts in which they occur (Schatzki, 1996; Wenger, 1998; Stetsenko and Arievitch, 2004; Kaenampornpan and O'Neil, 2005).

[14] In a set of trend-setting publications, (e.g. Weiser, 1991), Wieser observed that one of most valuable clues to aid computer scientists in the design of a truly "invisible computer" lies within the humanities and social sciences, because of the disciplines' ability "in exposing the otherwise invisible". He noted, for instance, that ethnography can teach us something of the importance of the details of context and setting and cultural background.

CHT, like activity theory, is not viewed by most scholars (Kutti, 1996; Holzman, 2006; Vyas, 2011, p. 30), as a theory per se, but rather a philosophical framework, based on Marxist philosophy, for investigating historically and institutionally developed traditions of actions (Leont'ev, 1978). What underlines the "theory" or "metatheory" (Robbins, 2006) as a philosophical framework is an exploration of the "development of human culture and individual personality based on dialectical materialism" (Bødker, 1991, p. 552). Thus, CHT provides a theoretical perspective, within a much broader framework of cultural-historical science (Chaiklin, 2011), for studying human practices. It aims to understand the structural dynamics that organise people's historically-developed traditions of actions in carrying out their tasks within a work environment (in relation to available tools and technologies) and in producing services that satisfy collective needs (Chaiklin, 2011).

CHT not only explores the relationship between activity and context, but also interprets work practices as socially distributed manifestations of individual and collective actions – an activity system – over a period of time (Engeström, 1987). As a result, it has, as a subset of its much broader concept of practice (Chaiklin, 2011), the notion of a socially distributed activity system (Engeström, 1987) that is the basic unit of analysis in activity theory. An activity system, which is usually represented using what has come to be known as the basic mediational triangle (see Figure 3.1), consists of objects, subjects, actions and operations. In describing the activity system, the Center for Research on Activity, Development and Learning (CRADLE)[15] offered the following:

> In the model, the subject refers to the individual or sub-group whose agency is chosen as the point of view in the analysis. The object refers to the "raw material" or "'problem space" at which the activity is directed and which is molded and transformed into outcomes with the help of physical and symbolic, external and internal mediating instruments, including both tools and signs. The community comprises multiple individuals and/or sub-groups who share the same general object and who construct themselves as distinct from other communities. The division of labor refers to both the horizontal division of tasks between the members of the community and to the vertical division of power and status. Finally the rules refer to the explicit and implicit regulations, norms and conventions that constrain actions and interactions within the activity system. (para. 3)

[15] CRADLE is based at the University of Helsinki, Finland, can be reached at http://www.helsinki.fi/cradle/info.htm http://www.edu.helsinki.fi/activity/pages/chatanddwr/activitysystem/

An activity system seeks to depict the basic premise of the CHT, namely to understand the unity of consciousness (the human mind) and activity (what we do) as being meaningfully inseparable[16] (Bannon and Bødker, 1991) by focusing on human practices at the level of concrete interactions of individuals acting in a meaningful social context (Chaiklin, 2007). It incorporates strong notions of intentionality, history, mediation, collaboration, interpretation and development in constructing consciousness within and out of everyday practices that are firmly and inextricably embedded in the social matrix, e.g. communities of practice, work organisation, play group, family, etc. of which every person is a part of (Nardi, 1996; Kaptelinin, 1996; Kuutti, 1996).

CHT has, as its basic assumption, the notion that doing (and learning) is a cognitive process, which is dialogical, oriented towards an object or goal, mediated by conceptual, psychological and material artefacts within a work environment, and socially embedded in the history and culture of a community of practice (Wenger, 1998). It is analogous to the concept of social construction of technology (Gay and Hembrooke, 2004, p. 15) by seeking to explore ways that individuals, due to their various histories and positions, construct the components and objects of a work system in various ways that meet their needs and circumstances.

An artefact encapsulates the practices of a people through its properties and the knowledge of how it should be used (Sandom and Macredie, 2003); i.e. the tools we use mediate, i.e. shape the way we work. Through conscious actions guided by a number of biases based on personal experiences, available tools and prevailing work circumstances, individuals within the social-interactional context of work (Kaptelinin, 1996; Kaptelinin and Nardi, 2006; Engeström et al., 1999; Sandom and Macredie, 2003; Holzman, 2006; Robbins, 2006) seek to understand work practice or the consequences of it, and often reject the imposition of pre-formed plans (Chaiklin, 2011, p. 238; Suchman, 1987). Development and transformation of work emphasizes the study of historically-developed practices both as part of the process of forming psychological capabilities and as the source of psychological contents acquired by individuals (Chaiklin, 2011; Nardi, 1996, p. 7). Within CHT, work assumes a hierarchical structure consisting of three distinct levels – the activity level, the action level and the

[16] It arguable that the principle of "unity and inseparability of consciousness and activity" has manifestation in human work.

operation level; the subject transforms object through actions and operations in accordance with the motive of work. Thus activity provides the minimal meaningful context necessary for making sense of situated actions (Sandom and Macredie, 2003).

Over the years, studies of Vygotsky have resulted in varying interpretations of his original idea leading to the existence of different approaches to, and theories of, cultural-historical psychology, including socio-cultural theory (Robbins, 2007), cultural-historical theory (Chaiklin, 2011), activity theory (Nardi, 1996) and cultural-historical activity theory (Engeström, 1987; Stetsenko and Arievitch, 2004). They are often compared with social practice and social developmental theories (Lave, 1977). To a large extent, they represent, in the words of (Holzman, 2006, p. 5), lines of scholarship denoting "a set of articulations that more often than not overlap rather than separate."

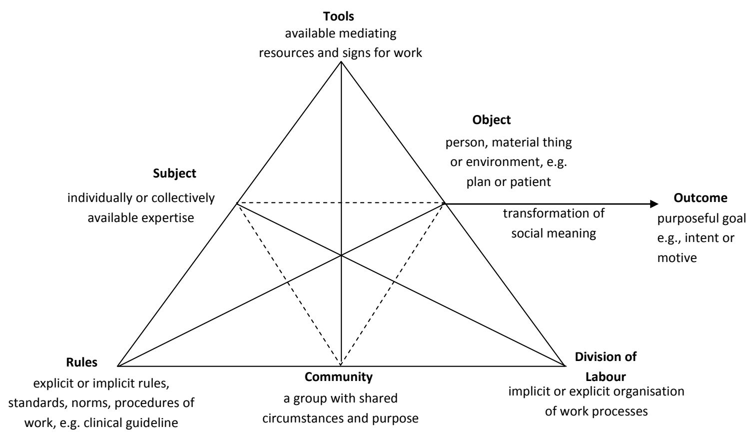

Figure 3.1: The generic model of a human activity system (adapted from Engeström, 1987; Kuutti, 1996)

3.3.1 Using Cultural-Historical Theory

Without a background in Soviet psychology tradition, we found the concept of CHT difficult to understand, particularly in relation to deciphering the subtle shades of differences between the "sibling theories"[17] because currently there exists "no single definition of the entire Vygotskian model" (Robbins, 2006). With reference to activity theory (Fitzpatrick, 1998, p. 19) reports similar problems in understanding. Robbins (2007) observes that although the use of different labels to refer to the Vygotskian theories reflects the flexible and robust nature of current Vygotskian thinking internationally, it has resulted in a phenomenon that leaves many people not understanding the difference between the various interpretations. In this research

[17] Some scholars use this term to denote the list of theories, e.g. CHT, AT, CHAT, etc. within the Vygotskian family (Robbins, 2007)

work, we focus on CHT because of its huge emphasis on the concept of work practice as the key object of study (Chaiklin, 2011). However, where appropriate, we will refer to related works that use activity theory[18] to refer to concepts that apply to both activity theory and CHT. Generally, CHT is widely considered a useful tool for designing user interfaces and information systems based in the work settings in which they were to be used (Sandom and Macredie, 2003; Fitzpatrick, 1998; Zhang and Bai, 2004; Bai and Guo, 2010; Vyas, 2011).

In applying CHT, we are focused on addressing the following: How can we better understand work in the context of its historical developments? How does a local work environment, including the workplace, the work culture, the work community and available work tools and expertise, influence and shape how work actually get done? In particular, we seek to conceptualise clinical work as a relation between a clinician and the world (as represented by the patient and every other person or thing affected by the work) through change in the clinician's capacity for resource use and interpretation of artefacts within their historical and situated contexts of work, e.g. activity, institutional practices, available tools and expertise and work circumstances. Context and artefacts become an objectification of human needs and intentions already invested with cognitive and affective content. A key challenge, therefore, is show the relationship between the evolution of work practices (based on cultural-historical mediations) and the dynamics of constructing knowledge for clinical problem-solving and decision-making within the community of work practice.

3.4 Theory of Work Practice

Beginning with the work of the French anthropologist, Pierre Bourdieu (1977), efforts to define an “outline of a theory of practice” have been described across disciplines (Engeström, 1987; Chaiklin and Lave, 1996; Bourdieu, 1990; Schatzki et al., 2001; Goldkuhl and Röstlinger, 2006; Gabbay and le May, 2011), and have, often, taken on different labels – concept of practice (Wenger, 1998), theory of practice (Bourdieu, 1977) and workpractice theory (Goldkuhl and Röstlinger, 2006). Studies of work practice emerged into IS research mainly out of the concern to provide a means for organising work (Button and Harper, 1996),

[18] Activity theory (AT) has particularly gained a much wider acceptance within IS design and HCI studies (Fitzpatrick, 1998, p. 19), and remains to date the most widely applied Vygotskian theory within the HCI, CSCW and IS research communities (Cassens, 2008; Fitzpatrick, 1998; Forlizzi, 2007; Vyas, 2011 – just to mention a few recent Information and Computer Science PhD theses that have applied AT).

to account for the situated and contingent nature of work (Suchman, 1987; Fitzpatrick, 1998, p. 24), and as an instrument for explicating human actions and understanding people's work contexts and experiences (Chaiklin, 2007). A key contribution of the work practice-based approach to the challenge of work representation include the establishment of a framework for grounding the analysis of work well beyond what has been offered by rationalistic formalisms of work and workflow-based representations, which according to (Button and Harper, 1996, p. 279) is necessary to inform design about "the practices through which members orderly handle the contingencies of their work situations". Over the years, work practice has increasingly been a key object of investigations for informing systems design (Suchman, 1987; Bowers et al., 1995; Button and Harper, 1996; Fitzpatrick, 1998; Cabana et al., 1999; Karasti, 2001; Dourish, 2004; Chaiklin, 2007; Igira, 2008; Brézillon, 2011).

3.4.1 Conceptualising Work Practice

Practice – being one of the terms in common use in everyday conversation (Schatzki, 1996) – has got a lot of subjective connotations. The Oxford Online Dictionary[19], practice is defined as "(i) the actual application or use of an idea, belief, or method, as opposed to theories relating to it; (ii) the customary, habitual, or expected procedure or way of doing of something; and (iii) repeated exercise in or performance of an activity or skill so as to acquire or maintain proficiency in it."

One of the earliest attempts at the study of practice was in the social sciences, particularly in cultural-historical studies, which began in the 1920s, of historically developed traditions of human work activities (Chaiklin, 2011). A related line of inquiry, which has its roots in the theory of social practice as sketched by such authors as Wittgenstein, Bourdieu, Giddens, Garfinkel, Latour, Taylor and others, has equally been pursued in the fields of philosophy and sociology. However, it was not until Theodore Schatzki's 1996 work on *Social Practices* that a social philosophy with an explicit focus on the concept of practice was developed. Another notion of work practice is embodied in the concept of community of practice as found in the works of Etienne Wenger (Wenger, 1998; lé May, 2009). Broadly, notions of work practice exist in research works across disciplines such as psychology and education (Chaiklin, 2011), philosophy, sociology and anthropology (Bourdieu, 1977; Schatzki, 1996; Cole et al., 1997;

[19]http://oxforddictionaries.com/definition/practice

Tuomela, 2002), HCI (Dourish, 2004), IS design and decision support (Brézillon, 2007), and AI (Clancey, 2006).

Work practice can be defined "the ways of doing work, grounded in tradition and shared by a group of workers" (Bødker, 1991). This "customary way of doing things" (Allert and Richter, 2008), according (Reckwitz, 2002, p. 245-6), incorporates an appreciation of a people's cultural and historical phenomena, and is derivable from Leont'ev's hierarchy of activity (see Table 3.1). The importance of practice lies in its ability to locate the precise situation of work; the design of computer support for work, by default, implies the design for the work situations of the users (Fitzpatrick, 1998). Bødker et al. (1988) outlines this importance thus:

> By practice we refer to human everyday practical activity. In practice we produce the world. Both the world of objects and our knowledge about this world. Practice is both action and reflection. But practice is also a social and historical activity. As such it is being produced cooperatively with others, being-in-the-world. To share practice is also to share understanding of the world with others. (p. 378)

However, practice has been generally overlooked theoretically (Hopwood, 2010), often taken as a "thin" term with little meaning (Green, 2009; Kemmis, 2009), a times referred to as a loose family of not necessarily coherent ideas, and always treated as a background concept (Chaiklin, 2011). Some thinkers conceive of practice, minimally, as arrays of activity, others yet theorise practice as the skills, tacit knowledges and presuppositions that underpin activities.

Table 3.1: An extension of Leont'ev's three-level hierarchy of activity including work practice (Adapted from Mursu et al., 2007)

Unit	Directing Factor	Subject
Operation	Conditions	Non-conscious (Routinised, Human or Machine)
Action	Goal	Individual or Group
Activity	Object/Motive	Collective (Social)
Work Practice	Object/Motive/Culture	Collective (Socio-cultural), historical

Though this diversity in accounts of practice has, no doubt, dogged contemporary research interests in work practice, (Schatzki et al., 2001) observe that practice accounts are joined in the belief that such phenomena as knowledge, meaning, human activity, science, power, language, social institutions, and historical transformations occur within and are a fundamental aspect of how people work. Further unifying the different accounts is the notion that a practice is an embodiment of materially mediated arrays of human activity centrally organised around shared practical understanding (Schatzki, 1996). A key point in Schatzki's writings is the central notion that practice comprises doings (activities) and sayings (representations of activities). Such notion is equally evident in (Kemmis, 2009), who describes practice as comprising not only doings and sayings, but also "relatings" and setups. Schatzki's work points out that an analysis of work ought to consider both practicalities of work and their representations, as well as the "nexus of doings and sayings", i.e. the means through which individuals engaged in the activities seek to construct meaning out the bond between doings and sayings, which leads to the second point in Schatzki's writings, namely that a practice is "a social practice". Schatzki's analysis views practice as being temporally unfolding, spatially dispersed, and causally linked.

Chaiklin (2011) identifies three forms of practice that, according to the author embody an understanding of the theoretical concept of work practice. They include *universal, specific* and *concrete practices* (2011, p. 233-234). The universal form denotes the type of practice that is found in all practices; according to the author, "all practices appear as traditions that aim to produce objects or products that satisfy collective or generalised needs". Specific practices denote practices that "have become institutionalised in specific societies", and are organised in relation to producing objects for specific generalised needs. Concrete practices signify practices that are "grounded in the historical characteristics of a specific practice" (p. 234). Chaiklin's analysis of practice conceptualises practice as a nested hierarchy, where the universal form, as a generalised notion, includes the specific, which, in turn, embraces the concrete. Chaiklin's explication of practice is underlined by an interesting assumption, namely that we don't always have within our reach every resource required to achieve certain purposes; in other words, we work and live in situations of "lacks". And as such "respond to these lacks by making material transformations that produce material objects or conditions that overcome the lack, thereby satisfying the need" (p. 233). Chaiklin's approach can be summarised as an effort aimed at specifying, either generally or specifically, the object to which practice is directed. The author decried that practice is usually treated as "a background or precondition for understanding the development of psychological capabilities, rather than a central focus of investigation in its own right" (Chaiklin, 2011).

Arguments to develop more nuanced accounts about people's engagement with various technological artefacts in the course of working are equally evident in the works of organisational researchers, such as (Schultze, 2000; Orlikowski, 2002; Baxter and Lyytinen, 2005). A key focus in this line of research, which adopt both structurational (Giddens, 1984) and contingency (Suchman, 1987) approaches to emphasize the theoretical importance of work practices, is that work practices represent instantiations of individual level agency that are both constrained and enabled by structures (e.g. organisational policies, work resources and technologies) as well as contingencies (e.g. socially and materially situated context) (Baxter and Lyytinen, 2005, p. 69). A number of fascinating classifications of work practices have emerged out of this line of investigation, including a grouping of work practices described in Schultze's (2000) exploration of the informing practices of three groups of knowledge workers. Orlikowski (2002) notes that work practices consist of three ontological components, including 1) being recurrent, 2) being materially and socially situated, and 3) involving active engagement by members of a community, emphasizing that "practices are engaged in by individuals as part of the ongoing structuring processes through which institutions and organizations are produced and reproduced" (p. 256).

Inherent in Orlikowski's argument is the view that an understanding of work practices must incorporate multiple levels of analysis, notably the individual and organisational levels. Extending this line of research, (Baxter and Lyytinen, 2005) propose another fascinating classification of work practice. In their study of the impact of IT use on work practices, the authors outline four classes of practice, namely cognitive, representational, relational and material practices. Cognitive practices represent ways of thinking and doing manifested through beliefs, perceptions, and general understanding of the work engaged in. Representational practices deal with the creation, manipulation and sharing of ideas via symbols, while relational practices are used to engage communication or dialogue. Finally, material practices deal with the actual physical manipulation of objects and artefacts. Although Baxter and Lyytinen's classifications were generated out of empirical data, they, no doubt, show interesting connections to prior literature; e.g. (Hutchins, 1995), who related cognition to situated action bound by culture, mind, body and context, or a community of practice (Lave and Wenger, 1991; Wenger, 1998).

In his work on Communities of Practice, Etienne Wenger puts forward a rich notion of practice. Central to Wenger's notion of practice is the understanding that practice is not merely about doing, but also about the experience gained in the doing. ‘‘Practice,’’ according to him, ‘‘is first and foremost a process by which we can experience the world and our engagement with it as meaningful’’ (Wenger, 1998, p. 51). Wenger’s notion of practice is heavily rooted in his concept of community of practice as a shared sounding board upon which a group of professionals accumulate knowledge, and become informally bound by the value that they find in learning and doing together (Wenger, 1998; Wenger et al., 2009; le May, 2009). Inherent in Wenger’s analysis is role of context in specifying practice as “the situated, emplaced, and embodied ways in which people go on with each other in everyday (professional) life” (Hopwood, 2010, p. 2). This crucial role of context is clearly evident in Dourish’s (2004) specification of the meaning of context, and also well highlighted in Sue Saltmarsh’s the exploration of the co-implication of context and practice. Saltmarsh (2009) notes that

> Practice and context are not, and cannot be, finally separable – each produces and locates the other in a complex interplay of socially produced knowledges, practices and relations. (p. 160)

Saltmarsh, whose work draws upon the Schatzki, emphasizes that practice is intrinsically linked with contexts or, what she prefers to refer to as, “practiced places”. She argues that professional practices cannot operate independent of the contexts in which they occur. In that sense, practice is a reflection (or measure) of the extent to which context should and does dynamically influence work. Practice cannot be conceived aspatially (Hopwood, 2010); the meaning in what people do, as well as how and why they do it the way they do it, can only be fully understood when analysed in relation to “a particular place and time” (Kemmis, 2009, p. 23). Schatzki’s recent book (2010) adds voice to the importance of the “timespace” dimension of practice. As noted by (Dourish, 2004, p. 25), the questions of what constitutes context are essentially the focal questions of practice, namely how do people orient to features of the world as contextual, peripheral or central, how is relevance managed, etc?

Distinctions have often been made between practice and praxis (Reckwitz, 2002), practice and procedure (Brézillon, 2007, 2011), practice and business process (Goldkuhl and Röstlinger, 2006), as well as practice theory and practical theory (Goldkuhl, 2006). Of particular interest to this work, is the distinction between practice and procedure, practice and business process as they denote the distinct, but interrelated, roles that practice, on one hand, and such artefacts as clinical workflows and guidelines, and organisational procedures and routines, on the other, have to play within a work context. As noted in (Goldkuhl and Röstlinger, 2006, p. 47), business processes and procedures are a subset of practice; the former denote rigidly ordered sets of activities, e. g. clinical workflows, while the later consists of open sets of non-regularised actions that are organised by practical understandings and precepts.

3.4.2 Key Assumptions of the Work Practice Perspective

Drawing from these works as well as (Allert and Richter, 2008) modelling socio-technical system, we identify the following assumptions of a work practice perspective:

- Practices are socially mediated, i.e. they are shaped by and evolve within social communities and can even become part of the communities' identity (Büscher, 2001; Wenger, 1998, p. 143).
- Practices entail both a momentum of stability as well as change. While practices manifest and reproduce historically developed patterns of activity they are also open for change in that the concrete activities have continuously to be adapted to new situations and changing conditions (Chaiklin, 2011).
- Even though practices are often characterised by the use of particular artifacts (e.g. giving a power-point presentation), practices are not determined by these artifacts in a strict sense. This difference is due to the fact that an artifact becomes a tool only when interpreted as such within in a social and historical context, (Floyd, 2002).
- Practices do not exist in isolation but are part of a larger network of practices that is dependent on a broad-based notion of context. Practices are interrelated as both individual and collective actors as well as artifacts are usually enrolled and used in several practices simultaneously.
- Practice is the research object (Chaiklin, 2011, p. 229) to which studies of cultural-historical theory (Leont'ev, 1978) is directed. As a result, any scientific understanding of work practice must include some analysis of the socio-historical context in which the practice becomes enacted, since practice acts as a scaffold to augment and direct human actions (though in a non-deterministic way) within a work context.

- Practice represents a meaning-processing system, which processes information by constructing meaning, uniting action and meaning. It is essentially concerned with the ways in which actions can be rendered as meaningful, i.e. how a particular action, for example, becomes meaningful or is interpreted by certain people by dint of where it was performed, when it is performed, and with whom or what (Dourish, 2004; Wenger, 1998).

A central point emerging from the above characterisations is that work practice is prototypical, i.e. bounded and local (Star and Griesemer, 1989; Wenger, 1998) to, a community of practice, and denotes an evolving process by which individuals within the community could experience the world and their engagement with it as meaningful (Wenger, 1998, p. 51). The concept of work practice, on one hand, draws from plans, procedures and formal theories, and on the other, relates well with ad hoc practicalities of work. Theories are based on models, and models merely reflect aspects of the world that are of interest to the modeler (Chaiklin, 2011, p. 231), and do not, in all cases, reflect all contingencies that exist 'in practice'. In this sense, practice is very much a residual category of epistemological status, denoting the inexhaustible universe of actual occurrences that any given 'theory', 'rule' or 'plan' presumes, but does not and cannot express (Schmidt et al., 2007), since, as (Suchman, 1987) puts it, it is, as a linguistic construct, "underspecified". Practice denotes what is routinely done – so much that it may have become 'the stereotype' of a workplace – as opposed to "the innovative, the ad hoc, and the unpredictable rife in the workplace" (Schmidt et al., 2007). A practice is normatively regular, not something that happens once (Schmidt et al., 2007), or by chance. Work practice includes the explicit and the tacit, as well as the specific perspectives and terms that a community[20] has developed "in order to be able to do their job and have a satisfying experience at work" (Wenger, 1998, p. 47). It creates "an atmosphere in which the monotonous and meaningful aspects of the job are woven into the rituals, customs, stories, events, dramas, and rhythms of community life" (p. 46).

Key to all the analysis of work practice is a shift away from "traditional notions of practice as rational, cognitive, and knowable on unambiguous terms" (Hopwood, 2010) to an exploration

[20] In the same sense as (Wenger, 1998; Wenger et al., 2002), we use the term community to denote a group of people of the same professional working either physically or virtually together.

of practice as social (Schatzki, 1996), contingent, embodied (Dourish, 2004), experiential (Wenger, 1998), and ambiguous (Schwandt, 2005) phenomena, which comprise materially mediated (Schatzki, 1996), object-directed (Chaiklin, 2011), spatial-temporal (Schatzki, 2010) and contextually mediated arrays of human activity that are centrally organised around shared practical understanding. As technology designers, therefore, our goal is to support both the evolution and adaptive nature of practice. As noted by (Dourish, 2004, p. 25), we should not simply be concerned about supporting particular forms of practice, but rather supporting the evolution of practice, or what (Schön, 1983) refers to as the "reflective conversation with the situation" (p. 76), out of which emerges new forms of action and meaning (Wenger, 1998) – a design challenge that is crucially vital to the development of effective and context-aware decision support tools, especially for cross-boundary decision support in e-health.

3.5 Situation Awareness

Over the last twenty years, SAW has increasingly garnered much research attention in the fields of human factors, cognitive engineering, HCI and IS design (Adams et al., 1995; Endsley, 1995; Wong and Blandford, 2001; Blandford and Wong, 2004; Durso and Sethumadhavan, 2008). The growing interest in SAW was spurred on by many factors, chief among them are two related issues, namely: 1) the challenge of the increasing role of technology as meditational artefacts in the interaction between humans and their work environment (Kirlik and Strauss, 2003), and 2) the notion of SAW as being strongly associated with ideas that inherently enable the perception and assessment of situations in the real-world (Feng et al., 2009, p.455; Endsley et al., 2003). Numerous definitions and approaches to the phenomenon of SAW have been proposed in the literature[21], however, (Endsley, 1995) notes that, for the most part, they all point to the central concern of “knowing what’s going on” (p. 36).

Three theoretical approaches have dominated studies of SAW, and they include the information processing approach (Endsley, 1995), the activity theoretic approach (Bedny and Meister, 1999) and the ecological approach (Smith and Hancock, 1995). Inherent in all three approaches are the elements of perception of work domain and situation, comprehension of

[21] For a review of definitions of SAW, see http://www.raes-hfg.com/crm/reports/sa-defns.pdf. See also (Stanton et al., 2001)

current situation and projection of future occurrences and task requirements. Hence, Endsley's general definition of SAW as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995, p. 36) has been found to be applicable across a wide variety of domains.

At the core of Endsley's definition is the notion that *an awareness of a situation provides the primary basis for decision support*. For example, the awareness that clinicians have about a clinical work situation and a patient's medical condition situates the decisions and actions that they make and enables them to optimise how they use available resources, plan ahead based on prevailing work context and cater for any contingencies. Endsley went on to expand her definition into three levels of information processing model, including perception, through interpretation, to prediction. In the first level, a person seeks to perceive the elements of the current situation, and to make sense of the physical environment that they are in. In the second level, the person seeks to understand the dynamics of the physical elements and people in the situation in terms of changes in position, task goals and purpose. Since SAW must occur within a volume of space and time, the effect on current events on the near future must be projected, and this comprises the last level of Endsley's definition of SAW. SAW goes beyond an awareness of the elements in a situation to encompass a "gestalt ('big picture') comprehension and integration" (Holmquist and Goldberg, 2007) of those elements in light of domain rules, stereotypes and operational goals along with the ability to apply the resultant understanding to shape future decisions.

One of the underlying assumptions of SAW is that the actor is a direct of observer of the current situation. It enables an actor to construct an awareness of a situation on the basis of an internalised mental model of the current state of an environment. Hence, traditional studies of SAW, often, view situation in operational terms, and assume that the situation assessor (e.g. a pilot attempting to land an aircraft or a surgeon in a theatre) is an observer engaged in a task and seeking to achieve specific goals. Over the past two decades, the construct has been considerably applied in areas, such as aviation, patient monitoring, emergency care, naturalistic decision making, and system design and evaluation, and has been found to play a crucial role in real-time decisions made in the context of the situation (Klein, 1999; Endsley et al., 2003; Blanford and Wong, 2004; Fioratou et al., 2010). Despite this, there are still considerable criticisms and debate over how SAW operates in virtual work environments and distributed decision support systems, and how SAW can be best supported through interface design (Fioratou et al., 2010). This evokes a number of questions: how can the influence of unobservable concepts and phenomena be accounted for? How can a non-observer make sense of the situation, in other words, how can one make sense of a situation without being a direct observer of the situation, e.g. an expert clinician providing suggestion across work boundaries? Attempts to account for these concerns have led to approaches based on different theoretical frameworks, notably activity theory (Bedny and Meister, 1999) and ecological perspectives (Smith and Hancock, 1995), while still retaining much of the elements of Endsley's model (Dominguez, 1994). A key challenge, however, remains how the elements and components of a system, e.g. people, tools, monitors, organisational rules, including less obvious resources and work practices, can be coordinated to allow the system to accomplish its tasks (Fioratou et al., 2010), and, particularly for the questions we seek to address in this research work, allow for cross-boundary sense making and decision support.

3.6 Summary – Tying the Frameworks Together

The fields of HCI and IS design have, over the last three decades, adopted theoretical constructs and frameworks that were originally alien to computer science; a partial list can be found in (Halverson, 2002). In this chapter, we have discussed three of those. All three frameworks are valuable for analysing work context (Kirsh, 2001) from a socio-technical perspective (Lueg, 2002), and underscore the need to understand work from a practice-centred approach. In order to show how the three frameworks have provided a theoretical lens for the conceptual framework proposed in this work and discussed in Chapter 5, we depict pictorially in Figure 3.2 how they have been applied to enable an understanding of the three categories of work practices that emerged from the user-centred reported in Chapter 4 (Tawfik et al., 2012). As shown in the figure, the CHT and the theory of practice are used to understand the ontological and stereotyped practices, whereas the SAW theory is applied to understanding the situated practice. In addition, the concept of work practice is further understood using the practice theory.

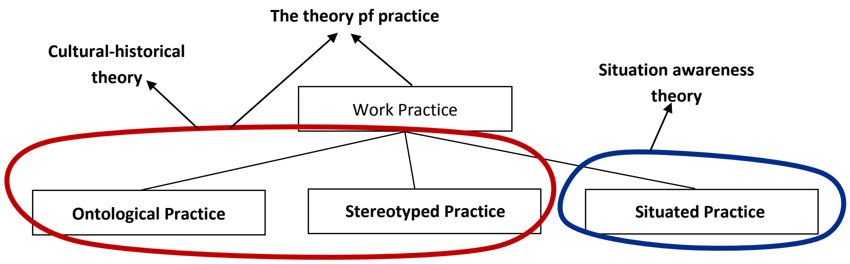

Figure 3.2: Applying the three theoretical frameworks to the proposed conceptual architecture (see also Section 5.5)

A common thread that runs through the three theories is the relationship between artefacts, context and situation, and how that relationship enables an awareness of a community's work practice, i.e. their evolving approach to activity. Context is dynamically constituted through activity involving people and artefacts in a specific setting; it is not just "out there" (Nardi, 1996, p. 38), but is consciously and purposefully generated through people's interaction with artefacts and the environment as represented in their practices (Dourish, 2004). This interaction is both shaped by situation and the result of specific historical, cultural and ontological processes within which work is transformed. The theories discussed in this chapter are valuable in explicating human activities and practices in real-world situations, bringing to light "the conflux of multifaceted, shifting, intertwining processes that comprise human thought and behaviour" (Nardi, 1996, p. 39. In the next chapter, we seek a user-centred basis to apply the theories to our research goal. Hence, we are confronted by the challenge, as noted by (Button and Dourish, 1996), of closing the gap between theoretical discussion and design, and do seek guidance in Christine Halverson's (2002, p. 244) question: what are we doing with these theories?[22]

[22] See also (Rogers, 2011)

4

Investigating Contexts of Work in e-Health: A User-Centred Study

Making work visible – discovering and describing how people accomplish their tasks, how work actually gets done – reveals what was previously hidden, albeit in plain view. As work practice analysts, our job is to make unbiased observations despite business goals or technology design requirements. … the challenge is [therefore] not the building of technologies, but the creation of technologies that fit into the workplace.

– Margaret H. Szymanski and Jack Whalen, Making Work Visible: Ethnographically Grounded Case Studies of Work Practice, 2011, (e-Book version), p. 42

4.1 Introduction

Clinicians in various work settings, owing to peculiar factors in their local work environments, have often evolved work patterns that go well beyond formally defined notions of a work process. Such work patterns have been shown to influence work at the work practice level – the level at which clinical practitioners seek to construct meaning out their experiences and interactions with the environment and perform their work in the real-world (Dourish, 2004; Gabbay and le May, 2011). Work patterns occurring at the work practice level remain under-studied in HCI and HIS research, and, to date, it is not clear what their design requirements are, or how information systems should be developed to address their needs (Novak, 2007). As a result, it becomes hugely challenging to develop e-health decision support tools to enable users to construct and maintain appropriate awareness of one another's clinical work contexts across work boundaries, since 1) the design process is currently underspecified, and 2) there is an inherent difficulty in establishing a shared context of work and users adequate for supporting practice-aware cross-boundary decision support among clinical practitioners.

To address this challenge, we carried out a user-centred study of clinical work practices across three different geographical areas – the UK, the UAE and Nigeria. In this chapter, we present the report of that field study. Our goal is to provide a user-centred basis for our research study and to identify design requirements to inform the development of technological support for cross-boundary awareness and decision support in e-health. Specifically, we believe that by collecting an account of the various ways by which clinicians often contextualise procedures, improvise practices in order to accommodate for peculiar workplace circumstances and specific patient-centred needs, and seek to construct meaning out of their local interactions with technologies, one can provide some useful insights into the design of technologies to support cross-boundary decision-making at a work practice level. The study integrates both quantitative and qualitative approaches as well as the use of a probe-based method for user-centred analysis in e-health, which we refer to as *practice probes*. Based on the results of the study, a formal characterisation of clinical work practices (in Chapter 5) and a set of design guidelines for the development of e-health decision support technologies are presented.

4.2 Related Work and Rationale

User-centred studies that seek to explore problem-solving and decision-making processes in their “natural” contexts, or more rhetorically “in the wild” (Hutchins, 1995; Rogers, 2011), have been widely considered a more viable approach for building work support systems grounded in the real-world (Ackerman and Halverson, 2000; Fitzpatrick et al., 1995; Suchman, 1987; Pinelle, 2004; Vyas, 2011), and for enhancing the ecological validity of conceptual designs of decision support systems (Burstein et al., 2010; Brézillon and Brézillon, 2008; Nguyen et al., 2006; Cuthbert et al., 1999; Huber, 1997; Klein et al., 1989). Early work drew largely from user modelling and requirements elicitation in software engineering in order to design systems and interfaces that meet the usability requirements of varying groups of users (Benyon, 1993). One crucial thing that emerged out of such work is the realisation that the hitherto focus on task as the unit of analysis of clinical workflow (Chandrasekaran 1990; Bellotti et al., 2003) is not sufficient to understand how usability and usefulness issues are subjectively and collectively experienced and perceived by different user groups in different clinical contexts (Pace, 2004; Razavim and Iverson, 2006), nor enough to design and implement effective systems for ubiquitous work support in healthcare (Cairns and Cox, 2008, p. 138).

Over the years, systems designers, influenced by the criticism of traditional system design by anthropologists, such as (Suchman, 1987), have looked to the social sciences with the aim of developing more user-informed technologies to support divergent ways of working (Szymanski and Whalen, 2011). This has led to a remarkable resurgence of interest in work practice, or as (Schatzki et al., 2001) put it, the "practice turn", and helped inspire a significant body of research in work practice studies that has informed the design of advanced technologies for supporting new ways of working (Luff et al., 2000; Brown and Duguid, 2000; Dourish, 2001; Llewellyn and Hindmarsh, 2010). A central goal was to uncover the non-explicit differences between how work is specified and how it actually gets carried out “in practice”. It has been argued (Winograd and Flores, 1987; Suchman, 1987; Weiser, 1991; Dourish, 2004) that conventional system design has often focused too rigidly on scientific workflows (Fan et al., 2011; Unertl et al., 2009), and fails to respond amenably to the informal and real-world settings in which actions unfold. The need, therefore, by designers to incorporate context has resulted in a wide adoption of social science based user-centred approaches for understanding the experiential and practice-based aspects of people's work settings and problem-solving patterns (Luff et al., 2000; Szymanski and Whalen, 2011).

However, the exact nature of the role of work practice studies (Luff et al., 2000, p. xii; Szymanski and Whalen, 2011) in system design, and the use of social science informed user-centred methodologies by HCI and HIS researcher to find ways to understand the social contexts in which both users and technologies are embedded (Dourish, 2006) has remained a matter of debate (Plowman et al., 1995; Schmidt, 2000; Bardram and Hansen, 2010, 2010a; Schmidt et al., 2007). A key issue is to distinguish how much a study contributes to the design of a proposed system, or how much it contributes to developing standardised, reusable techniques that inform theoretical foundations (Schmidt, 2000). Anderson (1997) as well as (Bentley and Dourish, 1995) have argued that in-depth work practice studies as used in social science will not be necessary in designing effective work support systems, since work practice studies “as a method for capturing end-user requirements for systems” is “predicated in a misunderstanding of the role of field studies in social science” (Schmidt, 2000). What is more important in achieving the goal of work practice studies in systems research, according to (Schmidt et al. (2007), is to critically analyse the rationale for the study in question (Shapiro, 1994; Plowman et al., 1995; Dourish and Button, 1998; Bannon, 2000; Dourish, 2007). The overarching goal has been to convey the importance of the sociality and situatedness of work and shed more light on the complex actions and interactions of meaning construction that occur during problem-solving and decision-making (Luff et al., 2000; Plowman et al., 1995; Randall et al., 2007; Bardram and Hansen, 2010). The contribution of work practice studies to contemporary research, according to (Luff et al., 2000), is not simply empirical, but also foundational; work practice studies build “a new and distinct foundation for our understanding of technology and social action” (p. xiv).

Research in work practice studies was originally associated to the pioneering idea of Xerox to involve social scientists in technology design for developing more human-centred systems (Szymanski and Whalen, 2011; Suchman, 1987). It has largely embraced three predominant methodologies, namely ethnography, conversation analysis and ethnomethodology. However, approaches that provide quantitative insights have also been advocated (Bardram and Hansen, 2010), including controlled experiments (Blandford et al., 2008), and statistical and questionnaire-based studies (Cairns and Cox, 2008). Recently, the probe-based methods – a technique, though informed by social science methodologies – have emerged and are increasingly gaining ground amid criticisms. Research in work practice studies has taken on a diversity of approaches (Luff et al., 2000); however, (Szymanski and Whalen, 2011) have recently proposed a methodology to guide work practice studies (see Figure 4.1).

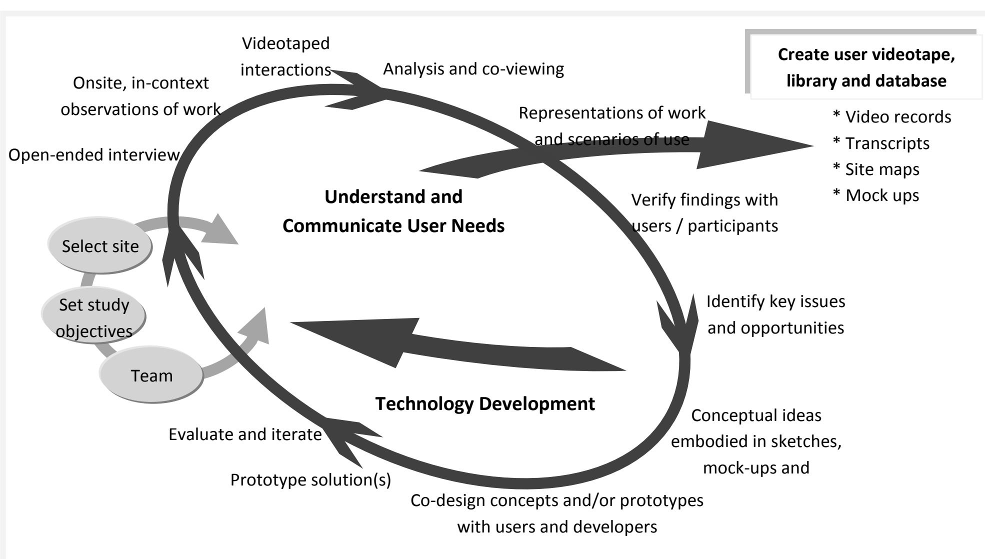

Figure 4.1: Work practice methodology (Source: Szymanski and Whalen, 2011)

Though only a few papers report the use of the work practice methodology (Szymanski and Whalen, 2011), the methodology appears to encompass significant aspects of what is required to understand work at the practice level and to design for the variety of ways in which tools and technologies feature in everyday problem-solving conduct (Luff et al., 2000). More research is needed in order to standardise the methodology for more effective guiding of this "reflowering of the sociology of work" (Luff et al., 2000, p. xiii) towards the design of effective tools for work support in diverse contexts. Recently, research in work practice studies has grown to incorporate design issues for mobile and nomadic work and for augmented social cognition and sensemaking in distributed and pervasive environments (Chi et al., 2007).

The goal of designing for work support at the work practice level has similarities with the concept of activity-based computing (Bardram and Hansen, 2010), including the focus on support for human activity, user-centredness, support for mobility and use of heterogeneous tools and support for context-aware adaptation. However, our practice-centred approach differs from the activity-based approach by incorporating a much broader set of concerns and emphasizing a people's local ways of doing things as a more deep-seated and people-centred way of understanding of activities. While activity-based computing aims to create computational support for human activities based on the idea that people organise and think of their work in terms of activities that are carried out in pursuit of some overall objective (Bardram, 2009), our approach seeks build a similar support but rather based on a much deeper realisation that people carry out their activities differently depending on their local contexts of work and varying circumstances and needs.

Within medical informatics and HIS design, a number of approaches are related to our use of the notion of practice, and have sought to address various aspects of technology support for healthcare through user-informed studies. In a study of two oncology clinics, (Schmidt et al., 2007) observe that work is "massively contingent" as lines of action differ from one patient to another and, even for a single patient, from one visit to another. The authors note that the variations are not handled in any ad hoc manner, but dealt with "routinely", using procedures, organisational workflow prescriptions and guidelines as "coordinative protocols" and to moderate deviations from known diagnosis and treatment pathways (as equally found out in the user-centred study reported in this chapter). Goud et al. (2010) describe a qualitative study of the effect of computerised decision support on barriers to guideline implementation. They note that while much work dwell on how system characteristics affect the effectiveness of CDSSs, little is known about the relation between cognitive, organisational and environmental factors and CDSSs' effectiveness. Most problems in HIS design and its integration with existing clinical systems are rarely as a result of technical issues, but rather due mainly to social and work process issues (Kuziemsky and Varpio, 2011; Respício et al., 2010). Though the work suggests that guideline implementation could be improved through increased understanding of preferred practices, it falls short of specifying how this could be achieved.

Other issues, particularly relevant in the design of cross-boundary EIS, include variations in clinical practices between hospitals and regions. Martinez et al. (2005) found that differences in needs and conditions of primary healthcare between developing and industrialised countries lead to the use of different solutions and approaches by different stakeholders, while Chen and Akay observe that "varying needs of developing countries" (2011) influence the type of electronic medical records and primary healthcare systems in use there. The design of EIS for clinical decision support in order to ensure "appropriateness in medicine" by allowing clinicians access to online medical literature, expert opinion, and through recommendations has been proposed in (Duan et al., 2011; Vanoirbeek et al., 2000). Two major challenges become prominent: how to construct generic models of work practices given the significant variations in what are defined as work practices in different areas? Will work practices be modelled as context or content in relation to task execution? How will the models be integrated into existing EIS and WfMS both for inter-organisational workflow integration and e.g. ensure minimised error and coordination load (Bowers et al., 1995; Cheng et al., 2003)?

Despite its strong role in explicating work processes in different contexts (e.g. in healthcare, Gabbay and le May, 2011), the concept of practice still attracts very little research attention as an approach to the design of IS for decision and work process support. As a result, our study appears relevant in the face of new movements towards designing in the wild (Rogers, 2011) and emerging trends in integrated health information networks and EIS (Xu, 2011), recent advances in e-collaboration (Karacapilidis, 2005) and the increasing need among professionals in healthcare and elsewhere (Sari et al., 2008; Xu, 2011) to harness globally distributed knowledge and leverage collective intelligence and social creativity across work boundaries for improved decision-making and, does have enormous implications for the design and adoption of future CDS technologies for e-health.

4.3 Underlying Assumptions

One of the major challenges facing researchers conducting a user-centred study, or indeed any empirical study, is to establish the necessary ontological and epistemological assumptions to drive the scientific inquiry, and, no less importantly, to define how such assumptions fit with their research question and inform methodological choices. This becomes even more challenging in view of the fact that most of the humanistic methodologies being employed for user-centred investigation in HCI and IS are “non-native” to computer science. The degree to which they should be applied by researchers in HCI and IS research has remained a matter of debate. However, over the past twenty years, for a variety of reasons – including the multidisciplinary nature of HCI and systems development (Cairns and Cox, 2008; Dix, 2008, p. 195) – these approaches have become increasingly incorporated into the core of HCI and IS research (Cater-Steel and Al-Hakim, 2009; Cairns and Cox, 2008). The challenge, for the HCI and IS researcher, as a result, is to construct sufficient justifications for approaching system design based on a set of hitherto “alien” paradigms, underpinning assumptions and worldview (Hirschheim and Klein, 1989), bearing in mind the consequences of conceding to those assumptions a foundational role within their investigations (Dourish and Button, 1998).

Broadly, three foundational research paradigms exist in social science, namely positivism, phenomenology or interpretivism and the critical paradigm[23] (Dourish, 2004; Creswell and Plano Clark, 2007, p. 22). However, the first two paradigms are more predominantly used within the HCI and IS research community; critical theory, which is essentially an extension of Marxist analysis, is less pertinent to this thesis and will not be further discussed here[24]. Put succinctly, the positivist paradigm derives from the rational, scientific tradition, and assumes that there exists an objective social reality that can be studied independently of the action of the human actors in this reality. Accordingly, positivist theories seek objective, independent

[23] An in-depth analysis of these paradigms and methodologies is outside the scope of this work, and is well discussed in the social science literature (Creswell and Plano Clark, 2007; Tashakkori and Teddlie, 2010).
[24] Discussions of critical theory can be found in (Kincheloe and McLaren, 1994; Carr and Kemmis, 1986).

descriptions of reality by reducing "social phenomena to essences or simplified models that capture underlying patterns" (Dourish, 2004, p. 20), akin to the way physical sciences seek to abstract and reduce complex objective phenomena to underlying idealised mathematical descriptions often through "the use of hypothetic-deductive logic and analysis" (Khazanchi and Munkvold, 2000, p. 34). In contrast to the empirical and quantitative stance of positivist theory, the phenomenological paradigm assumes that social phenomena have no objective reality beyond the meanings that individuals and groups ascribe to them. In this view, reality and our knowledge thereof are subjective "social constructions, incapable of being studied independent of the social actors that construct and make sense of reality" (Cater-Steel and Al-Hakim, 2009, p. 60). Phenomenological theorists often adopt a qualitative perspective, and uphold that social facts are "emergent properties of interactions, not pre-given or absolute but negotiated, contested, and subject to continual processes of interpretation and reinterpretation" (Dourish, 2004, p. 21).

The approach we have taken in this user-centred investigation has grown out of the work of empirical research scientists in the health sector, social sciences, psychology and ubiquitous computing, such as (Gabbay and le May, 2011; Creswell et al., 2004; Leech and Onwuegbuzie, 2009; O'Cathain, 2009; Cairns and Cox, 2008; Bardram and Hansen, 2010). We have also been influenced by historical and philosophical discourses that have underpinned emerging trends and the search for research methods in HCI and IS design for the last few decades (Grudin, 1990; Weiser, 1991; Button and Dourish, 1996; Myers, 1998; Dourish and Button, 1998; Rogers, 2004). As this study seeks to "explore" an understanding of how clinicians seek to construct meaning out of their clinical work practices and experiences in the real-world in order to design appropriate systems for cross-boundary awareness and decision support in e-health, an interpretive paradigmatic approach seemed most appropriate. Cultural representations, particularly in cross-boundary studies, are often constructed in terms of the researcher's perception of the world (Aldridge et al., 1999).

Equally emphasized is the need to align research investigations with the pragmatic orientation of the study as well as the appropriateness of the study measure (Creswell and Plano Clark, 2007). As such, we chose a methodology that remains flexible during data collection and analysis, and a pragmatic methodological approach that allows us to remain open to interpretation. Walsham (1995) warns that while “theory can provide a valuable initial guide, there is a danger of the researcher only seeing what the theory suggests, and thus using the theory in a rigid way which stifles potential new issues and avenues of exploration” (p. 76). It, therefore, becomes pertinent for the researcher not only to be influenced by philosophical assumption in finding their research questions, but also to be guided by pragmatic reasons and go for a set of theory that “fits” their specific cases or contexts (Brannen, 1995). For this investigation, a mixed methods strategy offered such an approach.

4.4 Data Capture Method

This study follows a mixed methods research design with an underlying interpretive paradigm (Brannen, 2005, p. 17; Plano Clark, 2010). In social science (Aldridge et al., 1999; Creswell and Plano Clark, 2007) and more recently IS and HCI (Cairns and Cox, 2008; Cater-Steel and Al-Hakim, 2009), mixed methods approaches have become increasingly popular because of their potential to lead to greater understanding in both exploratory and comparative research studies. In this investigation, combinations of quantitative, qualitative and probe-based methods were used. The questionnaire survey sought to provide descriptive and contextual data for the study, while the in-depth interview study was intended to explore decision-making concerns in relation to clinical practices, focusing on clinicians’ experiences and approaches for constructing meanings out of purposeful interactions with their local environment. The practice probes, in turn, were intended to discover more emotional and practice-based aspects of those interactions. In addition, the questionnaire survey serves a sampling aim, i.e. to identify, particularly at the initial stage, the participants for the interview and probe-based studies.

There are a number of arguments against this approach, but two are of particular prominence. Firstly, direct observation and ethnomethodology have become something of a favoured approach, within HCI and IS literature, for this kind of research (Dourish and Button, 1998; Luff et al., 2000; Bardram and Hansen, 2010; Szymanski and Jack, 2011; Gabbay and le May, 2011; Vyas, 2011), and should have been used. Secondly, in-depth interviews are “subject to the same fabrications, deceptions, exaggerations, and distortions that characterize other conversations” (Taylor and Bogdan, 1998, p. 98); for example, how can a researcher trust the accuracy of a clinician’s account of a situation (Pace, 2004)? However, we do not only take an interest in understanding the clinicians' work patterns and real-world clinical practices, but also in the meanings and experiences that they draw upon in their practices in the real-world. As noted by (Pace, 2004, p. 333), work patterns and practices may be captured by direct observation, but individual and collective meanings attached to phenomena, such as clinicians' responses to decision-making concerns within their local practices, are not directly observable; experiences, being such subjective phenomena, can hardly be externally verified.

Our approach provided a pragmatic oriented strategy, which allowed our investigation to be driven not only by the philosophical assumptions (discussed in Section 4.3), but also by the peculiar "situations" of our study (Creswell and Plano Clark, 2007, p. 15; Rossman and Wilson, 1985; Bryman, 1984). Approaches combining the use of questionnaires and interviews have been suggested in (Cairns and Cox, 2008, p. 146). Probe-based methods are increasingly being favoured, within the HCI community, as a technique for eliciting the more emotional and experience-focused aspects of people's engagement with technology (Gaver et al., 1999; Vyas, 2011, p. 46). Thus, we designed and structured our user-centred study as an extension of the mixed methods approach (Tashakkori and Teddlie, 2003; Creswell and Plano Clark, 2007) by combining the use of questionnaires, interviews and practice probes. The mixed methods approach (Plano Clark, 2010) is considered appropriate since it is potentially more pragmatic oriented (Denscombe, 2007, 2008), and has particularly been shown to be useful in investigating sensitive organisational issues and tacit practices and experiences (Jehn and Jonsen, 2010; Brannen, 2005).

Data were collected and analysed iteratively over a twelve-month period – from May 2010 to April 2011. Ethics-related clarifications and approval were obtained (see Appendix A.6). A pilot study involving an initial observation of three clinical practices in the UAE, a focus group interview with two general practitioners in the UK, a semi-formal interview with two hospital resident doctors in Nigeria confirmed the potential and relevance of our mixed methods approach. In particular, it suggested the need to incorporate semi-structured interviews to fill in details and capture clinical work habits, practices and experiences, and the use of probe-based method to capture more in-depth tacit work practices. Data from the pilot study were used to inform the main study.

The study design focused on understanding, from the perspectives of the study participants, how clinicians seek to construct meaning out of their interactions with available resources and technologies within their real-world local work environments, and how that understanding could be used to facilitate cross-boundary decision support in e-health. We hypothesize that the task of enabling informed decision support, and interactive knowledge sharing across boundaries in e-health, can be addressed, with acceptable results, through a deep-seated understanding, and a formal characterisation, of the types, dimensions and roles of work practices in various healthcare work contexts, and a specification of how practice can be used, managed and transformed to suit various clinical problem situations and patients' needs. It is, thus, this concern – to test our hypothesis and to gain a deep-seated understanding of clinicians' experiences with their work practices as they seek to construct meaning out of their engagement with available resources and technologies within their real-world local work settings – that drives our methodological approach.

4.5 Questionnaire-based Data Capture

The aim of the user-centred study was to identify the factors that characterise contexts of clinical practices in various work settings and find out if there is a difference in clinical practices and decision-making for clinicians across regional and geographical locations. In particular, the study seeks to understand the relationship between clinical work contexts and differences in local practices in the UK, the UAE and Nigeria, and to explore how that relationship will affect the sharing and adaptation of clinical knowledge and practices across those areas. To achieve this, the study focuses in the following questions:

- How much of the way clinicians carry out clinical decisions and practices in the real-world can be explained by a set of work context factors that define clinical practices in various hospitals (e.g. work culture, available tools, available expertise, available drugs, and patients' level of health awareness)?
- Which of these factors is a better predictor of actual patterns of clinical practice and decision making?
- How much of actual clinical practices and decisions made in different clinical practices relate to best evidence practice?

- Can the difference between clinical work contexts and local practices be quantified with regard to our three areas of study?
- What factors give rise to the perceived differences in local practices and what percentage of clinical knowledge and practices shared across borders is adapted?

While it was understood that it may not be completely necessary to attach numerical values to these issues, it will suffice to provide relevant quantitative insights to guide e-health technology developers in their design of cross-boundary decision support tools. In order to achieve the study objective, *it was hypothesized that differences in local work context will lead to differences in clinical practice and decision making*. In exploring these objectives, best practice guidelines and the need to offer patient-centred care were used to moderate the transfer and adaptation of clinical knowledge and practices across boundaries.

4.5.1 Questionnaire Method

Participants in the questionnaire study were clinical practitioners drawn from the UK, the UAE and Nigeria. Criterion sampling method was used to ensure that only healthcare professionals involved in clinical decision-making were targeted. Participants were approached in hospitals, medical institutions and professional healthcare bodies in the three sample zones. Both paper-based and online questionnaires designed using the QuestBack software[25] were deployed. Paper-based questionnaires were used where the researcher could physically approach the participants, and online versions sent out via email and web interest groups, or according to participant's preferences. Participants were provided with an information sheet explaining the purpose and goal of the study. In all, 300 questionnaires (100 for each sample zone) were administered, out of which 101 complete responses were collected – 21 from the UK, 36 from the UAE and 44 from Nigeria.

A pilot questionnaire study was used to obtain initial data for re-designing the questionnaire in a pretest with two clinicians in the UK. One thing that emerged from the pilot study was the need to re-design the questionnaire around a clinical case that reflects everyday experiences of clinicians in the three study sample areas. This form of triangulation, aimed to draw expert opinion into the design of the questionnaire, was considered appropriate in order to enhance

[25] http://www.questback.co.uk/

the quality of data captured through the questionnaire, and to secure an in-depth understanding of the clinical work settings in each country.

Each questionnaire contained a number of demographic questions and validated scales. A majority of the respondents (83%) were hospital doctors or registrars, 11% were general practitioners, 3% were consultants, 2%, nurses, and 1%, hospital administrators. Sixty-six per cent of the respondents were from internal medicine, 14 per cent were from oncology, 6 per cent were from surgery, 12 per cent from general practice, and 2 per cent from anaesthesiology. Fifty-four per cent of the sample accepted that they have, in the course of their career, worked in another hospital for more than three years, 17 per cent have only worked for up to three years in another hospital, while 30 per cent have only worked in one hospital. The respondents ranged from less than 25 to 60 years (64% were between 25 and 40, 35% were between 41 and 60, and 1% was less than 25). Eighty-seven per cent were males, and 13 per cent females.

Table 4.1: How significant perceived differences in clinical practices and decisions making patterns is for hospitals clinicians have worked in?

Scale	**UK**	**UAE**	**Nigeria**
Not significant	14.3%	5.6%	11.4%
Fairly significant	22.8%	2.8%	11.4%
Neutral	4.8%	19.4%	20.5%
Significant	52.4%	50.0%	50.0%
Very significant	4.8%	22.2%	6.8%

The questionnaire consisted of 27 questions in all. In one of the questions (see Table 4.1), respondents were provided with a list of context factors, and were required to indicate how much each factor influences their clinical practice and decision-making using a 5-point Likert scale ranging from 1 (not significant) to 5 (very significant). Another question asked how often clinicians were faced with challenging problems that required their seeking further opinion from outside of their workplaces (see Table 4.1). Two questions included a list of information sources, and explored how they contribute to clinical decision-making and how confident respondents are in using them. Four questions investigated how often respondents felt the need to seek information or opinion outside of their workplace, while one question asked whether or not they needed to adapt the information or opinion to suite their prevailing working context and problem requirements (see Table 4.3); while four explored the various factors they considered in doing that, such as adherence to guidelines and need for patient-centred care. A 5 point scale ranging from 1 to 5 was used to measure frequency of need (from never to always) as well as level of confidence (from not confident to most confident).

Table 4.2: Clinical problems that require clinicians to seek opinion from outside their hospitals?

Scale	**UK**	**UAE**	**Nigeria**
Never	4.8%	-	-
Rarely	14.3%	8.3%	22.7%
Sometimes	52.4%	36.1%	40.9%
Often	28.6%	30.6%	25.0%
Always	-	25.0%	11.4%

Table 4.3: Perceived need of clinicians to adapt information obtained from an expert outside of their hospitals to suit their prevailing local context of work?

Scale	**UK**	**UAE**	**Nigeria**
Never	-	-	-
Rarely	4.8%	2.8%	6.8%
Sometimes	42.9%	41.7%	43.2%
Often	47.6%	47.2%	36.4%
Always	4.8%	8.3%	13.6%

The independent variable, Local Work Context Factors, was designed to investigate the factors that could be used to define and characterise clinicians' local work context, and respondents were asked to rate a list of factors on a scale of 1 to 5 (with 1 = "not significant", 2 = "fairly significant", 3 = "neutral", 4 = "significant", 5 = "very significant"). The dependent variable, Difference in Practice Patterns, explored a clinician's perceived difference in clinical practice and decision-making pattern. The key sub-scale in this variable explored clinicians' rating of the differences they have noticed in the way clinical decisions are made between any two hospitals on a scale of 1 to 5 (with 1 = "not significant", 2 = "fairly significant", 3 = "neutral", 4 = "significant", 5 = "very significant"). Table 4.4 illustrates the key variables for this investigation.

The main research variable constructs (see Table 4.5) were derived using appropriate tests of internal consistency and reliability. In this study the Cronbach's alpha coefficient for Local

Work Context Factors (variable 2 in Table 4.5), which consists of a 7-item scale, was .71, and for the variable, Difference in Practice Patterns, (variable 1 in Table 4.5) consisting of three separate 10-item, 7-item and 1-item sub-scales, the Cronbach's alpha coefficient was .70, which indicate good internal consistency (Pallant, 2010).

4.5.2 Questionnaire Results

Table 4.1 shows that 52.4% of respondents from the UK, 50.0% from the UAE and 50.0% from Nigeria believe that there are significant differences in patterns of clinical practices and decisions making among clinical practices in different areas. In Table 4.2, the total percentage of clinicians who believe that they often encounter clinical problems that require their seeking information from outside their workplace is 81.0% - from the UK, 66.7% - from the UAE and 65.9% - from Nigeria. Table 4.3 indicates that 90.5% - from the UK, 88.9% - from the UAE and 79.6% - from Nigeria believe that they often find it necessary to modify information obtained from experts outside of their workplace so as to adapt it to suit their prevailing local clinical work. The results indicate that differences exists in clinical practices among clinicians in different areas, and that clinicians feel that there is the need to often seek information from across boundaries (perhaps owing to non-availability of local expertise) to support clinical decisions. The results equally confirmed that there is a need to adapt such information (obtained from across work boundaries) to suit clinicians' local context of use.

Pearson product-moment correlation coefficient was used to investigate our prediction that differences in local work context will lead to differences in clinical practice and decision making. The statistical tool was, in particular, used to test the relationship between a clinician's local work context factors as measured by the Local Work Context Factors scale and their clinical practice and decision-making pattern, as measured by the Difference in Practice Patterns scale. Preliminary analysis was performed to ensure no violations of the assumptions of normality, linearity and homoscedasticity. Results indicate that there was a significant correlation between local work context factors and local practice and decision-making pattern, $r = .308$, $n = 101$, $p < .01$, two tails. Table 4.5 shows correlation analysis.

As a result, we reject the null hypothesis. This indicates that differences in clinical practice and working pattern are associated with local work context factors. As shown in Table 4.5, Difference in Practice Patterns is strongly correlated with tendency of clinicians to adhere to best practice guidelines (r = .693) and to offer patient-centred care (r = .359). Significant correlations (r = .229 and r = .680) were also obtained for the variable construct, Local Work Context Factors, and the constructs tendency adhere to clinical practice guidelines and tendency to offer patient-centred care respectively, indicating the moderating role of adherence to clinical practice guidelines and tendency to offer patient-centred care.

Table 4.4: Descriptive statistics for the key variables (5-point Likert scale [LS])

	LS	**Frequency**				**Percent (%)**	**Mean**	**SD**
		UK	**UAE**	**Nigeria**	**Total**			
Factor influencing Local work context:								
Patient's circumstances	2	-	1	4	5	5.0	4.07	0.852
	3	1	6	11	18	17.8		
	4	6	16	21	43	42.6		
	5	14	13	8	35	34.7		
Organisational characteristics of a clinician's workplace, e.g. work culture or hospital treatment guideline	1	-	-	2	2	2.0	4.08	0.935
	2	-	-	4	4	4.0		
	3	5	7	4	16	15.8		
	4	7	14	20	41	40.6		
	5	9	15	14	38	37.6		
Clinician's attitude	1	-	-	1	1	1.0	3.31	0.771
	2	3	4	5	12	11.9		
	3	11	16	20	47	46.5		
	4	6	14	17	37	36.6		
	5	1	2	1	4	4.0		
Clinician's knowledge and experience	3	1	5	5	11	10.9	4.15	0.590
	4	13	21	30	64	63.4		
	5	7	10	9	26	25.7		
Availability, or lack, of relevant equipment and/or drugs	2	-	-	1	1	1.0	4.06	0.719
	3	4	6	10	20	19.8		
	4	9	19	24	52	51.5		
	5	8	11	9	28	27.1		
Demographic characteristics of a clinician's area of work, e.g. policy of the Ministry of Health	1	-	-	3	3	3.0	3.79	1.023
	2	1	2	5	8	7.9		
	3	6	6	11	23	22.8		
	4	11	14	15	40	39.6		
	5	3	14	10	27	26.7		
Observed difference in practice patterns	1	3	2	5	10	9.9	3.44	1.144
	2	5	1	5	11	10.9		
	3	1	7	9	17	16.8		
	4	11	18	22	51	50.5		
	5	1	8	3	12	11.9		
No. of participants		21	36	44	101	100		

Table 4.5: Correlations of main variables (see Appendix A.5 for other variables)

Variable		**Mean**	**SD**	**N**	**Variable**		
					1	**2**	**3**
1	Perceived differences in local practice and decision-making patterns	51.37	7.11	101			
2	Local work context factors	23.43	3.24	101	0.308**		
3	Tendency to adhere to best practice guidelines	18.19	3.27	101	0.693**	0.229*	
4	Tendency to offer patient-centred care	11.35	2.46	101	0.359**	0.680**	0.434**

** – Correlation is significant at the 0.01 level (2-tailed)
* – Correlation is significant at the 0.05 level (2-tailed)

A one-way between groups analysis of variance was conducted to investigate if clinical practice and decision-making patterns are different for clinicians in different regional and geographical locations. Participants were divided into three groups according to the geographical location of their workplace – the UK, the UAE and Nigeria. Levene's test of homogeneity of variance gives a significance value of .004 (less than .05), indicating that the underlying assumption of one-way ANOVA that the group variances are statistically equal is not met. As a result, the Welch and Brown-Forsythe tests (with significance values of .212 and .184 respectively), rather than the usual ANOVA, were used. This further indicates that differences in clinical practice and decision-making among clinicians, which have been shown to be associated with differences in their local work contexts (r = .308), are moderated by clinicians' adherence to best practice guidelines and strong emphasis on patient-centred care hence the low significance value of .004. As a result, the two factors – adherence to best practice guidelines and emphasis on patient-centred care – act as a common ground to moderate differences in practice and decision-making (in spite of differences in local work context), and, thus, provide a common reference point during cross-boundary knowledge transfer and decision support.

4.6 Interview-based Data Capture

In the second phase of the user-centred study, we used two qualitative research approaches, semi-structured interviewing (Charmaz, 2002) to gather the data and grounded theory (Glaser and Strauss, 1967) to analyse it. A background study of the grounded theory (GT) approach is presented in Chapter 2; in this section, we focus on how we have applied the approach in our study. While the questionnaire study sought to provide descriptive data about clinical work contexts across different geographical settings through hypothesis testing and a broader statistical account of the work practices of a large number of clinical practitioners, our focus here is, rather, to explore more deeply how clinicians responded to decision-making concerns in relation to the varying contexts of work of their real-world clinical practices, local workplace circumstances and patient-centred needs. GT provides us a set of procedures for gaining a deeper understanding of issues highlighted in the questionnaire study, and for analytically developing theory about additional issues and phenomena, including tacit work patterns and practice-based behaviours, not previously conceptualised during the questionnaire design. The use of in-depth semi-structured interview, which has, in previous studies in social science, been asserted as the data collection method of choice for GT allowed us the freedom of unstructured ethnography (Fontana and Frey, 2000), since the study goal here is primarily exploratory, in particular “the generation and rectification of theoretical concepts” (Tang, 2008, p. 12).

4.6.1 Sampling

Quota and snowball sampling techniques were used to purposefully identify, from the questionnaire study sample, potential interviewees for this study phase. Though the techniques are potentially prone to biases; the use of quota sampling allowed us to target, from each of our three sample zones, those participants who are responsible for clinical decisions and have had the experience of participating in clinical decisions in hospitals in different regions, while the snowball technique allowed us to select future respondents from among the social network of existing respondents with a focus on maximising opportunities for exploring emerging concepts. The sampling techniques were used in accordance with the “collect, code, analyse” cycle advocated by the theoretical sampling technique commonly used in GT (Glaser, 1967, p. 45) where, as noted in (Taylor and Bogdan, 1998) “researchers consciously select additional cases to be studied according to the potential for developing new insights or explaining and refining those already gained” (p. 26-27). Essentially, descriptions of GT methods have given rather scant attention to how data collection is carried out, focusing more explicitly on data analytic procedures (Charmaz, 2002; Fassinger, 2005).

During the sampling, the number of participants interviewed was not specified beforehand, rather, we started with a general knowledge of the participants' professional background and interest in our study, and proceeded until theoretical saturation – the point at which "no additional data can be found that would add to the categories being developed and examined" (Minichiello et al., 1995, p. 162) was achieved – this was necessary since theoretical sampling is "conducted on the basis of emergent concepts" (Pace, 2004, p. 334). In theoretical sampling, selection of participants, episodes and interaction is driven by a conceptual question, not by a concern for "representativeness", because the primary concern lies "with the conditions under which the construct or theory operates, not with the generalisation of the findings to other settings" (p. 29). In applying the sampling techniques for this study, certain characteristics of the respondents were consciously varied with the aim of allowing the emergence of a broad range of perspectives. This was achieved by laying out the dimensions on which variability was sought, e.g. the level of clinical experience of participants in the questionnaire study, and then selecting representatives.

4.6.2 Interview Method

A total of 11 interviews involving 9 clinicians – 3 (33.33%) from the UK, 4 (44.45%) from the UAE and 2 (22.22%) from Nigeria – were conducted during this phase of the study. All 9 participants took part in the questionnaire study. The correspondence established in the course of the questionnaire study heightened the interviewees' interest in the study and trust in the researcher, and led them to speak openly and passionately about the decision-making concerns within their clinical practices. Each interview last between 15 and 25 minutes. Three (33.33%) of the participants are GPs, 2 (22.22%) registrars, and 4 (44.45%) consultants. One of the interviewees (from the UK) has had experience working both in Nigeria and the UK, while another, who currently works in the UK, had experience working in Asia. Four (44.45%) of interviewees are females, while 5 (55.55%) are males. At the start of each interview, participants were presented with a written explanation of the aim of the study, and appropriate consent duly obtained. Five (55.56%) of the participants agreed that they have, in the course of their career, worked in another hospital for more than three years, 3 (33.33%) have only worked for up to three years in another hospital, while 1 (11.11%) have only worked in one hospital. All of the interviews were tape-recorded with the permission of the participant. Standard procedures were followed to maintain confidentiality of the interview data as well as anonymity of the participants. Lastly, the recorded interviews were transcribed to provide accurate records for data analysis.

4.6.3 Data Analysis

Since GT allows for the formulation of a theory about a phenomenon based on systematic collection and analysis of empirical data, it enabled us to approach data analysis without being biased by the earlier outcome of the questionnaire study. In particular, we used GT's inductive analytic method, which involved an iterative process of data collection, comparison and coding, to identify the "latent" patterns of behaviours (Elliot, 2010, p. 2713), practice-based interactions and recurring tacit strategies that clinicians often employ as their "knowledge-in-practice-in-context" (Gabbay and le May, 2011, p. 64) in order to accommodate for peculiar workplace circumstances and patient-centred needs during decision making. A key rationale of the GT approach (Strauss and Corbin, 1998) was to keep the researcher open to the general idea of the study and allow the theory to emerge "naturally" from the data; since theory derived from such approach, as noted by (Strauss and Corbin, 1998), is "more likely to resemble the reality … and provide meaningful guide to action" (p. 12).

Consistent with GT, a theory was derived from the data using an iterative and constant method of comparative analysis consisting of four stages: generating categories and their properties, integrating categories and their properties, delimiting the theory, and writing the theory. As a result, each interview was transcribed and analysed (coded), and themes identified that were used to inform the next interview until saturation was reached. A combination of both manual and computer assisted methods[26] – a technique that has been shown to achieve the best results (Welsh, 2002) – was used. The software-based process was used, as a follow on, to confirm the manual procedure. This was considered necessary because it allowed the researcher, as one who was not an expert in the techniques of social science research, to strengthen their skills in transcription and coding via a manual process; and to validate the results using software.

[26] NVivo 8, a computer assisted qualitative data analysis software (CAQDAS) package developed by QSR was used. For more information, visit http://www.qsrinternational.com/products_nvivo.aspx.

Open Coding

The first stage of the analysis, known as open coding, is concerned with identifying, naming, categorising and describing phenomena found in the transcript in order to establish categories and properties. As with much qualitative research, the researcher was concerned with understanding and making sense of the subjective experience (phenomenology) of the research participant and allowing a theory to self-emerge "grounded theory" without necessarily wanting to impose preconceived variables or meanings (Storey, 2007; Glaser and Strauss, 1967). A category denotes a conceptual element of a theory – an abstract representation of something the researcher identifies as being significant in the data. The conceptual characteristic or attribute of a category is called a property (Strauss and Corbin, 1998, p. 113; Pace, 2004, p. 337). For example, in this study, institutionalised practice is cited as a category representing a pattern of problem-solving and decision-making predominantly used in a workplace. Communication, shared activities and search for second opinion are cited as properties of this category.

During this stage, the transcript was iteratively read and re-read, and incidents identified and grouped into concepts based on similarity of patterns. O'Callaghan (1996) suggests that the process should be pursued with an eye on addressing the following questions: What is happening in this data? What is the basic socio-psychological problem? What accounts for it? And, what patterns are occurring? A range of theoretical coding families have been identified, the most commonly used of which is the 6Cs that encourages researchers to look for causes, contexts, contingencies, consequences, covariances and conditions in the data. As more data were coded, concepts were compared, and merged into new concepts. As concepts emerged, they were compared "with the appropriate emerging category" (Spiggle, 1994, p. 494) for verification, and with other concepts for establishing the best fit with the data in order to generate categories and properties (Glaser and Strauss, 1967; Pace, 2004, p. 337). Categories and properties are abstractions in the sense that they "encompass a number of more concrete instances found in the data that share certain common features" (Spiggle, 1994, p. 493), and their relevance to all cases in a study accords them explanatory power (Pace, 2004, p 337-338). To illustrate this idea, Table 4.6 shows some examples of comments that gave rise to the concept of stereotypical practices.

Table 4.6: Examples of comments that gave rise to the concept of stereotypical practice

Participant	Example Comment
7	Normally, one works within the confines of his knowledge, available men [medical expertise] and materials.
3	Cases don't always present as they appear in theory. For example, it common in our environment coupled with ignorance for patients to seek unorthodox interventions and when they will have exhausted all such options, and their condition worsened … Then, they will come to the hospital.
2	Though, the key goal is to offer the best possible treatment to the patient… Often, you have operate with the facts and circumstances of where you are… that is, are you in a specialist centre; or for example, if a cancer of the breast is in a much smaller place, the patient would only have had possible biopsy and referral.

Axial Coding

The next stage of analysis consists of what (Strauss and Corbin, 1990, 1998) referred to as axial coding, and consists of "a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories" in order to derive propositions about the emerging relationships. Essentially, it is this appreciation of concepts in terms of their dynamic interrelationships that provides the basis upon which the researcher begins to the process of theory construction. Spiggle (1994, p. 493) notes that "the theoretical significance of a concept springs from its relationship to other concepts or its connection to a broader gestalt of an individual's experience". Thus, the emerging propositions were used to form the theoretical framework, which served as a guide to a further cycle of data collection and analysis (Pace, 2004). As with the categories and properties (derived during open coding), the integrated theory emerged from the data; it was not preconceived or forced upon the data (Glaser and Strauss, 1967, pp. 108-109). To illustrate this idea, Table 4.7 presents some examples of comments that gave rise to the proposition that clinicians often contextualise procedures and improvise practices in order to accommodate for peculiar workplace circumstances and patient-centred needs.

Selective Coding

As the theory developed, it crystallised around a tentative core category that appeared to provide an explanation about the decision-making concerns of the participants in their local work practices. The spotting of the core category led to selective coding – the process of delimiting coding so as to create the propositions that offer an explanation (i.e. the emergent theory) of a phenomenon (Pace, 2004, p. 339). During selective coding, data collection and analysis become more focused, in the sense that the researcher selectively codes data with the core category guiding the process, and not bothering about concepts with little importance to the core category. Also, new data are now selectively sampled (theoretical sampling) with the core category in mind. As a result, data analysis "automatically" gives rise to the emergence of a theory with a narrow set of higher-level concepts (Glaser and Strauss, 1967; Spiggle, 1994; Kelle, 2005).

Table 4.7: Examples of comments that gave rise to the proposition that clinicians often contextualise procedures and improvise practices to accommodate for peculiar workplace circumstances and patient-centred needs

Participant	Example Comment
5	Usually, I seek second opinion in diagnostic dilemmas, where the investigations do not tally with the clinical findings… in medicine; no one has a monopoly of knowledge.
7	If I'm not seeing a patient together, for example, in cross-boundary clinical support you just describe, I will like to share the clinical notes, while maintaining confidentiality of patient's record as much as possible
2	In such cases, one is guided by experience in dealing with the case at hand. Lack of facilities is a problem in less developed countries … Improvisation is often driven by experience and local knowledge, and works well. There are cases where guidelines and excessive systematisation might become a bottle neck, too rigid. Take for example the use antibiotics between doctors in developed and less-developed systems.
8	In seeking how well a piece of information could assist in clinical managment, you apply experience, best practice, guidelines and background knowledge to decide how well the information suits his case. Seek more information, esp from experts and research advances

Memo Sorting and Theory Writing

At the end of each draft study cycle, i.e. the "collect, code, analyse" process, theoretical memos were written[27] about categories, properties and their relationships that emerged. The memo contains a record of the hypotheses and ideas that emerged from each draft study. When theoretical saturation was achieved, data collection and analysis stopped. At that point, the researcher began writing up the emergent theory – the final stage of the study, and involved drawing on the theoretical memos that had been written about the category derived during each cycle (Strauss and Corbin, 1998, p. 245-263; Glaser and Strauss, 1967). The emergent theory should not be seen as "findings" but, rather, an integrated set of propositions abstracted out of a pool of empirical data (Dix, 2008, p. 187); the grounded concepts are suggested, and not proved – thus, lending credence to the suitability of the GT approach to exploratory research.

[27] Nvivo 8 was used to assist in memo writing

4.6.4 Interview Results

The concept map shown in Figure 4.2 depicts the conceptual model that has emerged from the interview data. Related work suggests the use of affinity diagrams (Sharp et al., 2007, p. 377). Concept mapping is increasingly being used in GT-based qualitative research (Pace, 2004), and has the advantage of aiding the derivation of a theory by "highlighting the macrostructure of the research data" (Kozminsky et al., 2008). The diagram consists of a collection of boxes or circles connected by arrows in a manner that organises and represents knowledge about a phenomenon. The boxes or circles represent concepts and the arrows represent relationships between concepts. The concepts have been arranged to depict how awareness implies sensemaking in the ecology of clinical work practice.

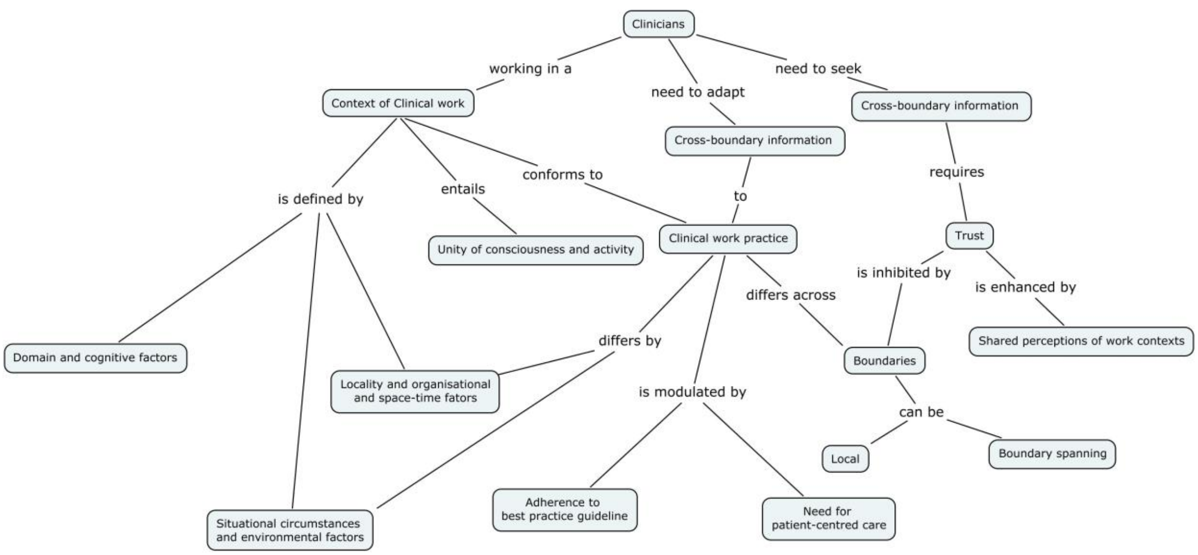

Figure 4.2: Concept map representation of the interview results

4.7 Practice Probes

In addition to the questionnaire and interview studies, we also sought to engage clinicians in reflective reasoning about their work practices in order to obtain a further account of what *actually* informs their actions and use of knowledge in response to local work contexts and patients' needs. We noticed, in the course of the study, that to uncover the more emotional and practice-based aspects of how clinicians construct meanings out of purposeful interactions with their local environment and the context-driven motives that guide their decisions requires much more than what the questionnaire and interview methods could offer. This observation resonates with the findings in (Gabbay and le May, 2011). In their ethnographic study of how clinicians develop and use knowledge in everyday practice, the authors report that

> When we asked Lawndale practitioners what led them to deal with any given clinical condition or situation in the way they did they would perhaps, if they could answer at all, tell us a story about an incident that stood out in their memory, … we would be met on the whole with an unusual degree on inarticulacy (p.71).

In developing practices from procedures to deal with the specificity of the context they have at hand, people generally fail to explain the elaboration process of their practices (Brézillon, 2011). Other studies of professional problem-solving and decision-making in action (notably, Bourdieu, 1977, 1990; Schön, 1983; Luff et al., 2000; Higgs and Jones, 2000; Patel et al., 2004; Benner et al., 2008) affirm that professionals' use of knowledge "in practice" is so ill-defined and situation-dependent that the users themselves can hardly articulate it in a narrative nor can another person accurately capture it through observation. Hence, we developed *a set of practice probes* – a technique inspired by the cultural probes approach (Gaver et al., 1999) and the technology probes method (Fitton et al., 2004) in HCI – with the aim of further understanding the motivational forces that influence clinicians' actions and use of knowledge in real-world practice.

The idea of probes, as tools for user-centred data capture, contextual inquiry or experience-focused design in HCI and IS, emerged in the wake of the pioneering work of Bill Gaver and his colleagues in the EU Presence Project that developed the cultural probes (Gaver et al., 1999). The underlying motivation was to provide researchers with an additional form of engaging with participants (Gaver et al., 1999). Over the years, different forms of probes, e.g. cognitive probes (Mamykina et al., 2006), organisational probes (Vyas, 2011, p. 46) or technology probes (Hutchinson et al., 2003), have emerged. Probes methods have also been named to denote their remarkably diverse types of uses, e.g. identity probes, value probes and empathy probes. Probes have been referred to as "discount ethnography" (Dourish, 2006, p. 548), and their nature, concept and application have come under criticism for lack of a uniform structure and methodology (Graham et al., 2007). Boehner et al. (2007, p. 1077-1078) note that though probes are a useful contribution to the productive debates around method, practice and epistemology within contemporary HCI, the method does pose a particularly epistemological challenge, since it does not necessarily denote another technique for data capture, but rather frames an alternative account of knowledge production in system design. Owing to the multidisciplinary nature of HCI and IS design, which requires that methodologies are often borrowed from outside of the fields, researchers are a times, as in the case of ethnographically informed data capture for system design, faced with a dilemma, namely how best to apply the in-depth nature of qualitative research to review complex phenomena, on one hand, and on the other, develop applicable frameworks for system design (Cairns and Cox, 2008, p. 152). In that sense, it is arguable that probe-based methods remain a valuable contribution to IS and HCI research.

Probes offer a strategy of pursuing experimental design in a responsive way by encouraging active user participation in the actual process of technology development, while allowing minimal interference in their work (Gaver et al., 1999, p. 22). Hence, they are valuable in inspiring design ideas for technologies that could enrich people's lives. However, deploying probes usually comes with an element of risk; they might fail or bring unexpected results (Hutchinson et al., 2003, p. 18). Moreover, the design philosophy of probes relates more to generating design inspirations based on an interpretive approach than just data collection (Boehner et al., 2007). Generally speaking, probes represent a useful contribution to the search, in HCI, for a delicate balance between the use of the social science interpretive approaches for making sense of people's experiences and engagement with the environment and the formal methodologies for systems design and engineering (Dourish, 2004. This diversity of styles and uses of probes, we believe, represent a genuine search for both a methodological basis and an epistemological value – crucial issues already highlighted in (Boehner et al., 2007) – and which, at this stage in its evolution, the approach so desperately needs.

Cultural probes are a design-led approach to understanding users that stressed empathy and engagement (Gaver et al., 1999); they include collections of evocative tasks meant to elicit inspirational responses from people, and evoke fragmentary clues about their lives, experiences and thoughts. Technology probes draw upon the merits of cultural as well as informational probes (Gaver et al., 1999), and aim to inspire people to reflect on their lives, behaviours and circumstances in different ways using a set of simple, flexible, adaptable technologies with the goal, among others, of understanding the needs and desires of users in real-world settings (Hutchinson et al., 2003, p. 17). In practice probes, we seek a set of participatory investigation and reflective thinking techniques with the goal of aiding a deeper understanding of less formal aspects of people's work routines and practices, and to reveal the "inexpressible knowledge" Gabbay and le May, 2011, p. 71) that shape how they act in response to the requirements of their local work context and situation. The goal is to engage clinicians in reflective analysis about the factors that scaffold their cognitive capabilities and shape their work practices in the real-world. As opposed to just providing inspiration for design, we aim to "embed inspiration within the design process" (Fitton et al., 2004) by seeking to uncover contextual issues that go beyond what formal workflows and clinical guidelines currently incorporate, but which contribute significantly to shaping work "in practice" and for effecting practice-centred cross-boundary awareness and decision support.

4.7.1 Participants

Four clinicians, selectively drawn from our interview study, participated in this investigation. Two of participants were from the UK, and one each from the UAE and Nigeria. The sampling approach was selective and the size small, which was meant to reflect primarily the deeply engaging nature of the study; important to the selection process was the degree to which participants were willing to articulate, discuss and reflect on their work processes and engage in imaginative speculation about how technology could be designed to support cross-boundary decision. Participants were approached face-to-face and called on phone for a record of their practice probes worksheet at the end of every working day[28] throughout the four-week period of the study. Two of the participants were general practitioners, one, a consultant and the other, senior registrar.

4.7.2 Design

The practice probes package is depicted in Figure 4.3. The package consists of a diary and a logbook. The package also included tools such as a disposable camera, postcards, a map of the world highlighting the 3 study areas, a set of grid paper, 3 differently coloured sets of sticker notes, 4 differently coloured pencils and 3 popular clinical guidelines one from each of the study areas. Instructions were provided on when the clinicians should use the package.

[28] The study took place on selected working days depending on participant's convenience

The postcards were specifically selected to gain insights into clinicians' experiences and impressions about various settings of healthcare work. Each doctor-patient encounter is entered in to the logbook. Any aspect of the encounter, which strikes them as "special" is recorded in the diary. The postcards also include creative metaphors used to portray conceptualisations of different ways of doing the same thing and the clinicians' position on them. The stickers were used to make notes of their impressions about each case in the course of their work. We collected recording done by each clinician in their clinical practice, and obtained further information about the clinician's reflections about them. The recording and the clinician's reflections about it were re-written as electronic posts and used to further shape the research process.

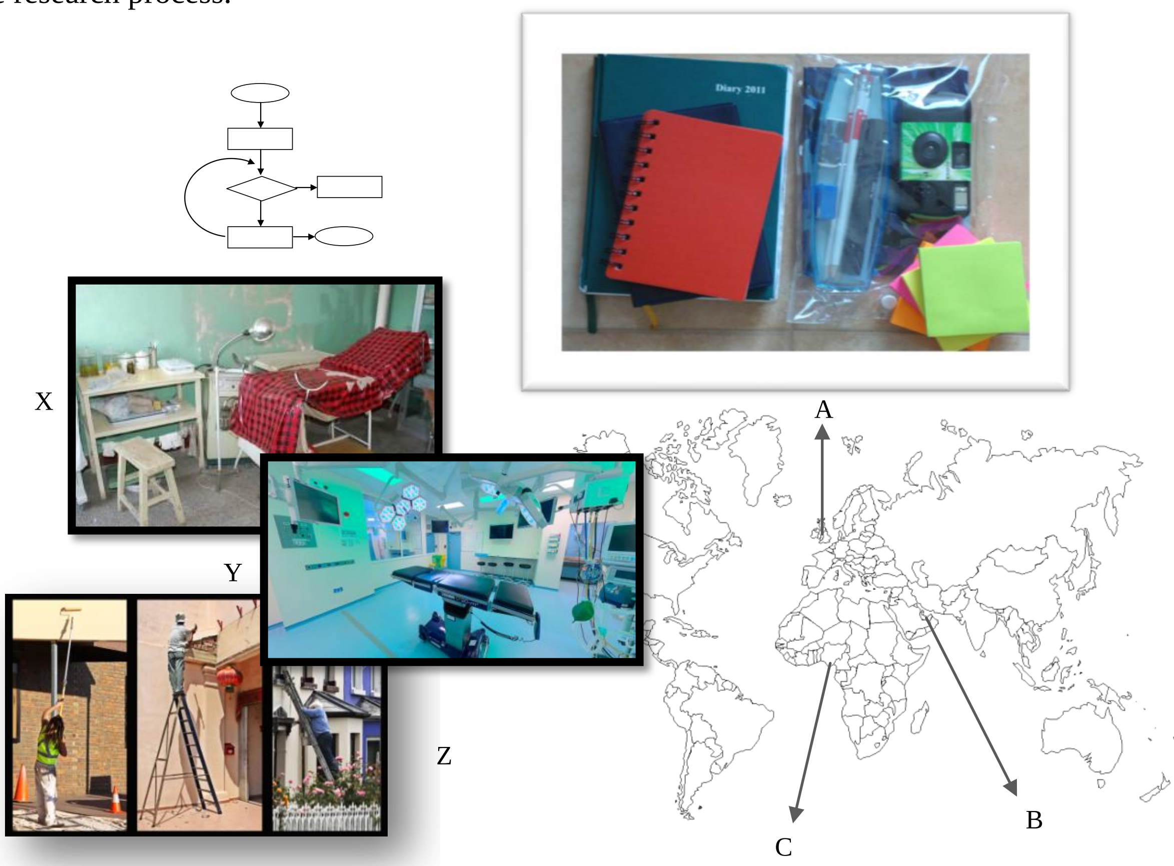

Figure 4.3: Practice probes[29]

Some example questions of practice probes are shown in Appendix A.3, which includes both a series of interview-style questions and a set of "probe" questions depicted on the activity

[29] Postcards X and Z were obtained with permissions from Amity Foundation and Curdnatta Photographers respectively. They are respectively available at http://www.amityfoundation.org/wordpress/category/health/ [accessed on 30 Jan 2012] and http://www.flickr.com/photos/georgiesharp/6290542529/ and http://www.flickr.com/groups/curdnattaphotographers/ [accessed on 21 Jan 2012].

system diagram (Engeström, 1987). Using these materials as a provocation, the clinicians were asked specific questions to give an account of their everyday experiences about their decision-making processes, including what roles the various aspects of their work setting have played in each clinical encounter. The questions were formed intentionally to allow an active participation of the clinicians, and to elicit the tacit motives behind their use of knowledge in practical action. For example, clinicians were asked to describe their typical day in three different pictures. The information obtained served as the basis for the probe data analysis with the aim of generating design inspirations for a new technology.

4.7.3 Analysis and Results

All four participants returned their practice probes materials. The data together with the information obtained on the discussion board were analysed to explore important patterns and themes. The data were analysed using open coding (Glaser and Strauss, 1967; Pace, 2004, p. 333). A theme occurring across all probes data suggest that although patterns of clinical practices are influenced by prevailing local work contexts, no clinician is limited to acting on local patterns alone or in accordance with some predefined rules. As argued by Dave Snowden and his colleagues in their work on the Cynefin framework, all human interactions appear to be strongly influenced and frequently determined by the patterns of our multiple experiences, and are in a state of constant flux between global and local influences, order and un-order, structured processes and uncertain conditions; out of which our actions emerge (Kurtz and Snowden, 2003). The authors refer to this complexity of human work context as "contextual complexity" (p. 465). Hence, any effective cross-boundary decision systems must construct awareness of work based on all scales of human contextual complexity. We found out that clinicians constantly seek to make sense of their world based on three interrelated constructions: 1) the formal domain knowledge gained through years of training, 2) issues of the locality and organisational context of work, and 3) experiences and varying circumstances that arise in the course of work. However, we found out that the themes were, in a large sense, similar to, and confirmatory of the results obtained from the questionnaire and interview study.

4.8 Key Issues from User-Centred Study

Although cautious attempts were made to ensure that the results from any of the questionnaire, interview or practice probes study do not influence one another, we found out that a number of interrelated issues emerged independently out of the studies; this is not uncommon in mixed methods research (Creswell and Plano Clark, 2007). The key issues emerging from the three studies are discussed as follows:

The study indicated that most clinicians employ a framework couched in three levels to organise their information and actions, namely concepts in the domain of work, issues, resources and policies provided by the locality and institution of work, and the entities within the local context of work. When asked what information he would require in order to provide an appropriate suggestion to another clinician from outside his work place, one of the respondents notes that:

> *They may include such information as location of patient – in his/her home, in hospital or in private chamber, situation of the patient ... and if it's an emergency case, request transfer to hospital. This is because there may be a minimum situation that can save life. Then symptoms; what is going on with the patient, investigations done and results, as well as treatments given.*

Boundaries of practice are a defining characteristic of hospitals, and the link between the hospital as an institution and the wider environment (Aldrich and Herker, 1977, p. 217). Several research efforts, in information systems, have focused on the issue of boundaries as a way of characterising resource use within particular communities and organisations. Based on the user-centred study, we found out that the following constitute boundaries in healthcare practice: a) task domain, b) location, c) time, d) organisation, e) socio-cultural factors and institutional agenda, f) personality, and g) circumstances. Research has shown that what we do and how we do it often becomes so strongly bonded with our consciousness – within a framework of contextual complexity (Kurtz and Snowden, 2003) – that for most people, e.g. clinicians, (Gabbay, and le May, 2011, p. 71), the less explicit actions, which they perform in dealing with situations at work, become highly ineffable. The role of the unity of consciousness and activity is akin to what (Giddens, 1984) terms "practical consciousness" – as the pathway by which the social structures and principles of individuals and communities enter the routines of our everyday work, and is related to the concept of "clinical mindlines" (Gabbay, and le May, 2011) and Gibson's ecological psychology (1986).

It was indicated that making sense of the other's situation and pattern of work is made difficult as a result of boundaries of contexts of work. Boundaries lower the trust people have for one another. From the study, about 96.1% of the respondents said that they do not have confidence in accepting information from across borders because of lack of trust. Work practices and local knowledge are amenable to transfer across boundaries (Gasson, 2005), but the process requires tools with the capability to bridge boundaries between work practices. One way of bridging boundaries is through mutual co-construction of meaning between workplaces. The transfer and utilisation of local knowledge lie at the intersection between reflective involvement in those local systems of interaction, practice and sense-making that constitute local work culture, e.g. clinical mindlines (Gabbay and le May, 2011); and the engagement in that detached sense-making and analysis, by which situated knowledge and practices are externalized, reified and made explicit (Gasson, 2005a).

The study revealed tension between prevalent realities of practice and pre-specified guidelines: The difficulties associated with implementing a predetermined plan, e.g. a clinical guideline, in response to the opportunities and circumstances that arise in the context of work practice has been the subject of research across numerous disciplines (Robinson, 1993; Bowers et al., 1995; Dourish, 2004; Gabbay and le May, 2011). Bowers et al. (1995) observe that often people employ plans as tools for organisational ordering and accountability, rather than for addressing the challenges of daily practice. Most respondents note that at the core of their work of clinical practitioners is the call to utilise every resources at their disposal, including their knowledge, hospital protocols and resources and lately the Internet, to provide the best possible care to their patients. Consider the following comment from Respondent 5:

> *I ensure as much as possible that whatever procedure I decide to take in order to provide the best possible care to my patient based on prevailing circumstances must not be in utter conflict with the hospital's guidelines*

From the user-centred study, we found out that clinicians, irrespective of the location of their workplace, have the same goal, namely, to provide the most effective care for their patients.

Though individual and organisational emphasis, in terms of a clinician's attitude and knowledge, or the policies and agenda of a hospital, may differ, the goal remains relatively the same. It is noticed that, for this reason, clinicians tend to use the concept of a common goal to regulate the extent of their deviation from known diagnosis and treatment pathways. From the user-centred study, about 53.5% of the respondents significantly consider patients' perspectives and interests, while about 87.1% adhere to guidelines, during clinical decision making. The use of shared artifacts, such as guidelines, to moderate practices, enables those artifacts to contribute to work as situated "artifacts of reasoning about action" (Suchman, 1987, p. 39), and as a coordinating mechanism (Schmidt and Simone, 1996). The following comment from Respondent 9 illustrates this coordinating role:

> *Underlying my actions and clinical practices is the need to strike an appropriate balance between the challenges of providing the best possible care to my patients and what available resources and guidelines can offer. I often say to myself ... what can be done to this patient ... what do we have available. If the resources seem insufficient, I ask, what can we do next?*

We found out that the way clinicians use and re-use information obtained across boundaries of work to suit their peculiar work contexts involves notions of *de-contextualisation* and *re-contextualisation*. The user-centred study shows that clinicians employ a considerable degree of de-contextualisation and morphing (i.e. comparing their local work context the work context of another clinician elsewhere), e.g. when dealing with medical cases in new contexts. During de-contextualisation, clinicians move from more concrete aspects of his work situation back to more abstract description of the work (i.e. de-contextualisation).

4.9 Design Implications

A key implication of this user-centred study is that effective technology support for cross-boundary e-health entails designing for practice-based awareness through: 1) bridging of boundaries in order to maximize transparency and 2) sharing of awareness information on the basis of "commonalities" (Schmidt et al., 2007), common domain practices or boundary spanning practices based on user intentions, shared goals and mutual differences. As a result, the design of systems for effective cross-boundary e-health decision support should incorporate support for the following characteristics:

- *Perception of the subject domain or field of work*: As noted earlier, formal professional knowledge is crucial and highly emphasized in the medical profession, and as in any other field of knowledge work. Numerous researches in knowledge-based systems design and machine learning have investigated approaches for knowledge acquisition based on domain modeling. From the user-centred study, we found out that the underlying essence of clinical work is identical across geographical and regional boundaries, and, as such, knowledge of subject domain becomes crucial in understanding activities and tasks in any workplace. We model subject and task-related factors in any work process as ontological practices, and we suggest that technologies support for cross-boundary e-health should incorporate knowledge of subject domain.
- *Bridging boundaries in order to maximize transparency*: Awareness is made difficult as a result of boundaries of contexts. Boundaries lower the trust people have for one another. From the study, about 96.1% of the respondents said that they do not have confidence in accepting information from across borders because of lack of trust. We are of the view that "local knowledge is amenable to transfer across organisational boundaries" (Gasson, 2005), but the process requires tools with the capability to maximize transparencies by bridging boundaries between work practices. In Chapter 5, the technique of ContextMorph is proposed to realise this.
- *Perception of the place and time of work:* Brézillon (2007) argues that a crucial step in dealing with context as regards decision making is the proceduralization step. Organisations establish procedures based on their experience in order to guide reasoning and decision making in identified situations. The user-centred investigation indicated that the three samples zones studied showed significant differences in clinical patterns and decision making. We model the distinctive patterns of work associated with a particular place and time as stereotypes, and our proposed model incorporates perception of place and time using spatio-temporal context.
- *Differences are reconciled by common goals and shared artifacts*: We found out that clinicians, irrespective of the location of their workplace, have the same goal, namely,

to provide the most effective care for their patients. Though individual and organisational emphasis, in terms of a clinician's attitude and knowledge, or the policies and agenda of a hospital, may differ, the goal remains relatively the same. We noticed that, for this reason, clinicians tend to use the concept of a common goal to regulate the extent of their deviation from known diagnosis and treatment routes. From the user-centred study, about 53.5% of the respondents significantly consider patients' perspectives and interests, while about 87.1% adhere to guidelines, during clinical decision making. Based on this, we propose that tools for cross-boundary decision support should incorporate representations of common goals, in form of boundary-spanning practices, shared guidelines or clinical goals.

- *Sharing awareness information*: Mutual co-construction of knowledge between workplaces breeds awareness. Collaboration, social networking and co-construction of knowledge increase transparency across borders and enhance awareness. The transfer and utilisation of local knowledge lie at the intersection between reflective involvement in those local systems of interaction, practice and sense-making that constitute local work culture (e.g. clinical mindlines Gabbay and le May, 2011); and the engagement in that detached sense-making and analysis, by which situated knowledge and practices are externalized, reified and made explicit (Gasson, 2005a).
- *Perception of situated or circumstantial factors*: We found out from the study that despite the stereotype attached to a particular place and time, not every work process within the given place and time follows stereotype. We model such circumstantial factors as situated practices. On further investigation, we found that situated practices have a correlation with the stereotypes and the local work context factors. As a result, we suggest that support for situated practices should be considered in the design of cross-boundary decision support systems.
- *De-contextualisation, re-contextualisation and morphing in clinical reasoning*: Design of systems for cross-boundary decision need to incorporate the techniques of de-contextualisation, re-contextualisation and morphing maximise transparency by which clinicians seek to find common grounds in using information obtained across work boundaries in decision support.

4.10 Discussion

This user-centred inquiry has highlighted the importance of cross-boundary studies in helping our understanding of clinical work contexts across boundaries of organisations, regions and cultures, and in generating new insights for technology design. The study was distinctive in its use of multiple research methods to help the researcher better understand various aspects of clinical work contexts and examine a broad range of issues that influence decision-making based on real-world clinical work contexts. Studies such as (Nardi, 1996; Wilson, 2006) have noted that the use of varied methods of data collection in CHT research is necessary for the emergence of full range of contextual issues. The mixed methods approach was useful, since it allowed us to avoid the potential criticisms that occur with small sample size in interviews or the superficiality of the information gathered from the questionnaire (Denscombe, 2007); probes were distinctive in their ability to uncover deeper aspects of the issues that define clinical practices and decision making, and as a more engaging form of contextual inquiry (Beyer and Holtzblatt, 1999).

From a research perspective, this study further illustrates that value of quantitative method in testing a hypothesis, the usefulness of qualitative research in uncovering the richness of details of clinical decision making, and the potential of the probes method in allowing us to understand the “whys” behind the clinicians’ actions and use of knowledge in decision making. As shown in this study, clinical decision-making occurs within a milieu of the unity of consciousness and activity that involves complex actions and interactions with the environment. One means of gaining an understanding of this complexity, particularly for cross-boundary decision support, is through the combined use of diverse methods of investigations. As a result, the mixed method approach adopted in this user-centred study enable the research to weave together the data collected from multiple paradigms and research methods, and to examine components that could be influenced by context and culture of work, such as situational factors, social expectations, organisational norms, personal factors, task definitions and social cues that otherwise might be overlooked (Creswell and Plano Clark, 2007, p. 235). One of the limitations of the study is the narrow range of work settings studied, which could affect generalisability to other geographical settings and work domains. Further research is needed to see the extent to which the results of this user-centred study are applicable to domains other than healthcare. Furthermore, this type of investigation could equally benefit from the use of other research methods, such as ethnography. We think that it would help further validate the results of this study and even lead to additional insights for the design of CDSSs for cross-boundary e-health decision support.

4.11 Summary

In this chapter, a user-centred study aimed to investigate clinical practices across three different geographical areas – the UK, the UAE and Nigeria, is presented. The study confirms that clinicians often need to seek information and opinion from outside their workplaces and to adapt the information obtained to suit their local work practices. The findings indicate that differences in clinical practices among clinicians are associated with differences in local work contexts across work settings, but are moderated by adherence to best practice guidelines and the need for patient-centred care. One of the other major findings of this study further is that an awareness of clinical work practices especially of the ontological, stereotypical, and situated dimensions plays a crucial role in adapting knowledge for cross-boundary decision support. In the next chapter, we will discuss how the set of design guidelines outlined from this study could be harnesses for the conceptual design of CaDHealth, a practice-centred framework for making sense of clinical practices across work settings for effective cross-boundary e-health decision support.

5

Conceptualisation of Practice-Centred Awareness and Decision Support

Tasks = Data + Action + Context.

– Alan Dix, Keynote at Engineering Interactive Systems, 2008

5.1 Introduction

In Chapter 3, we discussed a fairly comprehensive set of theoretical frameworks that would inform the practice-centred awareness and decision support approach proposed in this research work. In Chapter 4, we sought to understand, through a user-centred study of clinical work across three geographical regions, how clinicians' practices and everyday decision-making processes are influenced by the context of their specific real-world situations. On the basis of the findings of that study and using primarily the armamentarium of the frameworks discussed in Chapter 3, we seek to construct in this chapter a conceptual model of practice-centred awareness and cross-boundary clinical decision support for e-health. Our goal is to show how a practice-centred approach to context modelling could contribute to the challenge of building computer applications that allow individuals to more effectively construct and convey information about their contexts of work, including actual work practices, local circumstances and varying work situations (Bødker and Christiansen, 2006) in a manner that facilitates cross-boundary decision support beyond what is currently offered by existing workflow-based approaches.

5.2 Related Work

The problem of building models of work contexts, processes, local practices and situations of problem-solving in human organisations has been approached by a variety of authors using different techniques, languages and formalisms (Malone et al., 1999; Akman, 2000; Clancey, 2002; Goldkuhl and Röstlinger, 2006; Haake et al., 2009; Szymanski and Jack, 2011; Böttcher and Fähnrich, 2011). Most of these work have been published in a wide range of research communities, including HCI, IS, context modelling, health informatics, intelligent work environments and service systems modelling. The works can be roughly categorised into three broad groups, namely approaches that model context based on the notion of activity system (Kaenampornpan and O'Neil, 2005; Kofod-Petersen and Cassens, 2006; Geyer et al., 2006; Bardram, 2009), approaches that incorporate the notion of SAW for context-aware system behaviour (Tadda and Salerno, 2010), and systems that seek to extend the formal workflow models by incorporating aspects of social and cultural contexts of work (Agostini and Prinz, 1996; Bucur et al., 2006; Goldkuhl and Röstlinger, 2006; Allert and Richter, 2008; Szymanski and Jack, 2011; Brézillon, 2011). Recently, hybrid approaches have been proposed (Feng et al., 2009).

In his work on the Brahms system, (Clancey, 2002) models human work activities as "workframes". Workframes are related to Marvin Minksky's concept of "frames" (1974) in AI, Schank and Abelson's "scripts" in cognitive science, Barker's "behavioural settings" in ecological psychology and Suchman's situated actions (1987), which derive heavily from sociological concepts as well as Csikszentmihalyi's "flow experience" model (1990). The primary concern in Clancey's approach is to simulate human behaivour as it occurs "naturally" in work environments (Clancey, 2006), and thereby to model the stereotyped actions in a given setting. However, because "workframes" need to be created manually, the model does not sufficiently account for the actual dynamics of how actions and operations unfold, e.g. during learning and knowledge adaptation in problem-solving and decision support.

Similar to Clancey's "workframes" is the concept of "worklets" (Adams, 2007). The focus in "worklets" was to move workflow technologies beyond the "production line" paradigm and enable them to account for the wider range of real time exceptions in a work environment. The approach derives from the theoretical foundation of Activity Theory to provide an extensible repertoire of self-contained selection and exception-handling processes for workflows (Adams et al., 2003). However, by mirroring the notion of workflows without deeper empirical studies, the approach fails to adequately account for the situated and socially mediated nature of work practices (Szymanski and Whalen, 2011; Allert and Richter, 2008; Clancey, 2006; Suchman, 1987).

Equally driven by activity theory's conceptualisation of human behaviour, (Christensen and Bardram, 2002) explore support for work processes that are “radically different from the ones known from office work”. Their system, which was designed for the healthcare domain, seeks to efficiently organize and provide context information about current patients and their required services. Although the system has proven useful and is supported by a pervasive computing infrastructure together with domain-specific services, it relies on pre-defined activities already entered into the database and, as a result, fails to address two issues. Firstly, it lacks the capability to handle spontaneous and improvisational activities that are an inherent feature of modern work environments. Secondly, it lacks the ability for proactive support since users need to interact with the systems in an entirely query driven mode. The concern in the authors’ works was primarily to design for the social, temporal, and spatial awareness of workplaces and work activities based on the paradigm of “activity-centered computing” (Bardram, 2009; Bardram and Hansen, 2010).

Approaches that seek to extend formal workflow models largely argue that despite the attractiveness of workflow-based technologies (Fischer, 2007) in guiding work and aiding "organisational accounting", (Bowers et al., 1995), their existing forms render them too inflexible to account for contingent aspects of work (Grinter, 2000; Robinson, 1993; Suchman, 1987). One of the emergent trends has focused on redefining "the workspace" in order to uncover inherent contextual complexities of work (Suchman, 1995; Kurtz and Snowden, 2003), accommodate for "naturally" occurring interactions and practices (Brézillon, 2007; Clancey, 2006) and increase the amount of control that users have over work processes (Fitzpatrick, 1998; Dourish, 2004; Goldkuhl and Röstlinger, 2006). Other research efforts have focused on extending the basic structure of the activity theory framework in order to more deeply analyse the relationship between social and technical entities in a work environment (e.g. Kofod-Petersen and Cassens, 2006), and operationalise the historical aspect of CHT into a context model that accounts for both user- and system-driven adaptability at runtime (Kaenampornpan and O’Neil, 2005). As result, a number of activity-aware context models and systems have been proposed in the literature. Examples of these include the task/practice model (Brézillon, 2007, 2011), the ADEPT system (Reichert et al., 2005), the Adapte approach (Harrison et al., 2010) as well as context-aware work environments and activity-centric collaboration spaces, e.g. the ECOSPACE (Sari et al., 2008) and Activity Explorer (Geyer et al., 2006).

However, the challenge of applying practice-based models of work processes to enable context-aware decision support in a distributed work settings remains to be fully investigated. Existing models seek to extend the SAW theory (Tadda and Salerno, 2010), integrate SAW theory with context models (Feng et al., 2009; Kofod-Petersen and Aamodt, 2009; Nwiabu et al., 2011) or apply the notion of morphing to simulate changes in task requirement and adapt knowledge artefacts to different problem contexts (Hussain and Abidi, 2009). A recent publication that relates to the approach adopted in this work by focusing on knowledge translation between clinicians for decision support based on emerging Web technologies appears in (Stewart and Abidi, 2012), but differs from our work since it does not address, from a practice-centred perspective, the relevance of context of work in adapting knowledge for CDS. A distinguishing feature of our work, therefore, is the focus on practice, rather than activity, as the logical "workspace" that incorporates not only the tools, people, and resources needed to get a job done, but also the reasons for selecting certain tools and resources in relation to local work contexts and circumstances. Work practices, (Clancey, 2006), consist of much more than inferences applied to facts and heuristics, and denote the culturally and historically informed setting into which new technologies are deployed (Gautier et al., 2009). Designing CDSSs around a computation concept of work practice offers a new paradigm with the potential to enable deep-seated understanding of the dynamics of human work and people-centred approach to work support.

5.3 Usage Scenario for Cross-Boundary Clinical Decision Support

In order to illustrate the applicability of our proposed model, we construct three usage scenarios based on a number of salient issues that emerged from the user-study described in Chapter 4, which we re-state as follows:

- Though clinical cases have considerable elements of commonality, no two clinical cases are exactly the same.
- It is not unusual in healthcare to find remote hospitals, particularly in less economically developed countries, that do not have the range of specialist services or equipment that are available to other hospitals in the major cities or in more economically developed countries. This can result in poor quality care services because of lack of expertise or necessary tools. Clinicians in such situations could benefit from getting suggestions from their colleagues elsewhere (Fitzpatrick, 1998, p. 183).
- Clinicians, like every other person in real work situations, seek to get their done through arts of improvisation that are often borne out of such factors as personal training and experiences and the prevailing circumstances of their workplace, and may not strictly adhere to idealised work models.
- Existing CDSSs and technologies for telehealth appear inadequate because they do not incorporate explicit descriptions of clinical practices to allow for effective remote e-consultations and cross-boundary clinical decision support.

We are concerned with developing a PCA model, which provides explicit descriptions of clinical work situations in various healthcare settings in order to facilitate effective cross-boundary clinical decision support in a manner that adapts to user work context. The first two scenarios will help ground what we actually mean by PCA and cross-boundary decision support, whereas the third is aimed to illustrate the future scenario that is possible via the approach proposed in this work.

1 Practice-centred Awareness: Bob is a general practitioner (GP)[30] in a remote village. Bob has a patient, Alice who recently had breast cancer surgery. While managing Alice post-operatively, Bob needs to decide whether Alice needs adjuvant therapy, since not all women with breast cancer need adjuvant therapy (NCI, 2009). In larger clinical settings, determining which patients might benefit from adjuvant therapy as well as the appropriate course of treatments is often a complex decision (England et

[30] In this work, the term GP is used in the general sense of a medical practitioner, or a primary or secondary care physician.

al., 2004; NCI, 2009) usually made at multidisciplinary team (MDT) meetings (Patkar et al., 2011). However, Bob is able to find a UK-based consultant oncologist, who is inclined to offer "second opinion" to assist them. Mr Smith wants to gain an understanding of Bob's clinical work situation and Alice's circumstances in order to provide Bob with the most effective suggestion.

2 Cross-Boundary Decision Support: Mr Smith provides Bob with a suggestion based largely on what obtains in the UK where there is a state-funded health service. On getting the suggestion, Bob has difficulty adapting it to suit his local work practices, where there is no funded health service and poor availability of drugs, to suit Alice's peculiar circumstances.

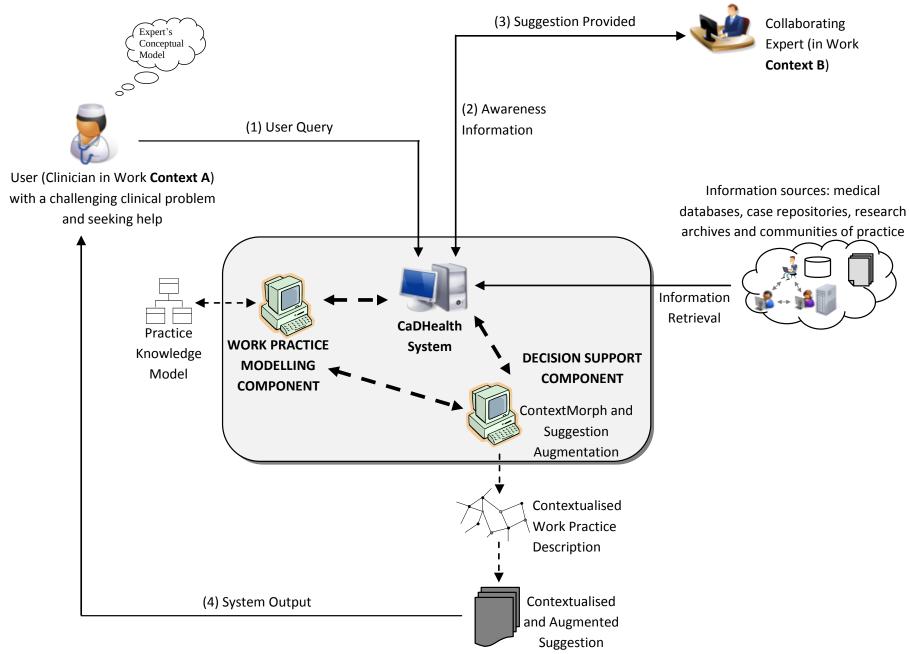

Figure 5.1: Example Usage Scenario

3 Using CaDHealth[31]: In this scenario, we illustrate how the use of our proposed model could help in this situation (see Figure 5.1). CaDHealth consists of two main components: the work practice modelling and decision support components. The former combines knowledge of the domain of work (e.g. breast cancer management) with context information about the hospital and the region (e.g. availability of secondary care specialists' services) as well as situational information about a given

[31] CaDHealth is the proof of concept prototype developed based our proposed approach, and is discussed in greater detail in chapters 6 and 7.

task (e.g. changing status of patient's ill health) in order to build models of work practice. The latter comprises the ContextMorph and Suggestion Augmentation sub-components. ContextMorph uses this model of work practice to enable information sharing between users across work contexts A and B with regard to a given task. The Suggestion Augmentation subsystem is developed as part of ContextMorph, and is responsible for retrieving more information from Web-based information sources (see Figure 5.1) in order to enrich the suggestion provided by the expert in context B (Mr Smith's context) in a manner that adapts to the context of user in A (Bob's).

5.4 Our Notion of Work Practice

A key construct at the core of the PCA approach proposed in this work is the notion of work practice. We define work practice as:

the set of working patterns, including choice of artefacts, forms of information organisation and collaboration, and techniques for contextualising procedures that have become part of a people's way of performing activities in order to account for the specificity of given contexts.

Our notion of work practice (and proposed modelling approach) is based on a number of elements borrowed from existing approaches. In conceptualising work practice, we derive from Dourish's phenomenological analysis of context as an interactional problem arising from activity (2004), and emphasize the crucial process by which "people reconfigure their organisation and tools to bring resources to bear on a given situation" (Clancey et al., 1998, p. 835). Whereas the notion of work practice can be generally abstract; in this work, we restrict our discussion of work practice to a set of working patterns associated to a people in a specific place and time. We argue that work practice is embodied in the way people carry out their activities in everyday, located, circumstantial interactions in the real-world. Since "contextuality is a relational property" of activity (Dourish, 2004, p. 22) that arises from the activity and, in particular, from how the activity is performed (i.e. work practice); it follows that work practice – as a problem-solving approach or pattern of working driven by context – is potentially crucial for understanding and modelling work context as comprising activity, artefacts and resources for work and the socio-cultural environment of work (Rosson and Carroll, 2002, p. 38).

Work practice[32] is distinguishable from the concept of activity (Engeström, 1987; Geyer, 2006) and the traditional notion of a task – a representational construct that describes human behaviour in terms of an input-output pair (Chandrasekaran, 1990). While, activity denotes "a form of doing directed to an object" (Kuuti, 1996, p. 2), practice embodies "meaning as an experience of everyday life" (Wenger, 1998, p. 52). The task of transforming object to outcome by engaging through mediating artefacts, according to (Kuuti, 1996), gives rise to the existence of an activity; however, the notion of practice brings to light the actual process of engagement, which is context-driven and central to understanding the differences between goal and outcome in real-world problem-solving. In contrast to activity, a practice represents "a recurrent pattern which can be filled out by various activities actualising the practice" (Allert and Richter, 2008), and denotes the contextual characteristics of a set of activities including forms of activity, patterns of interactions, tools and their usage, as well as certain forms of knowledge.

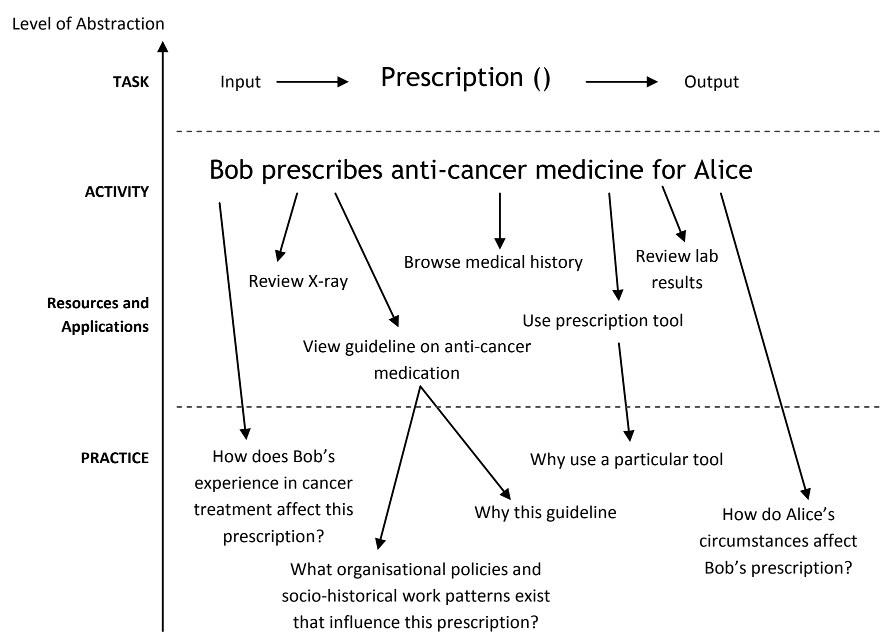

Figure 5.2: A work process depicted at task, activity and practice levels

To illustrate these differences further, consider the sketch in Figure 5.2 depicting a simple process of Bob giving prescription to Alice. This process is depicted as a task with simple input and output, as an activity that includes the resources and applications that Bob uses in executing this process, and as work practice that incorporates how Bob's context of work has

[32] A detailed review of the concept of practice appears in Chapter 3. See also (Wenger, 1998, part I; Schatzki, 1996; Bourdieu, 1977)

influenced how he has carried out the process and why. If we view this process from a computational level, we can identify at least three levels of abstraction: the task, activity and work practice levels – where each level is a superset of the one before it. Computer systems currently support the first two levels – the task and activity levels; notable exceptions, however, include (Goldkuhl, 2006; Sierhuis et al., 2009). A central focus of the argument of this research is that cross-boundary decision support systems should be designed to include support for work processes at the practice level. In what follows, we discuss the perspectives offered by the practice-centred approach as well as the categories of context and classifications of practice.

5.4.1 Five Perspectives of Proposed Approach

By moving beyond an activity-centric paradigm, the approach proposed in this research work allows us to design computationally-enhanced tools with the capability to support a work process from much deeper and broader perspectives. We identify five perspectives, which are described briefly below. The five perspectives draw from the three categories of work practice identified in the user-centred study in Chapter 4 (and discussed in Section 5.4.2), and focuses on broadly understanding how people do acquire the capabilities for problem solving and decision making.

Knowledge-level Perspective

Most research has approached the task of designing systems that relate with the context of computation by focusing on the technical issues associated with context, e.g. the syntactic connections between different concepts or the use of sensor technologies to enable systems to respond to changes in the computational environment. Notable exceptions, however, include (Doursih, 2004; Kaenampornpan and O'Neil, 2005; Brézillon et al., 2004; Kofod-Petersen and Cassens, 2006). However, much effort is still required to study and analyse context from a knowledge-level perspective (Newell, 1981). By seeking to construct a computational model of context of work, including organisations of people, tools and resources for work as well as the underlying motives and circumstances of problem-solving, our approach aims to build DSSs that are aware of their "context" through an ontology of "the structure of a total world" (Newell, 1981, p. 6). From a knowledge-level perspective, a thrust of this research is to understand the "work practices" of clinicians across various regional and organisational work settings in order to enable context-aware decision support in a manner that takes account of the "bounded rationality" (Simon, 1991) across work setting.

Cultural-historical Perspective

As stated previously, the computational concept of work practice offers a new approach not only for organising tools, actors and resources in a work environment, but also for portraying how and why certain tools, actors and resources are used in certain activities in relation to prevailing local contexts. From a cultural-historical perspective, the approach proposed in this work seeks to understand and design support for work practice – both as a necessary part of the process of forming psychological capabilities and as the source of psychological contents acquired over time by individuals (Chaiklin, 2011, p. 227). Our approach emphasises that the relevance of work practice lies in the focus on routine actions that are driven by context and organised in relation to the production of collectively-needed products (Schatzki, 1996; Hoft, 1996; Hofstede, 2001; Dourish, 2004; Schein, 2004; Chaiklin, 2011).

Socio-technical Perspective

The approach proposed in this work pursues an analysis of context of work on the level of socio-technical systems (Lueg, 2002). Arguably, one of the most important context parameters available in many work situations is the activity performed by entities in the work environment (Kofod-Petersen and Cassens, 2006). Empirical evidence shows that because activities are usually performed in relation to a complexity of social contexts, researchers and designers are often unable to provide precisely compatible technical support – leading to a socio-technical gap (Respício et al., 2010). By using socio-technical theories to design context-aware DSSs to supply seamless services to the user, our approach facilitates work practice analysis at the organisational level (Fox, 1986), and allows for the consideration of all entities in a problem-solving situation in terms of the stereotypes and situated behaviour patterns in the work environment. This approach helps to reduce the gap between the social and computational worlds by understanding what knowledge is applicable for a certain context and what social and technological contexts are relevant when solving a given problem.

Situated Perspective

One of the most significant things that has emerged from work practice studies over the last two decades is the notion of the situatedness of work (Suchman, 1987; Luff et al., 2000;

Szymanski and Whalen, 2011). This perspective argues that work, contrary to the commonly held views of plans and rationalistic thinking, unfolds in response to the contingencies of a situation. By combining the activity system and the SAW theory in a model that considers non-workflow based aspects of work, e.g. the situated factors of a work environment, our approach accommodates accounts of the situated perspective of work. The idea of accounting for the situated perspective of work is evident in the works of authors such as (Brézillon et al., 2004; Dourish, 2004; Feng et al., 2009).

Ecological Perspective

The notion of PCA is reminiscent of the dynamics of biological and social ecology where an ecosystem is said to consist of all the biological and social organisms "living" in an area, co-existing and interacting with one another and with their environment in a manner that maximises the use of available resources and adds to the achievement of the overall system goal. As noted in the user-centred study in Chapter 4, clinicians bring to bear on their decision a wide range of factors that is informed by the knowledge of the domain of medicine, resources within their environment and the circumstances surrounding the clinical case on hand. According to (Béguin and Clot, 2004), expertise implies being capable of "exploiting environmental resources" (p. 53) within a system that, according the ecological approach, is aware of itself and is constantly influencing interactions in order to achieve the goals of the system. Take for example a clinical system with the goal of providing the best possible care to the patient. With this motive in mind, a clinician who is aware of prevailing medical conditions in the area, e.g. available medical tools and services, effortlessly and consciously applies those resources in relation to the present circumstances of the patient in order to offer the best possible care.

The ecological perspective with its ability to purposefully unite the three classes of practice (discussed in the next sub-section) indicates – as highlighted by the user-centred study in Chapter 4 and equally confirmed by the finding in (Gabbay and le May, 2011, p. 71) – that clinicians, often, are unable to describe what they have actually done especially in situations that fall outside of the scope covered by protocols and guidelines. The ways that ecology relates is part of how work is mediated and actually gets done, and once understood is enormously productive as a resource for design insight (Randall et al., 2007, p. 223).

5.4.2 Classifications of Practice

Based on the concept of clinical work practice, we identify three classes of work practice: practices that relate to general task domain and span across boundaries (*ontological practices*); practices that are typical of a certain place and time of work (*stereotyped practices*); and practices that relate only to certain prevailing situations of work and circumstances (*situated practices*). Figure 5.3 shows the relationship between the three classes of work practice within a practice system; Figure 5.4 depicts the relationship hierarchically. We introduce the concept of *a practice system to denote the mental, social and physical space within which users interact with their resources and environment in order to accomplish tasks*. We show how our classification of practice would enable cross-boundary awareness in an e-health environment. We posit that in the context of cross-boundary e-health decision support, the idea of awareness rests on a participant's ability to make sense of the other person's context of problem-solving through an interpretative mechanism that seeks to share their understanding of the world in a manner that adds value to the other person's decisions. The real challenge here is to understand how people make practical sense of their world in ways that allow them to consciously engage in work, and effortlessly relate with their environment (Dourish and Bellotti, 1992; Schmidt, 2002; Dourish, 2004). We discuss the three classes of work practices as follows:

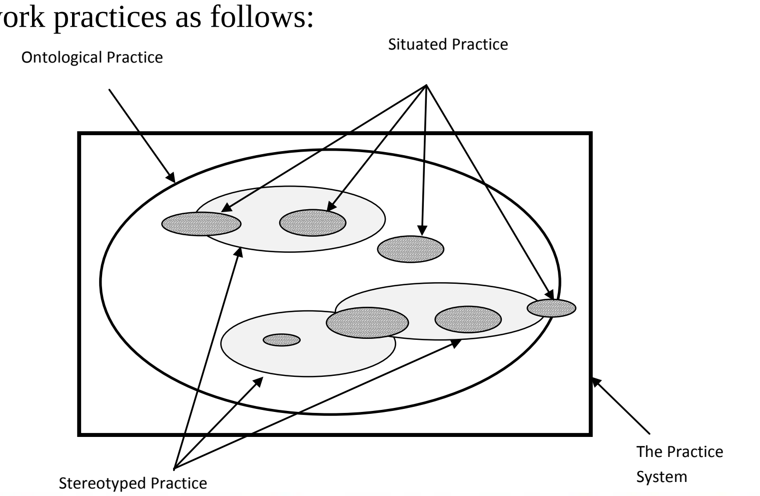

Figure 5.3: Illustration of classes of work practice in a practice system (adapted from Benjamin et al. 1994, p.22). Within a single practice, denoted by the practice system, the ontological practice acts as a single big container of the other two categories of practice, except perhaps the situated practice depicted lying on the perimeter of the ontological practice – denoting forms of situated practice that arise from common knowledge. Stereotyped practices may overlap. Situated practices may exist outside of stereotyped practices but inside the ontological practice – denoting a situated practice that conform to domain knowledge, but not to organisational norms and practices. A situated practice lying on the perimeter of stereotyped practice conforms partly to organisational practices, whereas the one inside a stereotyped practice conforms both to organisational and domain rules and practices.

5.4.2.1 Ontological Practices

Ontological practices describe aspects of a people's working patterns that are attributable to their domain of work. A domain defines the "area of knowledge or field of study that we are interested in" (Guinchiglia et al., 2012), and provides us with a bird's eye view of the whole of knowledge encapsulated by a problem task. This view can be as wide as a whole field of study, e.g. medicine, physics, business, music, or as narrow as a task or procedure, e.g. breast cancer surgery, management of type II diabetes, mastectomy or tomato soup.

The correlation between the domain and context of activity is well documented in research across disciplines such as computer science (Giunchiglia et al., 2012; Porzel, 2011). Context is domain-dependent, and situation-dependent problems are nothing but domain problems influenced, and made "contextually relevant" (Dourish, 2004, p. 22), by the state of the work environment (Nwiabu et al., 2011, p. 9). To execute a task properly (e.g. medical diagnosis), the person must have previous knowledge about the task and its knowledge domain (Vieira, 2008, p. 49). This knowledge, however, describes statically defined information and patterns of problem-solving within the domain. We refer to this generic and subject-related body of working patterns as ontological practice. Ontological practices acknowledge the role of plans, and provide the basis and ontological explanations for organisational (stereotyped) and situation-specific (situated) work patterns and practices. In order to design a system that can support awareness amongst clinicians across organisational and regional boundaries, we need to take into account diverse practices through which work is routinely and seamlessly integrated; these practices, as (Vyas, 2011, p. 16) observes, differ from domain to domain.

5.4.2.2 Stereotyped Practices

Expertise, or what (Gabbay and le May, 2011, p. 91) referred to as "professional artistry" involves the ability to act knowledgeably within a specific domain of application and, often, in relation to a specific area and time. It thrives on the assumption that "the situation at hand is one of a kind and that it enjoys the properties generally associated with that kind of situation" (Lehmann, 1998, p. 49). Stereotyped work practices denote a set of possible practices, working patterns (and objects) that are associated to a certain region, organisation or workgroup, and are a necessary component of the meaning of actions and situations. The notion of stereotyped work practice is evident in Marvin Minsky's work on "frame theory" more than thirty years ago; he notes that:

> [W]hen one encounters a new situation … one selects from memory a structure called a frame. This is a remembered framework to be adapted to fit reality by changing details as necessary. A frame is *a data-structure for representing a stereotyped situation*, like being in a certain kind of living room… Attached to each frame are several kinds of information. Some of this information is about how to use the frame. Some is about what one can expect to happen next. Some is about what to do if these expectations are not confirmed. (1974, emphasis not in original)

Minsky's suggestion underlines the fact that in making sense of a situation, one "by default" fills in certain stereotypes about the situation in terms of "things" associated with the situation, e.g. objects, levels of expertise, technology, etc. However, stereotyped expectations are not always confirmed – which highlights the reputation of stereotypes, in ordinary parlance, as "an impediment to intelligent thinking" (Lehmann, 1998, p. 50). Stereotypes have been a central tool in inferencing, and are inextricably linked to sense making in organisations (Weick, 1995).

In this work, we use the concept of stereotyped practices to denote practices that have been generally accepted by a workgroup, an organisation or area as a routine way of carrying out certain tasks in order to account for certain peculiar circumstances. The notion of stereotyped practices makes use of common protocols for the expression of intents and actions in organisations in order to associate to a community or workplace certain "shared knowledge about typical situations and appropriate actions" (Suchman, 1987, p. 27).

5.4.2.3 Situated Practices

The third class of work practice, referred to as situated practice, accounts for the actions that a clinician takes during decision-making that do not derive from their formal knowledge of medicine or the protocols and guidelines that depict the stereotypes of clinical practice in the region or hospital, but rather from the circumstances surrounding a certain clinical case or encounter. The notion of situated practice is evidently underscored by Suchman's concept of situated action (1987), which clearly points out that "people … achieve intelligent action" (p. 50) based fundamentally on situated practices that are tied in essential ways not to domain rules or conventional stereotypes of a workplace, but to "local interactions contingent on the actor’s particular circumstances” (p. 28). In Suchman’s view, to say that practices emerge from situations means two things: 1) actions are dependent on circumstances and 2) acting defines the context of actions – both occurring in a seemingly ecological sense. There is a danger of blindly constructing awareness of actions based on ontological and stereotyped practices, and not recognising the key role of situated factors. Situated practice emphasises that “while the course of action can always be projected or reconstructed in terms of prior intentions and typical situations, the prescriptive significance of intentions for situated action is inherently vague” (p. 27).

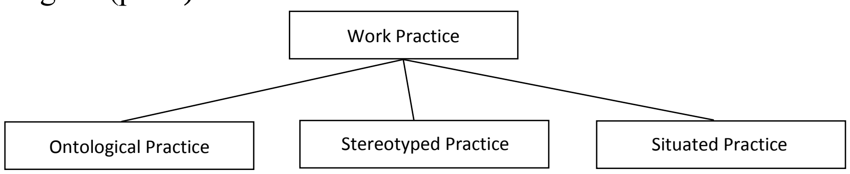

Figure 5.4: A hierarchical structure of the classes of work practice

Though Suchman recognises the crucial role of plans and the relationship between plans (as ontological practices) and situated actions (as actions that depend on people's material and social circumstances), it remains to be seen how the two “ends” of plans and situated actions alone would sufficiently enable cross-boundary decision support. What we have proposed in this work include a novel approach for addressing this issue, which incorporates a middle class of practices – the stereotyped practices in order to relate ontological actions and domain concepts to prevailing situations, and consequently enable cross-boundary support by identifying the actions and patterns of working associable to a region or work organisation.

5.4.3 Levels of Work Practice

We identify two levels of work practice, namely *boundary practices* and *local practices*. By levels of work practice, we mean how much a work practice can be understood, and even applied, by individuals working independently on similar problems in different work settings across boundaries of space and time. Boundaries, according to (Aldrich and Herker, 1977, p. 217), are a defining characteristic of organisations, workgroups and even regions, (Igira, 2008). Varying notions and forms of boundaries have been discussed in ISs literature (Star and Griesemer, 1989; Gasson, 2005; Akoumianakis et al., 2009; Kajamaa, 2011). In this work, we use boundary to mean the physical, social and cultural separations that often exist between work settings due to variations working patterns and circumstances. Generally, ontological practices are boundary (or boundary-spanning). Stereotyped practices may be boundary-spanning or local, whereas situated practices are by default local practices.

Boundary Practices

The notion of “boundary” has been used in relation to objects (Star and Griesemer, 1989) and knowledge (Carlile, 2004), as an approach for knowledge sharing in e-collaboration. In this research, we use the term to denote working patterns that extend over and across the separations between workgroups, organisations, regions or communities of practice. As shown in Figure 5.5, boundary practices are dependent on the ontological context. They are domain-specific, and provide the basis and ontological explanations for the use of organisational (stereotyped) and situation-specific (situated) work patterns and practices (see Figure 5.5).

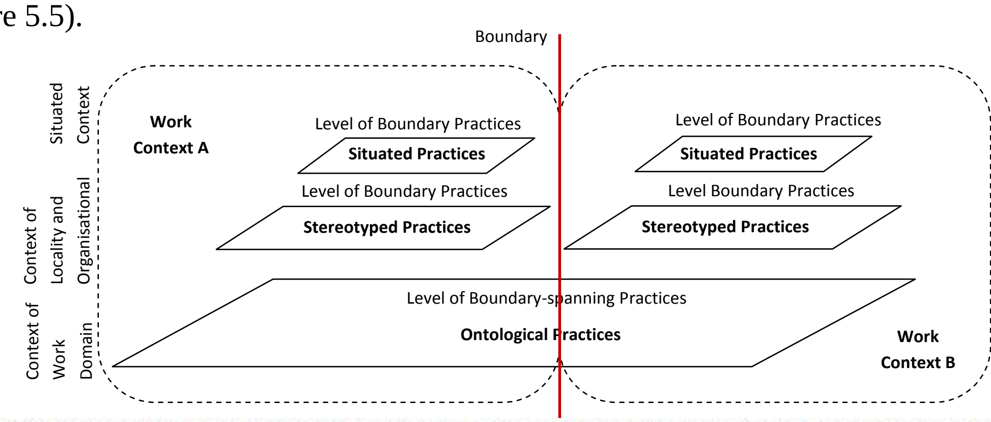

Figure 5.5: Levels of work practice. It is assumed here, as in our representation of the ContextMorph process (see Section 5.11) that situated practice is a subset of the stereotyped practice, which, in turn, is a subset of the ontological practice. Note that this assumption is strictly to simplify our model of the ContextMorph technique, and does not very well reflect the representation of the relationships among the three classes of work practice as shown in Figure 5.3.

Local Practices

As the name denotes, local practices are “localised” forms of practices that are “embedded” (Bourdieu, 1977) in people’s ways of doing things; they are dependent on, and usually arise in response to the prevailing situations of work. Boundaries practices are underlined by the fact that people’s actions and use of knowledge in problem-solving cannot be separated from their “lived experiences” (Dourish, 2001) and engagement in the “practicing” of their practice (Cook and Brown, 1999). Although the notion of local practice clarifies the situated and tacit characteristics of knowledge (Suchman, 1987; Nonaka and Takeuchi, 1995; Cook and Brown, 1999) as well as its pragmatic view, conceptualising practices at the boundary level is often more contentious, since all social practices are contextualised (Chaiklin and Lave, 1996) and involve local forms of interplay between systems and the adaptive transformation of systems across time (Gay and Hembrooke, 2004, p. 7).

5.5 Modelling Approach

We introduce, from this section, the conceptual design of our approach to modelling human work practice. We refer to this as the *practice-centred awareness* (PCA) model. We take a practice-centred approach to modelling work practice with a focus on awareness provision, i.e. on how knowledge of a clinician's context of work and patient's needs could be used to provide awareness for cross-boundary clinical decision support. Hence, we model work practice as context-driven interactions emerging out of a clinician's engagement with the environment, drawing from their knowledge of the domain of medicine as well as every day socio-cultural understanding of clinical practice in their workplace. Our goal is to enable an enhanced understanding of clinical work contexts and problem requirements across distributed work settings for cross-boundary decision support. We define PCA as:

an understanding of other people's local work contexts, problem-solving approaches, circumstances and task requirements, which include the ontological, spatio-temporal and situational factors that provide causal explanations for and influence how they utilise available resources, and contextualise plans and procedures to solve problems and achieve task goals in the real-world.

Developing the PCA model involves three major steps. In the first step, we extend the basic model of Engeström's activity system (1987) in order to derive a *work practice model*. In the second step, we integrate the work practice model with Endsley's SAW model (1995). This process is depicted diagrammatically (and arithmetically) in Figure 5.6. Finally, we incorporate into that our proposed context model. One of the novelties of our modelling approach is its potential to provide a knowledge-oriented, ecology-level understanding of actions in a work system. By using the CHT approach, we emphasize the historicity and situatedness of actions as well as the interactivity required to perform work; by using the SAW, we are able to highlight the constant evolution of the knowledge and contextual variables required to work done.

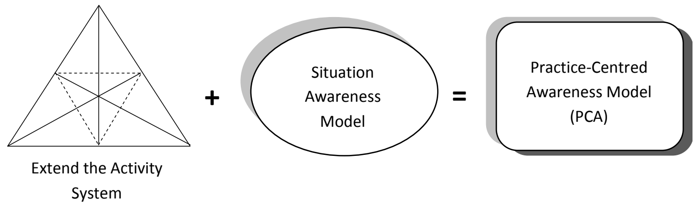

Figure 5.6: Overview of the practice-centred awareness model

5.5.1 Extending Activity System for Practice-Centred Awareness

As shown in Figure 5.7, the activity system has the potential to be used as a foundation for producing a sufficiently comprehensive description of a work context situation. Using the scenario example in Section 5.3, it has been shown that the elements of the theory take account of the key elements of a clinician's work context and how they influence their actions and use of knowledge within a local work environment (Kaenampornpan and O'Neil, 2005). Certainly, flows of information and interactions among elements are presented in the diagram, but the ontological, organisational and situational bases of those interactions are not altogether clear. CHT's activity system captures the key elements of human behaviour during problem-solving, but fails to account for the details of how work is realised out of the interplay between knowledge of a work domain, organisational practices and the socio-cultural aspects of a workplace as well as the prevailing circumstances of a work situation.

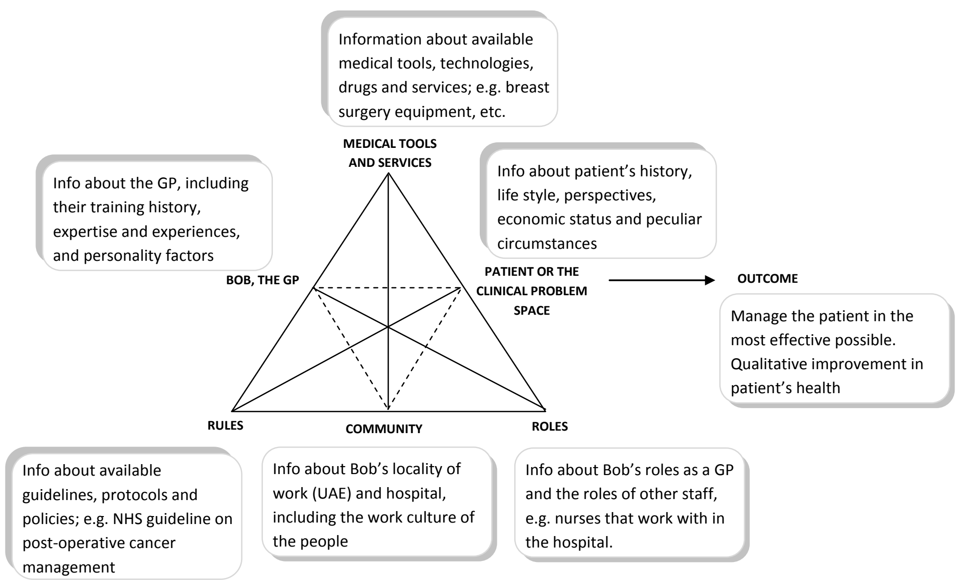

Figure 5.7: A CHT model of the example scenario

Research has shown that clinical work in the real-world, for example, is often influenced by a wide range of factors that draws on a clinician's formal knowledge of medicine, on organisational protocols and guidelines and on the changing situations of the clinician's work context and patient's needs (Gawande, 2002; Gabbay and le May, 2011). Activity system, as a result, lacks a sufficiently organised structure that is necessary to convey awareness information across boundaries of workplace, organisations and regions for effective e-health clinical decision support. To address this, we argue that dividing the activity system into three planes representing the three classes of work practice discussed in Section 5.4.2 would make it clearer which, and how, elements of the system (e.g. tools, subject, rules, community, etc.) influence problem-solving, e.g. from the perspective of the domain of work or based on known stereotypes of a workplace or as a result of prevailing situations of work (see figure 5.8).

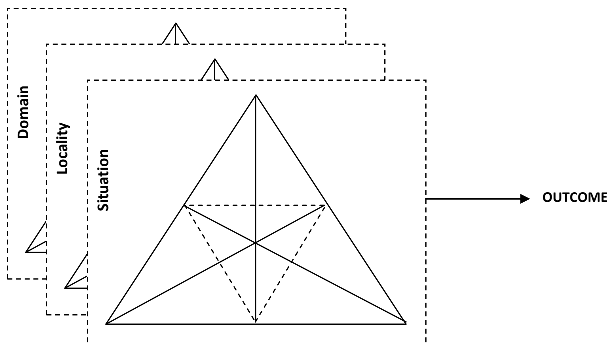

Figure 5.8: Extending the activity system to develop the work practice model

Our goal is to encapsulate the wide range of factors that influence work in the real-world and delineate them on the basis of the domain of work, locality of work and prevailing work situation (see Figure 5.7). By extending the activity system, we able to delineate the factors influencing clinical decision making based on domain of work, locality of work and the prevailing situation of work that correspond to the classes of practice discussed previously. For example, if we take problem-solving as the process of transforming work objects, then a task model indicates what methods are applied to transform the objects; an activity model tells who executes those methods, what tools are used and what constraints and dependencies are involved in the process. A work practice model emphasizes why and how those methods have become part of the work process and why they have been preferred in the prevailing context.

Our solution divides an activity system into three planes in order to enable granularity of analysis, and help locate an activity system at various layers of any given work setting, including the domain, locality and situation of work. This perspective resonates with Gay and Hembrooke’s approach to integrating activity theory and ecological principles (2001, p. 10). Their work highlights role of knowledge of both historical and contemporary contexts in aiding the understanding of activities in the context of interacting systems. Activities consist of dynamic and multifaceted interactions that occur at different levels of granularity due to varying durations, complexity and ownership (Voida et al., 2007, p. 196).

5.5.2 Work Practice Model

We describe the work practice model proposed in this work. The model is proposed as a tool to help designers build adaptive systems for cross-boundary decision support by enabling the construction of a bird's eye view of actual contexts of work based on work domain, stereotypes of workplace and situational circumstances. The idea behind the proposed model largely derives from the observation that the wide range of factors that clinicians usually consider during problem-solving are generally drawn from three separate but interrelated pools, namely the formal knowledge of the domain of work, information and rules within a locality and organisational work setting, and information about situational circumstances that contribute to define the problem being solved (e.g. patient's changing medical conditions). The model, as a result, consists of three separate layers – ontological, stereotyped and situated activity systems – arranged in a hierarchical order. We model these as (sub) activity systems (see Figure 5.9).

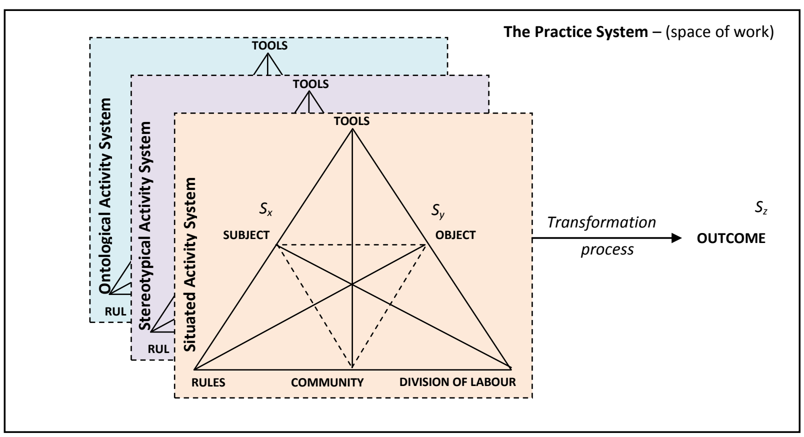

Figure 5.9: Proposed work practice model

The encompassing activity system within which the layers exist is what we refer as the practice system (described later) that depicts the space of work. We argue that particular instances of work practice gain their meanings in relation to three factors: knowledge of the domain of work, the stereotypes of the workplace or the organisational culture through which a clinician's lived experience of everyday work mostly acquire its form, and finally the situational factors of work. Identifying these factors and representing them as independent sub-systems have the potential to enhance cross-boundary awareness of people's work situations and requirements (Bedny and Karwowski, 2004, p. 140). Figure 5.10 depicts an example of how the three levels of a practice system can be applied to a diagnostic task, showing which stage of the diagnosis involves factors from the ontological, stereotyped or situated activity system.

Ontological Activity System

The first layer represents the vocabulary and key concepts of a domain of work. It describes the various entities, their attributes, roles and relationships as well as the constraints that govern the integrity of a model of problem-solving in that domain in a manner that is independent of any local instance of the model. An ontological activity system is an idealised work model and, as has been shown by numerous research (Suchman, 1987; Robinson, 1993; Gabbay and le May, 2011), often differs from real-world instances of the same model. Our goal here is to establish the foundation and epistemological justifications for any stereotyped or situated action applied in any work organisation or under any circumstance of work.

One of the main defining characteristic for adaptive decision support in CaDHealth is the system's model of knowledge of a clinical domain. This model specifies the knowledge and reasoning requirements of the system that is independent of any organisation, time and circumstances. A well-thought ontological activity system serves as a clear depiction of the conceptual fabric of a domain of work and, therefore, is invaluable for building "mutual intelligibility" (Suchman, 1987) and for ensuring that all agents in a cross-boundary decision support scenario align their suggestions and problem descriptions in the scope and meaning of the concepts and knowledge indigenous to the domain of work.

Stereotyped Activity System

A major goal of the PCA model is to enable CaDHealth to optimally adapt its behaviour to the idiosyncrasies of a clinician's work setting. We observed during the user-centred study (in Chapter 4) that for some clinical tasks it is possible to associate certain behaviour patterns to certain clinicians because they work in certain regions or organisations, or to identify typical categories of artefacts (e.g. medical tools and drugs) characterised by similar sets of features and used in a similar manner, or to expect certain types of requirements from patients in an area (e.g. based on their general level of education or economic status). Such categories of user goals, knowledge levels and preferences "constituting strong points of commonalities" (Kay, 1994) that characterise a work setting are what we model as *stereotypes*.

The notion of stereotypes has been a pervasive element of much work in user modelling (Rich, 1979; Kay, 1994; Sosnovsky, 2007), and has been used in relation to the notion of communities to depict groups of users and user situations with certain commonalities (Orwant 1993). A stereotype relies on the assumption that a situation is one of a kind (Lehmann, 1998), and denotes a pre-defined working setting and problem-solving model in which each stereotype contains one or more name-value pairs of attribute elements that constitute the stereotyped activity system. CaDHealth makes use of stereotype-based modelling to adapt information to different work situations. For example, whenever the system receives an evidence of a work setting being characterised by a certain stereotype, it utilises a stock of preset stereotype profile information. A work setting can be described by one stereotype or a combination of several orthogonal stereotypes. Stereotypes are organised in a generalisation hierarchy in which stereotypes inherit properties from their ancestors in the hierarchy. A stereotype has one or more characteristic properties called triggers used to identify its applicability to a work setting that exposes information according to it (Kay, 1994; Lehmann, 1998).

The concept of stereotypes, though somewhat controversial in social parlance, can provide a powerful basis for agents that help people in seeking information to support their work and in adapting it to suit their context of work. Stereotypes can be used in reasoning tasks of the form: individuals who know how to program in Visual Basic can easily learn the C Sharp programming language. Since patient Q lives in tropical area, they are susceptible to malaria.

Situated Activity System

Whereas the stereotyped activity system captures the roles that local representations of routine information play in the social, cognitive, organisational, and technological processes that accomplish work, it has been shown that some of these processes often occur by chance, and arise out of peculiar circumstances rather than as a matter of local customs. In CADHealth, we model such non-routine practices as situated activity system. The situated activity system allows variability in the description of how information and interactions occur within a work practice system. The principal idea is that a model can be more insightful and useful for cross-boundary decision support if it makes fewer assumptions about how work gets done than are built in conceptual and workflow-based models (Clancey et al., 1998, p. 7).

In building the situation activity system, we draw extensively from the related theories of situated action and situated cognition. A central argument of the theories is that task and problem-solving are bound to the specific situations in which they occur. The situated activity system upholds a model of knowledge and doing that requires "thinking on the fly" rather than the rationalistic view of storage and retrieval of conceptual knowledge (Winograd and Flores, 1987). In essence, it claims that work unfolds in situ, and that the ability to solve a problem is inseparable from the contextual, situated and socio-cultural definitions of the task.

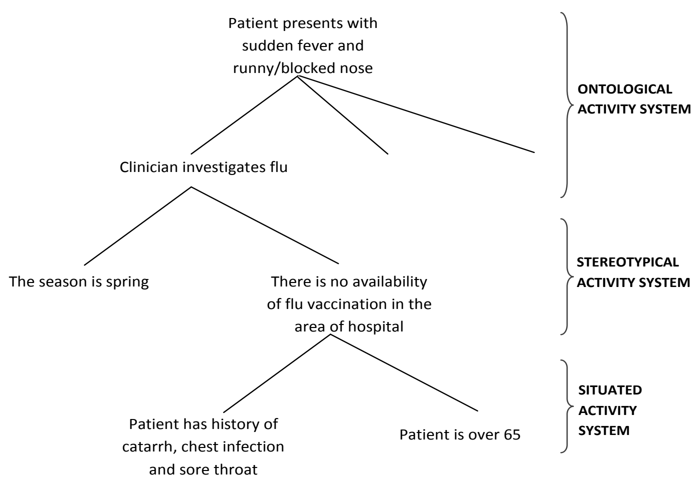

Figure 5.10: An example of application of the three levels of a practice system to clinical diagnosis

5.5.3 The Work Practice System

We conceive of a *practice system* as a work environment, including the socio-cultural, organisational, contextual and situational aspects of the environment, that involve not only actors and artefacts (Johri et al. 2007; Pipek et al., 2011), but also the interplay among system entities and the adaptive transformation of the system across time (Gay and Hembrooke, 2004, p.7; Kaenampornpan and O’Neil, 2005). A practice system offers a holistic view of a work environment and is aimed at identifying the details of activity systems at different levels of work context. Identifying activity systems at different levels of work context potentially allows a DSS designer to focus on a particular level and then isolate the mediating processes at that level for enabling cross-boundary awareness and support.

Table 5.1: A work practice system showing a clinical work process at three different levels of work context

Element	Ontological Activity System	Stereotyped Activity System	Situated Activity System
Focus	Work context analysis based on domain knowledge and rules	Work context analysis based on known stereotypes of a locality at a certain period	Work context analysis based on prevailing context and circumstances of a given case and encounter
Subject	GPs for primary care; specialist consultants for secondary care	GPs, nurses and few specialist medical professionals based in the cities	Bob, the GP
Object	Name and medical record of patient, e.g. Alice, age: 40, sex: female	Population predominantly poor and prone to infectious diseases	Alice, a patient of very low economic status and with history of cancer in family
Tools	Use of standard laboratory and medical tools, e.g. x-rays, EHR. Use of best evidence results based on state-of-the-art research findings	What are the likely available tool, guidelines and services in this area at this period? What is the rate of availability of required drugs?	Actually available tools include stethoscope, thermometer and other basic medical devices
Rules	Formal rules and theoretical knowledge of medicine	What are the guidelines in use in the hospital? How do institutional and regional policies affect the diagnosis and management of Alice	Informal aspects of Bob's actions toward the diagnosis and management of Alice
Community	GPs, nurses, laboratory scientists and social service providers as well as oncologists and surgeons for secondary care referrals	There is a low rate of availability of specialist doctors for secondary care services	A rural clinic run by the GP and two assisting junior nurses. Local charities offer help a times
Roles	What are the roles of GPs, nurses, laboratory scientists, social services providers, etc. in the diagnosis and management of Alice	GP provides primary care, lab technicians perform tests. Necessary referrals are given to secondary care for further investigation	What tasks and decision-making do the GP and nurses engage in?

By analysing and describing work settings as work practice systems consisting of three broad layers of activity system, we able to account for the natural fuzziness, chaos and nonlinear dynamics in regulation of people's activities (Bedny and Karwowski, 2004, p. 140). Our conceptualisation of the practice system is similar to constructs such as the product ecology (Forlizzi, 2007), the activity landscape (Kirsh, 2001), the locale framework (Fitzpatrick, 1998), the timespace of human activity (Schatzki, 2010) and even the systems thinking approach (Checkland, 1981), and aims to provide a broad-based view of a space of work by extending the traditional activity system

Focusing on the usage scenario in Section 5.3, we describe the use of a practice system in describing the activity of Bob (see Table 5.1). The rationale behind the extended version of the activity is to enable an agent to conceptualise the context and situation of work with hierarchical levels of details for cross-boundary decision support. This brings to light the wide range of factors (including formal, informal and logistic factors) that are potentially considered by a clinician during problem-solving and decision making. It allows agents outside the work setting to construct a more ecological view of a work environment and build a more accurate and holistic understanding of Bob's problem requirements including patient's needs in order to provide adaptive information to support Bob across boundaries of work settings.

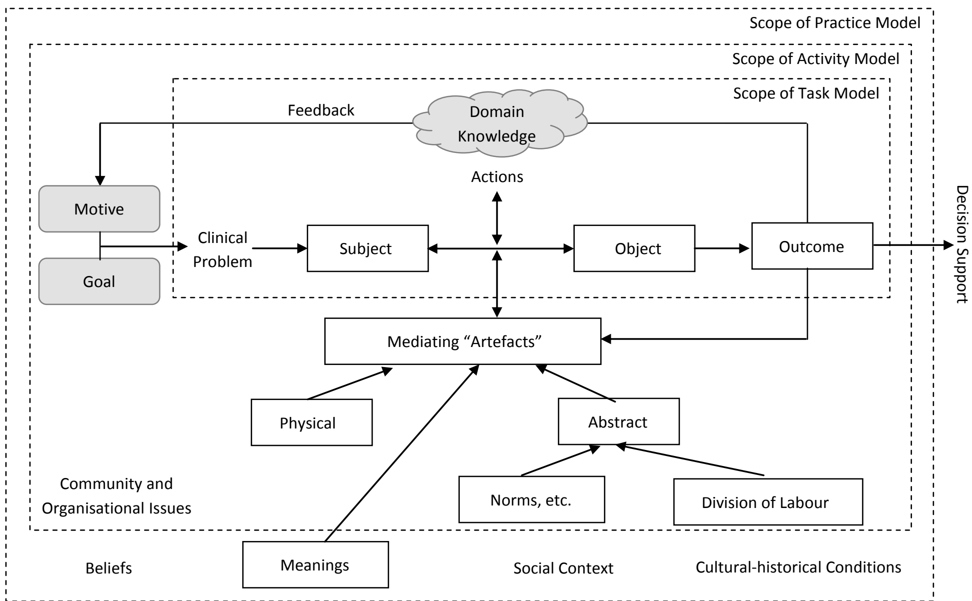

Figure 5.11: Scope of a work practice model (Adapted from Wilson, 2006). Wilson's model allows us to highlights the role and relationships among various elements of work practice, e.g. socio-cultural variables, beliefs, organisational and contextual issues, etc. in effecting the emergence of work at the work practice scope

A work practice model brings out details of the rich contextual framework in which work unfolds, and suggests lines of enquiry that would potentially lead to enhanced adaptive cross-boundary support to work, which a less-detailed analysis would not suggest. To further highlight this, we extended a process model of activity proposed by (Wilson, 2006), and show how a work practice model offers a much wider scope than an activity or a task model for understanding the context and setting in which we perform our activities (see Figure 5.11). Whereas Figure 5.9 depicts the practice system as a concept, Figure 5.11 shows how work is realised within this system from the perspective of a work process, driven by motive and goal and directed (by work practice elements and activity factors) towards desired outcome (Wilson, 2006 and also Figure 6.2). Scope of the practice model includes meanings and experience (Wenger, 1998; Dourish, 2001) of using mediating tools as well as the social and cultural-historical contexts of use (Rosson and Carroll, 2002, p. 38-39; Kaenampornpan and O'Neil, 2005; Chaiklin, 2007). As shown by recent observational studies of complex and knowledge-based problem-solving (Heath and Luff, 1992, 1996; Luff et al., 2000; Clancey, 2006; Suchman, 1987; Bardram and Hansen, 2010; Gabbay and le May, 2011), users often employ practices and procedures that not only fall outside of formal work processes, but also are hardly predictable at design time (Riemer et al., 2007). To enable designers to develop DSSs that take account of work at the work practice level is a key focus of our proposed model.

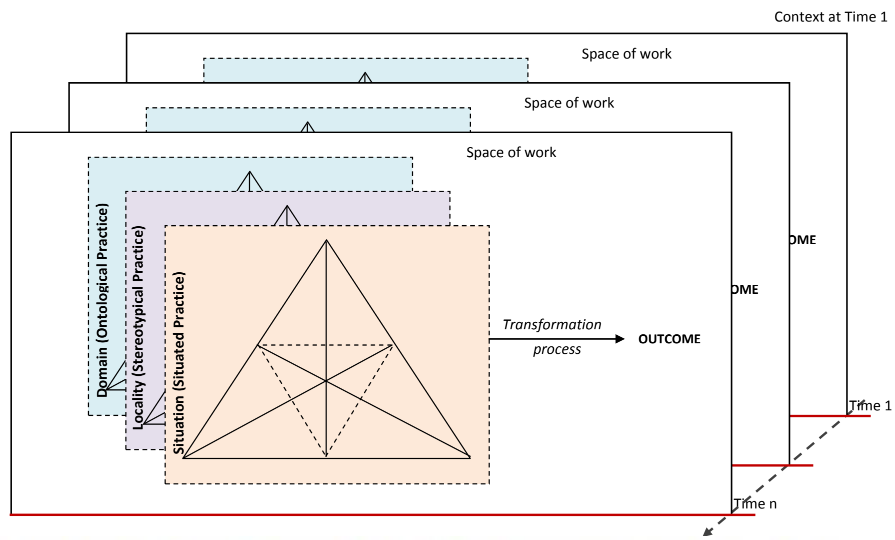

Figure 5.12: A work practice model showing a more detailed model of work context (Adapted from Kaenampornpan and O'Neill, 2005)

To further illustrate the capability of a work practice model in highlighting the cultural-historical dimension of context of work as well as the evolving meanings derived from the history of work and mediating artefacts in a work environment, we situated our proposed work practice model within the framework of the extended activity system proposed by (Kaenampornpan and O'Neil, 2005) – see Figure 5.12. As shown in the figure, within each space of work, captured by work context at time t, our approach further provides designers of DSSs with a lens for analysing and conceptualising a work process at three different levels of details – domain, locality and situation. This enables agents to gain a better understanding of user problems for adaptive cross-boundary decision support. Hence, the agents will, as competent social actors (Dourish, 2004, p.25), find the work settings and world views of the user meaningful in relation to the user's peculiar work circumstances and problem requirements

5.5.4 Situation Awareness Modelling

A key goal of the work practice model described above was to extend existing activity system model to take account of a wide range of situation-dependent factors, which has been shown to influence decision-making in the real-world (see Chapter 4), but lies outside of the scope of factors considered by existing workflow-based approaches. To appropriately model these situation-dependent factors, we employ the use a SAW model. In this section, we describe this SAW model, and how we have integrated it into the work practice model in order to derive the PCA model (as depicted in Figure 5.13). At the core of the SAW model is a situation model – a "setting" consisting of entities and interactions among entities, which one becomes aware of via the SAW model. The notion of a situation model enables us to understand "the complete state of the universe [of work] at an instant of time" (McCarthy and Hayes, 1968) in relation to what influences a clinician's actions and task requirements. We will show in the next section how we have further incorporated context modelling into the PCA model in order to portray the subset of this universe that are considered "contextually relevant" (Dourish, 2004, p. 22) to decision-making at any instant.

We apply the SAW model proposed by Endsley (1995), and briefly discussed in Chapter 3. The primary basis of the SAW model, as we apply it to this work, is to gain an understanding of the sate of a clinical work situation with a view to knowing how information, events, and one's own actions (or those of others) will impact the goals and objectives of providing the best possible care to the patient. Based on his notorious definition of SAW (see Chapter 3), Endsley's SAW model can be categorised into three hierarchical levels: perception of elements in current situation, comprehension of current situation, and projection of future status. At the perception level, the model recognises necessary information about the environment. The comprehension level interprets the perceived information in order to make sense of the current of the environment. The projection level uses the knowledge of the current of the environment to predict its possible future states.

Endsley's model has been applied in areas such as air traffic control, ship navigation and military operations (Endsley et al., 2003), but includes a fundamental assumption that makes it unsuitable to cross-boundary clinical decision support. Endsley assumes that the agent seeking to gain an awareness of a situation and to influence his decision by the elements in the situation is a direct observer of the situation. In cross-boundary e-health, this is not the case; a clinician A wanting to provide suggestion to support the decision-making process of another clinician B who is in a different workplace or even geographical region is not a direct observer of the situation B is in. As a result, we have refined the basic structure of the SAW model by inserting two new levels – conceptualisation and stereotyping between perception and comprehension – and moving projection to the decision support phase. This refined model, which we refer to as PCA model is shown in Figure 5.13, and consists of four phases: *perception of work situation*, *conceptualisation of work domain*, *stereotyping of work locality*, and *comprehension of work status and problem requirements*.

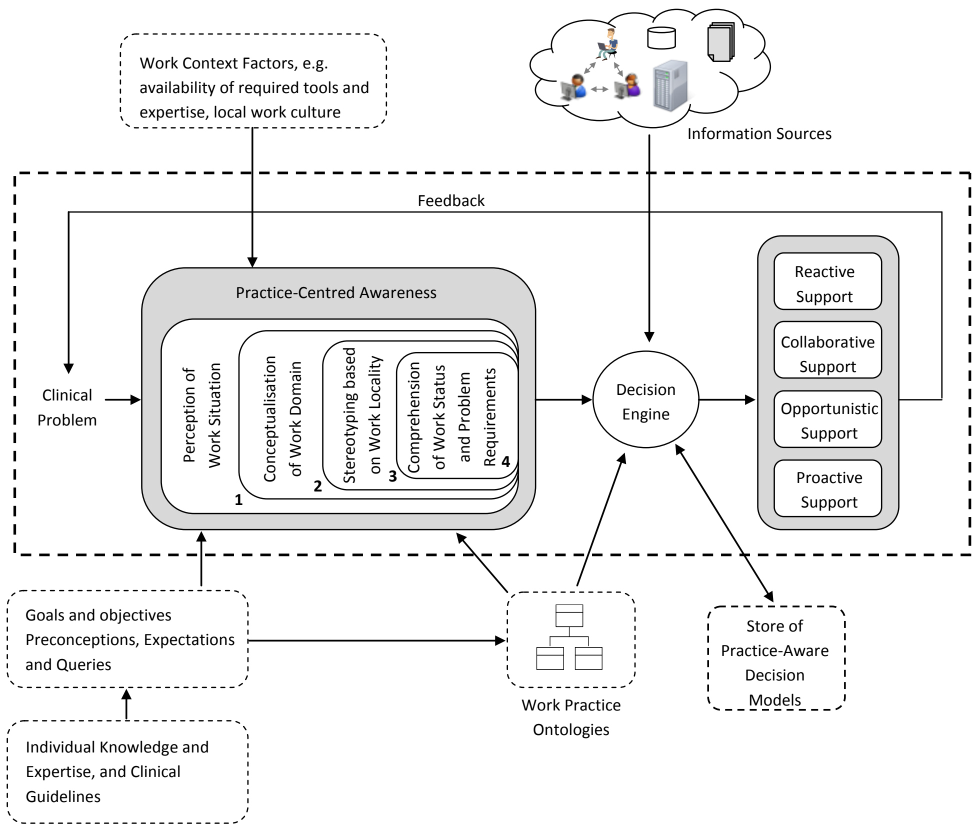

Figure 5.13: Practice-centred awareness model (Adapted from Endsley, 1995)

Related research efforts, such as (Tadda and Salerno, 2010; McGuiness and Foy, 2000), have attempted either to redefine Endsley's concept of SAW or to refine his mode in order to achieve their specific goals. A distinguishing feature of our approach is the attempt to integrate our enhanced model of SAW with an equally refined model of CHT's activity system for more effective and practice-centred cross-boundary awareness and decision support. The four phases in our PCA model have a correlation with Boyd's ubiquitous OODA loop[33] with PCA relating to Observe and Orient, decision-making to Decide, and performance to Act. Our key goal is to aid a non-observer to gain sufficient awareness of a work situation, which they are not involved in, so as to offer appropriate suggestions to "enable decision superiority" (Tadda and Salerno, 2010, p. 17).

The first stage of the PCA model is the perception level, which is the same as Endsley's perception layer, and is responsible for the recognition of all necessary information about a work environment. In the second stage of our PCA model, background knowledge about the domain of work is constructed. At the stereotyping stage, the knowledge acquired during the previous two stages is interpreted in relation to the typical work situations of a place (i.e. organisation, region or area) and time (i.e. period) of work. The comprehension level attempts to make sense of all information in relation to user's work goal in order to generate knowledge for decision support. As shown in Figure 5.13, decision support occurs in four modes – reactive, collaborative, opportunistic or proactive, which will be discussed further in Section 5.9.2.

5.6 Context Model

In this section, we describe the context model that is incorporated into our PCA model. In any work situation, a clinician's choice of action is, to a large extent, shaped by a set of domain, situational and personal factors that combine to scaffold the clinician's cognitive capabilities in solving a given problem. We refer to that set of factors as context. A wide range of issues surrounding the concept of context (Kirsh, 2001; Bettini et al., 2010) remains the single most important factor that must be addressed to achieve a computational representation of work processes at the practice level (see Figure 5.2). This raises a number of questions: How does one set up mechanisms to capture context? How does one recognise what context information is necessary? How can context associated with an activity or a work process be represented?

[33] http://en.wikipedia.org/wiki/OODA_loop

As shown in Chapter 2, different interpretations of context exist and various approaches have been adopted towards modelling context for different purposes (Dourish, 2004; Allert and Richter, 2008; Haake et al., 2009).

In this section, we introduce the context model used in this research work. The model assumes a subjective view on problem-solving situations. In contrast to existing approaches where context is described in a monolithic sense or as an objectively defined situation, we argue that any choice of contextual parameters and their relative weight in describing a situation need to be subject to prevailing practices. Hence, we model context from a pragmatic point of view and introduce a taxonomic structure of context that inherits from traditional models of context (Dey and Abowd, 2000; Dourish, 2004; Kofod-Petersen and Cassens, 2006). The classification is based on our proposed classification of practice (see Section 5), and derives from the definition of context given by (Dey, 2001). For the purpose of this research, we view context as *any information that can be used to characterise the situation in which something exists or happens, and which can help explain it* (Crowley, 2006). This situation is dependent on the knowledge, worldview, practices, settings and circumstances that can be used to construct an "infinite and partially known collection of assumptions" (Porzel, 2011, p. 10) that form the integral problem-solving approaches of an organisation or group of individuals, and which provide, for and within the organisation or group, a schema for generating, sustaining, and applying knowledge. The context model is divided into five main sub-categories, which we discuss as follows:

- **Ontological Context**: The ontological context describes knowledge about the domain of work in relation to the activities and tasks being performed including task goals and context. Ontological context can describe such things as concepts, entities and relationships between them. The idea of treating knowledge as context is not new, and is evident in the works of such authors as (Brezillon and Pomerol, 1999; Kofod-Petersen and Cassens, 2006; Brézillon and Brézillon, 2008; Giunchiglia et al., 2012).
- **Stereotyped Context**: The stereotyped context consists of the spatio-temporal, the socio-cultural and the actor contexts. This type of context is used to capture information about possible problem states as well as concepts and problem-solving patterns associated with the place and time of work and the actor. Examples of

stereotyped context include spatio-temporal context, i.e. the type of context that is concerned with attributes such as time or period, location, organisation, and socio-cultural context, i.e. the type of context that describes the social and cultural aspects of work and problem-solving approaches.

- **Situated Context**: Situated context captures information about the surroundings and environment of work, such as things, services, light, people and information accessed by the people in performing their work activities.

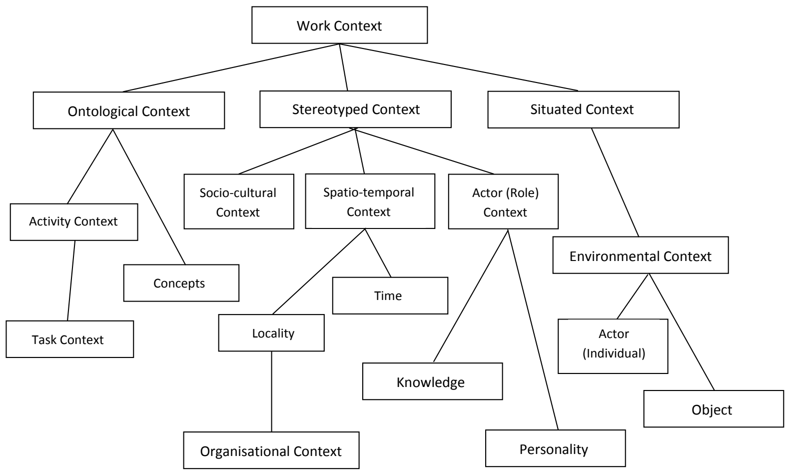

Figure 5.14: Proposed work context model. Note that having time against stereotyped context highlights "stereotyped context" as the characteristic attribute of a place and time, i.e. spatio-temporal. Thus, we view the work practices of an organisation as characteristic of the organisation's problem solving approach by virtue of being located in a specific place and time

The model depicted in Figure 5.14 shows the work context model. The upper-level structure of the model consists of ontological, stereotyped and situated contexts, and is akin to the three major context types in (Sowa, 2000). Sowa notes that in any situation, there exists an actual context representing something that is true; a modal context represents something that is related to what is actual by some modality, such as possibility or necessity; and an intentional context that is related to what is actual by some agent who determines what is intended. In order to enable contextualised reasoning (in CaDHealth), the context model is integrated with general descriptions of the concepts of a given work domain (e.g. diabetes, hospital ward, surgery, shopping mall, online chatting) as well as descriptions of the stereotypes of various places (e.g. Liverpool Hope University's lecture hall) and concepts about different situations (e.g. the task of prescribing antibiotics to sick children in a refugee camp) in a multi-relational semantic structure. The model enables the system to infer relations between concepts and entities by constructing context-dependent paths between them (Kofod-Petersen and Cassens, 2006).

5.7 Practice-Centred Awareness Model

In this section, we introduce a work practice awareness model, which we refer to as *practice-centred awareness* (PCA). PCA combines the notions of work practice, SAW and context models discussed earlier. In essence, a practice-centred awareness of a work process denotes knowledge of the work practice, i.e. the work setting in which the work process unfolds. Hence, we model PCA based primarily on the notion of work practice described in this work, and discuss, once again, the modelling of work practice.

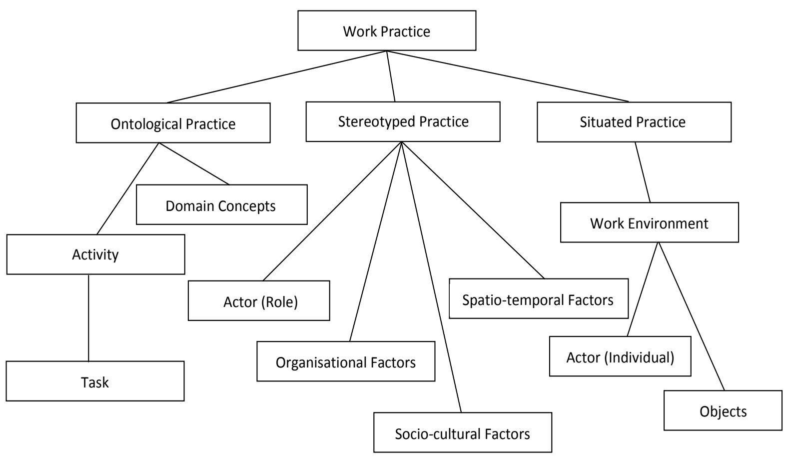

Figure 5.15: Work practice model in CaDHealth

5.7.1 Modelling Work Practice

Following from our notion of work practice (see Section 5.4), we describe work practices as the activities, artefacts and contexts of work in a particular place and time (Rosson and Carroll, 2002, p. 38). We define a hierarchy of terms for making sense of work practice. A *work practice* is organised in terms of a hierarchical structure *activities* and *tasks* holding in a *situation*, and shaped by factors, which we loosely refer to *practices*. *A task consists of entities, actions and roles; a task occurring in a given situation is an activity; and an activity shaped by a given context (e.g. policies and a patient's family circumstances) is a case.* We, therefore, model a specific case[34] as a *work practice,* whereby a work setting refers to a specific manifestation of a work situation. The notion of a *work practice* "naturally" lends

[34] Our approach conforms with the standard dictionary definition of a case as "the actual state of things" – see http://dictionary.reference.com/browse/case?s=t

credence to the fact that different activities or situations require different forms of practices (patterns of working) based on context or setting. Moreover, it would help provide answers to such questions as how would one handle a case? It is common knowledge that people in real life tend to handle cases based on the circumstances of a work setting. Hence, a key question becomes how can we construct a model for understanding a real-world problem-solving situation based on the notion of a work setting?

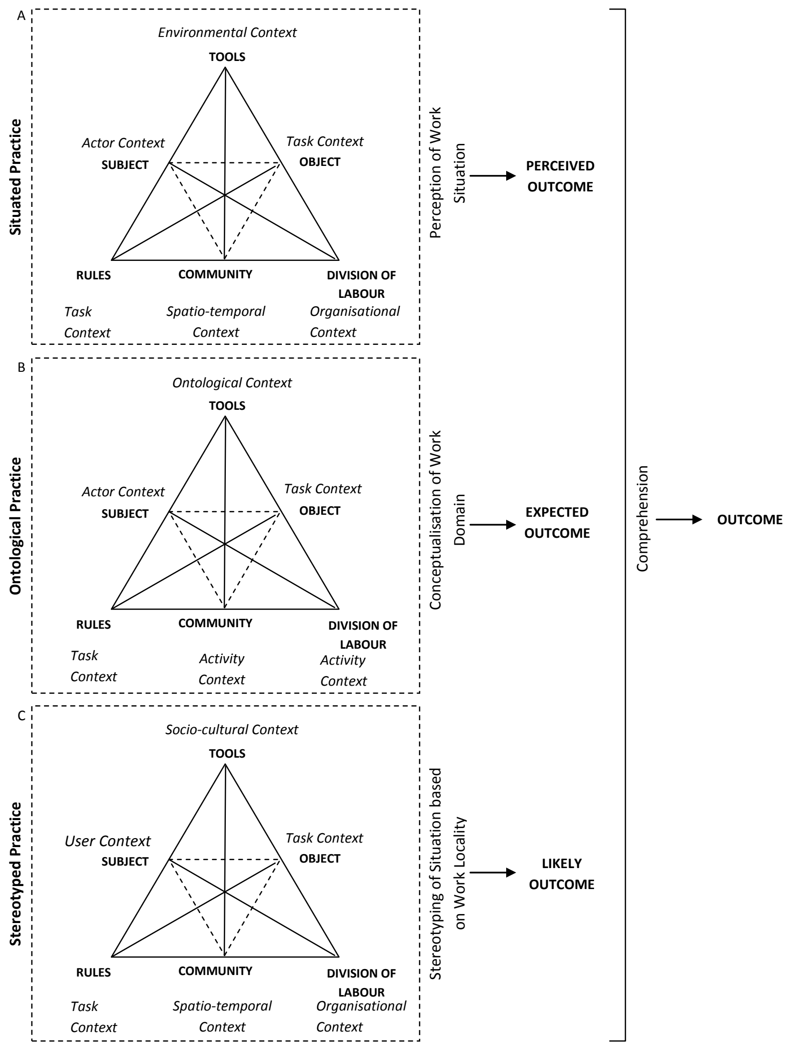

Figure 5.16: Mapping of CHT to context and situation awareness models

To address these questions, we first generate a work practice model (see Figure 5.15) out of our proposed work context model by replacing the core nodes of the context model. The work practice model consists of three major levels of practices, namely ontological, stereotyped and situated practices. As noted earlier, the three levels provide three distinct, but interrelated, views of the ecology of a work setting by distinguishing concepts and forms of interactions that occur respectively as a result of domain-specific rules or the stereotypes of a place or the prevailing circumstances of a situation. In this work, we view a situation as "a person's world view of a collection of activities" (Tadda and Salerno, 2010, p. 21), which forms "a local model that accounts for a precise goal" (Brézillon and Brézillon, 2008) in the work process, and which a clinician from outside of "the locale" (Fitzpatrick, 1998), i.e. from across boundaries, seeks to become aware of at any given instance in time. The goal of this awareness, as has been noted throughout this thesis, is to provide information to adaptively aid decision-making in the locale. In spite of the anomaly and fuzziness of activities in the real-world, human actions in organisations tend to follow certain scripts, heuristics and rules of thumb (Gabbay and le May, 2011, p. 56). We propose that whereas an ontological structure provides the domain knowledge that forms the foundation for conceptualising a work situation, a "stereotyped social script" (Crowley, 2006) can be used to orient observations and proactively guide the behaviour of services, and situated practices can be used to handle "situated actions" (Suchman, 1987) emerging out of prevailing circumstances of work.

Secondly, the concepts and entities in a work setting are gathered through the use of practice theoretic analysis (see Chapter 3), and modelled at three distinct levels of details and emergence. Thus, the PCA model is used to address several key assumptions of the CHT: 1) work processes are contextualised, 2) decomposing activities to actions, e.g. by moving bottom-up from practice to task levels in Figure 5.2, leads to loss of information, 3) activity systems cannot be reduced to chains of actions; in other words, the relationship between individual interactions in an activity system is not additive, 4) the elements of a practice system generate each other in a similar way to an ecological system, and 5) practice systems are meaning processing systems that derive their interpretative power from historically-developed and socially-mediated traditions of actions and beliefs of a work community (Allert and Richter, 2008; Chaiklin, 2011).

The assumptions resonates with the following suggestions of the pragmatic approach to context modelling: 1) context, most often, is not explicitly identifiable, 2) there are no sharp boundaries among contexts, 3) the logical aspects of thinking cannot be isolated from material considerations, and 4) behaviour and context are jointly recognisable (Ekbia and Maguitman, 2001, p. 5; Kofod-Petersen and Cassens, 2006). This view of pragmatism on work context underscores the relevance of a practice-centred approach in explicating interactions in real-world work settings based on the three-level approach proposed in this work. Figure 5.16 illustrates a mapping of CHT to context and SAW models. The integrated model covers the fact that human work is carried out in a social and cultural context (Kuutti, 1996; Mwanza, 2000; Kaenampornpan and O'Neil, 2005; Kofod-Petersen and Cassens, 2006; Allert and Richter, 2008; Feng et al., 2009), and include a structure of entities and interaction patterns that is defined by knowledge domain, evolved in the course of using the structure in problem-solving in a given locality or organisation and, at any instance of use, shaped by the circumstances of the given situation.

5.7.2 Practice-Centred Awareness Reference Model

We describe the reference model of our proposed PCA approach (Figure 5.17). The goal of the reference model is to demonstrate how the various models discussed in the previous sections – the work practice model, the extended version of Endsley's SAW and the proposed context model – could provide a unified and coherent framework of PCA for cross-boundary decision support. Hence, the reference model is built by combining the refined model of the CHT's activity system with the extended version of Endsley's SAW. In addition, we have incorporated into it a context mechanism for reasoning with contextualised knowledge so as to enable cross-boundary decision support. We provide definitions of various components of this model, and show how it acts as an abstract framework for understanding the significant aspects of a work setting.

The first step in the reference model is to *acquire* work context parameters associated to a work setting. This denotes the **Level 0** of the reference model. Research in context-aware computing generally classifies context parameters into a number of categories including location, time, identity and activity. In this research work, we argue for three broad categorisations of context, namely ontological, stereotyped and situated context. In this level, the category of context acquired includes the situated context. A computer system may acquire context parameters from simple activities or using a combination of physical and virtual devices – sensors, actuators, location-tracking services, RFIDs and software agents, including user interfaces (e.g. forms), persistent databases and cameras. In our proposed approach, context is acquired dynamically at run time. Information acquired is then sent to the context management subsystem, which transforms it into a format (e.g. using a special form of context cues, which we refer to as *practice cues*) that the *processing* subsystem (Level 1) can perceive (i.e. make sense of). Context management involves the definition of context parameters within a given work setting in order to allow for the specification of information about contexts of work and enable efficient use of the information by different context-aware systems. Hence, context management assists in the acquisition, manipulation and maintenance of a shared repository of work context information.

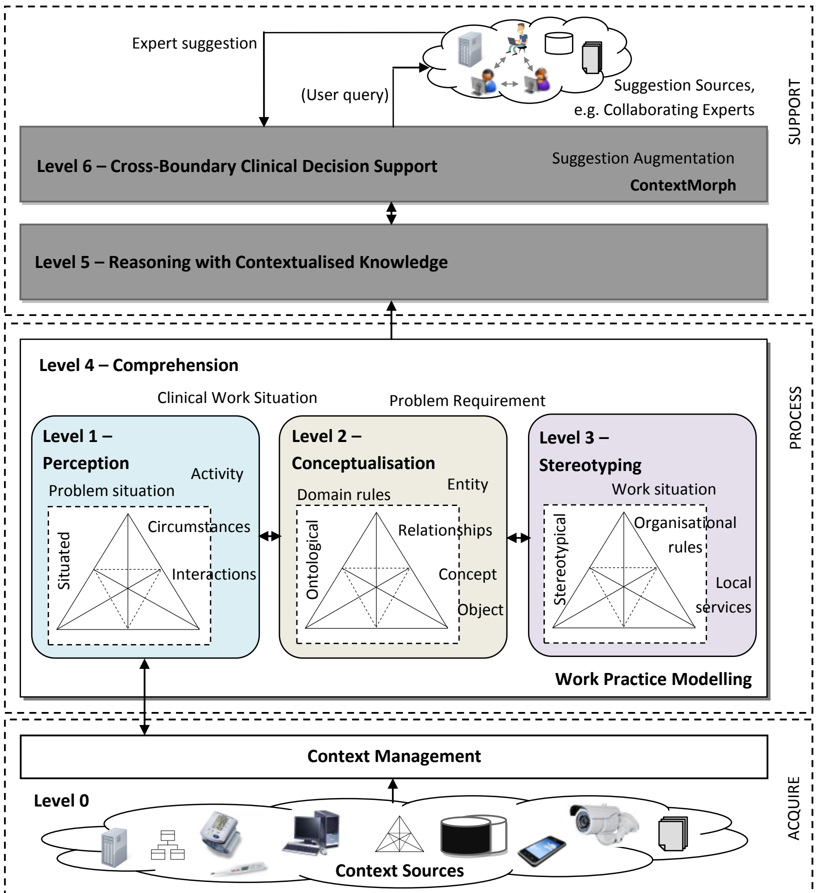

Figure 5.17: Practice-centred awareness reference model

Level 1 – Perception

The second step in achieving PCA involves the recognition of status, attributes and dynamics of relevant elements in the work environment. Endsley used the example of air traffic control, and noted that a pilot needs to perceive other aircraft, the terrain and weather information, and system status including airspeed, altitude, route position and direction of flight (Endsley and Garland, 2000). Within a healthcare work setting, a clinician needs to perceive information such as the presence and expertise of available healthcare staff, hospital protocols and guidelines, safe clinical practices, available and recommended drugs, patient's information including vital signs, medical history, relevant personal history and changes in medical conditions. These elements are modelled as entities in the work environment. An entity represents any element (or object) in a work setting, which have attributes (e.g. identity, role, capability, expertise, etc.). Entities relate with each other and with their environment via actions and interactions. A situation arises out of a related set of actions and interactions aimed to achieve a specific goal. A situation class (as will be illustrated in the next chapter) is a data structure that encapsulates all the relevant information about entities, their roles and goal-directed interactions in a given work setting. This layer recognises actual information from the work environment and from the user, using cues from the context management subsystem, and then structures the information into a coherent form.

Level 2 – Conceptualisation

The main goal of the conceptualisation phase (Level 2) is to generate a general knowledge base of domain-specific concepts and rules required to aid problem-solving in any work setting. The idea is to create a common pool of background knowledge that is used to assist clinicians across work boundaries in understanding what the other means. In CaDHealth, conceptualisation is a static phase. During the process, the system generates domain-specific descriptions of generic work process independent of any particular work setting, which are stored as work practice models in the system database. At this stage, the work practice models represent problem domain models. First, scenario-based analysis (Carroll et al., 1998; Rosson and Carroll, 2002 is used to produce domain-sensitive generic models of work descriptions represented in three chunks of analysis: problem scenarios, problem diagnosis and action planning. In problem scenarios, the requirements of a domain task are specified as a set of sentences that convey user goals. In problem diagnosis, the sentences are reduced to a network of propositions. The propositions are iteratively analysed, based on a systematic probing method involving a set of what, why and how questions, to generate activity models, objects, responsibilities, interaction models, methods, information models, and class structure. During action planning, the final sets of propositions are used to elaborate the scenario to decide more appropriate requirements of user goals. Secondly, the set of propositions from the scenarios are analysed and synthesised into their component elemental classes called facets[35]. Facets can be construed as perspectives, viewpoints, or dimensions of a particular domain. A faceted scheme provides a controlled vocabulary in the form of terms arranged systematically by facets and a set of rules on how to combine such terms to define conceptual descriptors, i.e. categories, of the work process.

The knowledge acquired during this stage is used in Level 4 to enable the system to address such problems as ambiguity and under-specification (Porzel, 2011, p. 3) of perceived objects and stereotyped interactions in a work environment, and to reconcile any differences in work practices in relation to overall work goal. For example, when a clinician has to "deal with anomalous situations" (Gabbay and le May, 2011, p. 62) or when their actions and work practices come into tension with situational, individual and organisational factors of work (Igira, 2008, p. 116).

Level 3 – Stereotyping

In Level 1, the system perceives information about a work environment based on recognition of relevant elements in the environment; in Level 2, the system generates generic formal conceptualisations about work situations within a domain of work. In this level, the system categorises a situation as one of a kind based on common sense knowledge about a set of possible states of affairs or prior descriptions of situations of that kind. For example, someone sends you an email describing himself as a medical doctor working in Sudan and requesting second opinion with regard to managing one of his paediatric patients with increasing diarrhea. You will assume that the child is malnourished, lives in a refugee camp, highly underweight, unkempt and an orphan. However, the child may have been well-fed, lives in the city, and is only suffering from food poisoning after a visit to the village. Though the use of the stereotype of an under-fed child may be a mistake, it provides a possible starting point for reasoning about the problem and enables efficient communication with the doctor in Sudan. Stereotypes describe a work situation based on typical characteristics of the users, an archetypal setting of their engagement in a task, the mainsteam tools they use and their representative organisational context. In CaDHealth, we model stereotyped reasoning

[35] This step is based on the faceted approach proposed by the Indian librarian S. R. Ranganathan in which the domain under examination is decomposed into its basic constituent parts called facets, each of them denoting a different aspect of meaning, usage scenario or perspective on the knowledge.

(Lehmann, 1997) by some logical distance between the perceived information (in Level 1) and the stereotype. As a starting point, we choose the best stereotype to fit the situation on hand – this is akin to what Rosch, cited by (Lehmann, 1997) calls a prototypical category – and use both the stereotype and the perceived information to draw conclusions.

Level 4 – Comprehension

At the comprehension level, the information perceived from the actual work environment, conceptual descriptions of the domain of work and the stereotypes are integrated to form a holistic picture of the environment, including problem requirements and patient's needs. This involves synthesizing new knowledge by understanding and reconciling the three major information sources: cues from the work environment, domain-based conceptual descriptions and the stereotypes. One way of achieving this is to query the significance of each item of information in relation to user goals and problem requirements. The comprehension layer is the same as Endsley's comprehension level; since the purpose of our model of awareness is to enable decision support, Endsley's projection level is replaced with the reasoning and decision support modules in the PCA model.

5.7.3 Practice-Centred Awareness Process Model

In this section, we expand on the preceding discussion, and analyse the PCA model as a process in an instance of time rather than just layers in a reference model. Observable data from a user's operations and work setting constitute the input to the process that provides a view of what is going in the world (i.e. primitive elements of the work environment). See Figure 5.18. The perception layer interacts with *practice cues*[36] in the context management subsystem to cleanse and normalise any attributes associated with the input data and transform into a form that can be used by processes in the PCA model. The observable data we are interested in, in this work, are prompts (information) about the work practices of a clinician as well as their work goals, queries, problem requirements, patient conditions and any logistics (e.g. institutional policies and regional agenda, available tools and services, organisational beliefs and values, and expectations and constraints) that can possibly

[36] Practice cues are prompts that provide signals as to what sort of behaviours, practices, artefacts, patterns, objects and interactions are to be perceived in a non co-located work setting. They are based on activity and work practice models, work goals and user queries, and can be stored and manipulated in a number of formats, including graphs, Bayesian networks, knowledge models, etc.

influence clinical decisions. The use of practice cues allows for non co-located perception. In cross-boundary e-health, individuals seeking to gain awareness of a user's work setting do not have visual cues about what is going on in the environment (Bardram and Hansen, 2010; Tadda and Salerno, 2010). As a result, having to rely on the mediation of social artefacts and work practices may lead to cognitive overload. The use of practice cues helps reduce an individual’s cognitive load by ensuring that only relevant work context information is perceived.

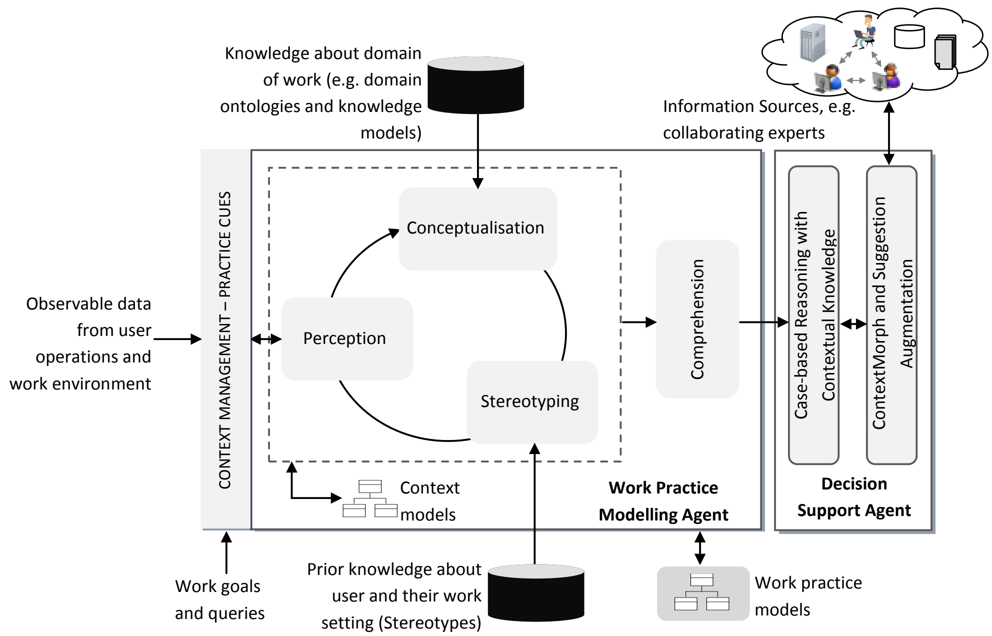

Figure 5.18: Practice-centred awareness process model (Arrow lines represent information and process flow)

Conceptualisation and stereotyping are performed statically at design time. At run-time, observable data are perceived and dynamically entered into the perception-conceptualisation-stereotyping cycle. As they are entered, they classified into *process-based data* and *practice-based data*. Process-based include explicit information, working patterns and knowledge that are largely codified in rules, tools, technologies and processes. Practice-based data are mostly unarticulated knowledge and tacit information and working patterns that are not easily captured or codified (Nonaka and Takeuchi, 1995; Leidner et al., 2006). The use of process-based data in problem-solving is mainly justified by the ontological activity system, whereas the central basis of the use of practice-based data is found in the situated activity system. The stereotyped activity system could provide a basis for process-based data (e.g. organisational guideline) and practice-based data (e.g. organiational values and informal protocols). Broadly speaking, practice-based data often act as “influencers” (Beyer and Holtzblatt, 1994) to enable or constrain the application of process-based data. A key argument of this work is that process-based data, which include only prescribed procedures for doing work do not often match what happens in the real-world, which are mainly practice-based (see also Chapter 4) and, as a result, DSS design approaches need to incorporate the later. Table 5.2 shows the key differences between process- and practice-based data.

Table 5.2: Process-data vs. practice-based data in decision support (Adapted from Leidner et al., 2006, p. 20)

Element	**Process-based Data**	**Practice-based Data**
Role	Handle task execution	Mainly act to influence task execution based on prevailing circumstances of work
Nature of data	Formal work specifications, domain rules and conceptual knowledge	Informal specifications, common sense knowledge, world views, local norms, organisational values and beliefs, power structures, rituals, stories and myths
	Rigid and generic, i.e. independent of work settings	Flexible and easily adapts to changes in local work settings, e.g. availability of tools and services
Type of knowledge	Explicit knowledge – codified in rules, tools and processes	Mostly tacit knowledge – unarticulated knowledge not easily captured or codified
Context/Model Type	Mostly ontological context and domain model, and stereotyped context	Mostly situated context and situation model, and often stereotyped context
Means of transmission	Formal controls, procedures, and standard operating procedures with heavy emphasis on information technologies to support knowledge creation, codification, transfer and decision support	Informal social groups that engage in storytelling and improvisation
Affecting factors	Factors within internal work processes, e.g. task methods	External factors, such as economic status, government policies and regional agenda
Means of enabling awareness	Through formal processes	Through the extent of influence on work processes in order to enable or constrain them
Means of mediation	Rules, tools, roles, subjects and objects	tools, roles, subjects and objects, community, history, and social and cultural practices
Paradigm	Rationalistic thinking, task structures, workflow-based technologies	Activity, cultural-historical and social theories
Practice system category	Ontological, stereotyped	Situated, stereotyped
Benefits	Provides structure to harness generated ideas and knowledge	Provides an environment to generate and share high value tacit knowledge for decision support
	Achieves scale in knowledge reuse	Provides spark for fresh ideas and responsiveness to changing environment
Disadvantages	Fails to tap into tacit knowledge. May limit innovation and forces participants	Can result in inefficiency. Abundance of ideas

	into fixed patterns of thinking	with no structure to implement them.
Role of Information Technology	Heavy investment in IT to connect people with reusable codified knowledge	Moderate investment in IT to facilitate conversations and transfer of tacit knowledge and "influencers" for more adaptive cross-boundary decision support

During the perception-conceptualisation-stereotyping cycle, the conceptual descriptions are retrieved from a store of domain models, which could be a database system, knowledge about the domain of work. Domain knowledge forms the general backdrop upon which perceived data can be substantiated. The stereotyping component retrieves into the cycle stereotypes about the user and their work setting, e.g. GPS coordinates, local times, weather information, disease demographics, organisational values and beliefs, and regional policies. As soon as no new data are being perceived, the information gathered is fused together in the comprehension component into a knowledge structure that forms a holistic picture of the user's work setting with a view to addressing user queries and achieving work goals. This picture represents a *work practice instance* – a clinical problem or case embedded with work practice information, i.e. information about how the problem or case is actually solved in a given *work practice* (see Chapter 6). This is then fed as a new case into the case-based reasoning component of the decision support agent. Newly generated parameters are used, at appropriate times in the cycle (e.g. when there is a significant change in the knowledge structure), to update context and work practice models (as shown by the double arrow lines).

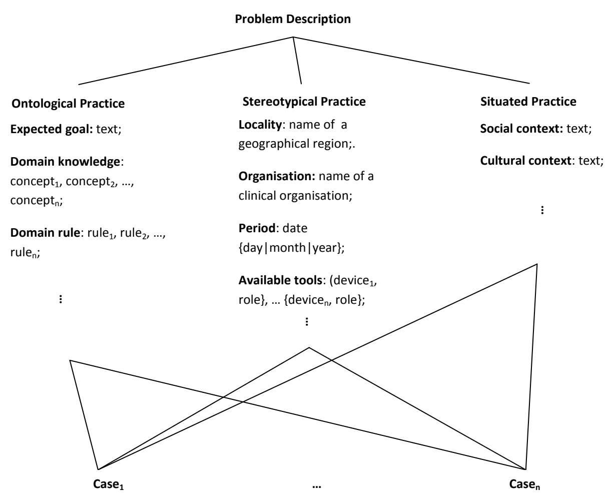

Figure 5.19: Case generation in CaDHealth

Figure 5.19 shows a representation of case generation using the PCA model. A problem description is decomposed into ontological, stereotyped and situated practices, which encapsulated the domain, contextual and situational information that describe a work context. For example in CaDHealth, a case model includes the activity being performed, the locality and time of work, the tools available for performing the activity, and a description of the socio-cultural context of work. As a result, a case, in CaDHealth includes features and their specific values that occurred in a particular situation as well as geographical information that help map a case to a point in a spatio-temporal space.

5.8 Cross-Boundary Awareness

Inherent in the notion of cross-boundary clinical decision support, which this research seeks to design technological support for at the work practice level, is the idea of cross-boundary communication and sensemaking (Weick, 1995). We assume that effective cross-boundary decision support pre-supposes effective awareness of work contexts across boundaries. CHT's activity system is deeply contextual and oriented at understanding historically developed practices, the role of mediating artifacts and the social organisation of a work setting (Foot, 2001). In this sense, work practices constitute the foundation upon which our interactions with technologies and artefacts unfold in the real-world.

In constructing a model of cross-boundary awareness of real-world work contexts, we derive from CHT's zone of proximal development in order to illustrate the part of a task that can be solved using the tools, technologies and social practices of a work setting. We refer to this new construction as the *zone of actual practice* (ZAP). We define ZAP (Vygotsky, 1978; Shabani et al., 2010) as *the difference between what an individual, a workgroup or an organisation can do using the formal specifications of a work process and what they cannot do using the actual resources and capacities currently available in their work setting*. This difference is shown as B in Figure 5.20; note that ZAP includes formal processes as well. ZAP is an adaptation of Vygotsky's concept of the zone of proximal development (1978), which was proposed in the context of child learning (Shabani et al., 2010) to denote the mental region within which a child can execute a task independently and with appropriate assistance (e.g. scaffolding).

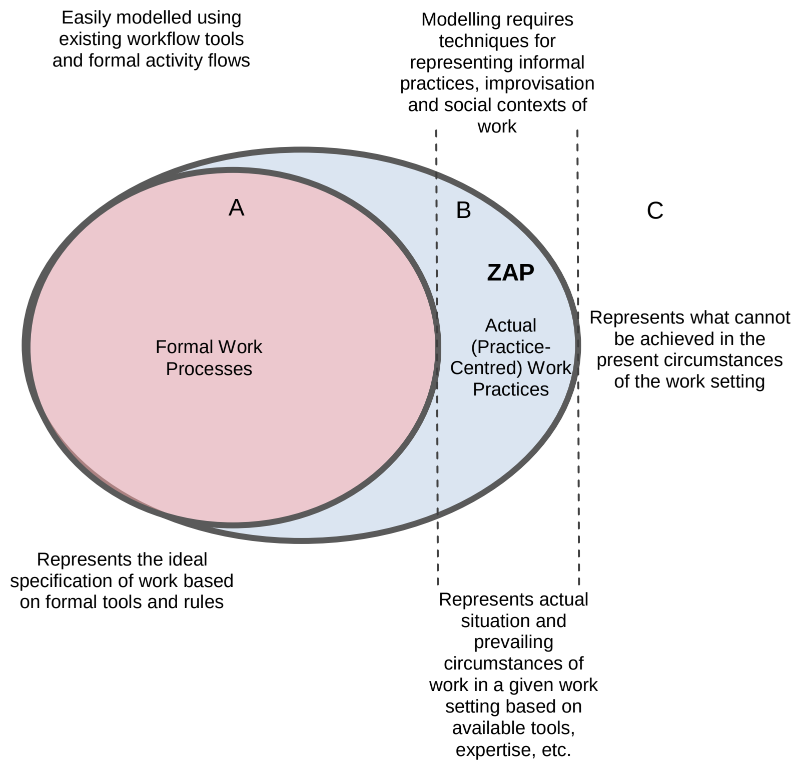

Figure 5.20: Zone of actual practice (ZAP)

Assume that a clinician is required to perform a certain task, t with expected output, p in their work setting, w. ZAP asserts that there is a part of t that can be achieved in w using formal work processes, and yet a part that can be achieved based on the current work practices at w, i.e. using the tools, services and technologies at w. According to ZAP (as shown in Figure 5.20), C designates that part of t that cannot be performed under the current work practices in w. By providing a means for analysing a work setting based on what can be achieved in the work setting following formal work procedures, and what can be achieved based on the current work practices in the work setting, ZAP enables a deep-seated understanding of the real-world contexts of work for cross-boundary awareness. In cross-boundary decision support, ZAP can be used to determine if the resources and practice structure currently available in a hospital is suitable to a particular case, and what degree of suggestion (e.g. in terms of information content) offered from across an individual's work setting is required for more effective solution to the task, t., and any required form of integration. The concept of ZAP is related to the idea of scaffolding in Vygotsky's zone of proximal development for achievement of higher mental functions (Chaiklin and Lave, 1996; Shabani et al., 2010) ZAP does not imply that formal procedures and work practices are differently used, but rather that the use of formal procedures in any work setting is shaped by the norms and practices of the work setting and the resources available for executing a task. As a result, ZAP denotes the focus of awareness in cross-boundary decision support. Figure 5.18 depicts cross-boundary awareness in CaDHealth; the PCA model and the domain of work (the ontological context) provide common references for cross-boundary awareness.

5.9 Context-Aware Cross-Boundary Clinical Decision Support

The primary role of the decision support agent[37] (see Figure 5.21) is to enable context-aware cross-boundary clinical decision support in e-health based on a work practice level representation of a clinical work process. By cross-boundary clinical decision support, we mean the process by which a clinician (the user) seeks information from another clinician (or a software entity) from across the boundaries of their work organisation or region in order to support their decision-making in a manner that adapts to the user's local context of work and patient's specific needs. In CaDHealth, cross-boundary decision support is achieved using the case-based reasoning (CBR) methodology and a novel technique for fusing context information, which we refer to as ContextMorph.

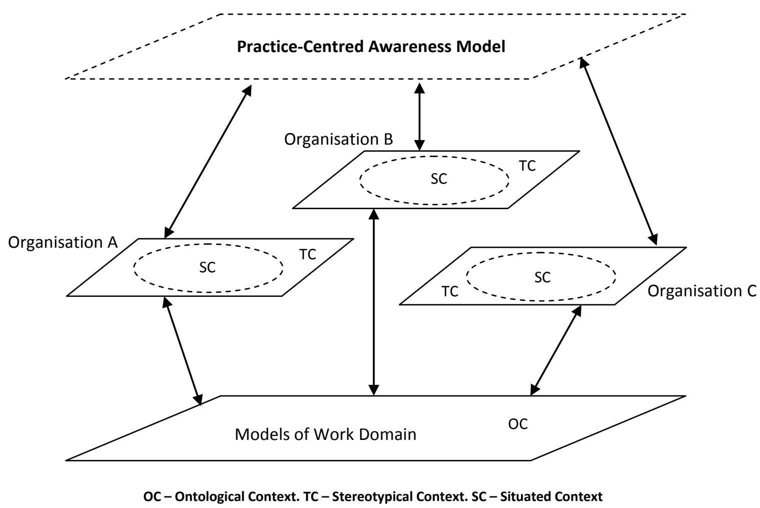

Figure 5.21: Cross-boundary awareness in CaDHealth

[37] We use the term agent in a general sense to denote an individual or entity in a distributed or cross-boundary decision support system, and not in the special sense of an "intelligent" agent in AI.

A major concern in cross-boundary e-health is to support clinicians working localities with limited medical facilities and expertise to access "second opinion" suggestions from experts across their work boundaries in order to further minimise errors (IOM, 2000) arising from such factors as low vigilance or impaired cognitive capacities (Pott et al., 2005; Nwiabu et al., 2011). In such scenarios, enabling the suggestion provider to maintain awareness of the clinician's work setting and patient's medical state beyond a formal work process is crucial to ensure the suitability of the suggestion provided. In this research, we have argued that a clinician's work context and decision-making situation in the real-world are grossly affected by work practice-related factors that are well outside of those currently addressed by guidelines specifications and workflow-based approaches (Rosson and Carroll, 2002; Gabbay and le May, 2011). In what follows, we discuss the unique challenges posed by this type of decision support from the perspectives of PCA, and describe our use of CBR and the technique of ContextMorph in cross-boundary decision support.

5.9.1 Challenge of Cross-Boundary Clinical Decision Support

There are a numerous challenges associated with the goal of cross-boundary decision support. With regard to the questions we seek to address in this research work, two of those challenges stand prominently; they include the problem of enabling context-aware knowledge sharing across boundaries of work settings, and the challenge of adaptive decision support.

Contextual Knowledge Sharing across Work Boundaries

One of the central concerns in cross-boundary e-health is to enable knowledge embedded within one community (e.g. a hospital, a clinical research unit or a CoP) to be optimally used by clinicians in a different community, region or geography in a manner that adapts to the users' work context and patients' needs. Studies such as (Oborn et al., 2010) show that our understanding of the processes of knowledge construction, particularly across regional and workplace boundaries, and most of what is known about cross-boundary decision support come from organisational knowledge management studies of collaboration between multiple work sites of a single organisation, including multi-national companies (Lagerstrom and Andersson, 2003) and multidisciplinary teams in hospital work situations (Mejia et al., 2007). As has been argued in this thesis (see Figure 5.22), this challenge is further heightened by the fact that clinical practices differ across organisational and regional work settings depending on local work contexts, institutional policies and prevailing circumstances.

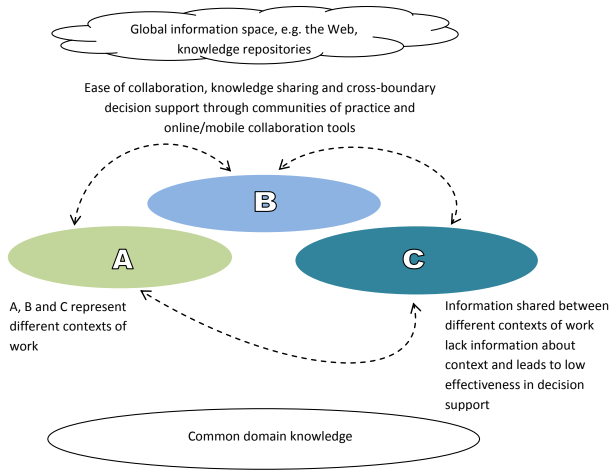

Figure 5.22: The challenge of contextual knowledge sharing; the dotted lines indicate cross-boundary decision support

Adaptive Decision Support

The use of information technology to enable cross-boundary clinical decision support in e-health is currently impractical because there is always a huge gap, which differs across work settings, between how work is planned to occur and how it actually unfolds amidst the complexities of real life situations. The former is driven by theories, principles and formal procedures; whereas, the latter draws from local work practices and informal reactions to contingencies (see Figure 5.23), and relates to ZAP in Figure 5.20. As has been noted previously, the reality of real-world clinical practice is that it involves the consideration of "off-task activities" (Clancey, 2002) that fall well outside guideline specifications (Gabbay and le May, 2011, p. 38). This is, for example, akin to what (Crowley, 2006) termed the "problem of disruption", and does have implications for cross-boundary clinical decision support. Over the years, approaches that seek to extend formal workflow-based models, for example, by incorporating aspects of social and cultural contexts of work, have, as a result, been proposed in the literature (Goldkuhl and Röstlinger, 2006; Allert and Richter, 2008; Aiyedun, 2007; Feng et al., 2009). A central argument of this research is that approaches for modelling human work processes should take on board the concept of work practice, which we believe has a potential for taking account of off-task work processes and for addressing the problem of disruption (Brézillon, 2007).

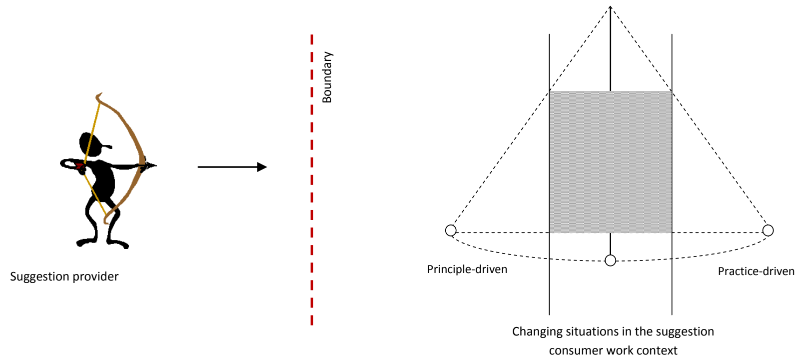

Figure 5.23: The challenge of adaptive decision support

5.9.2 Taxonomy of Modes of Clinical Decision Support in e-Health

We propose a taxonomy of modes of CDS in e-health. The taxonomy describes the various ways by which clinicians seek information from across the boundaries of their workgroups, organisations and regions in order to support decision making, and is largely informed by the findings of the user-centred study in Chapter 4. The study, for example, indicates that clinicians in different work settings are often bonded by a common motive, e.g. patient-centred care and by common professional language and structure of work exemplified by the use of such tools as best practice guidelines. Since this investigation is grounded in concepts from CHT, SAW and distributed cognition, the taxonomy is equally shaped by principles from these theories. The four modes include *reactive*, *discourse*, *opportunistic* and *proactive*, and are discussed in the context of CaDHealth. The motivation in presenting the taxonomy is to allow for the design of effective computer support based on a deeper and broader understanding of forms of social knowledge sharing (Hasan, 2009), and emergent practices (Kurtz and Snowden, 2003) in organisations.

Reactive Mode

The reactive mode (Figure 5.24) is a query-response mode in which the system retrieves information from its knowledge store in response to a clinical query. Often, the information retrieved is enriched, i.e. *augmented and morphed* (Anya et al., 2010), to better suit the user's work context and to adaptively support decision making. The reactive decision support mode is user-driven, bidirectional (user-machine) and synchronous. One example of this mode of support, as observed in the study in Chapter 4, was the tendency of clinicians to seek information from online medical portals. A problem observed with this mode of support is that such portals lack the capability to return context-aware information since they assume a generic knowledge of user context.

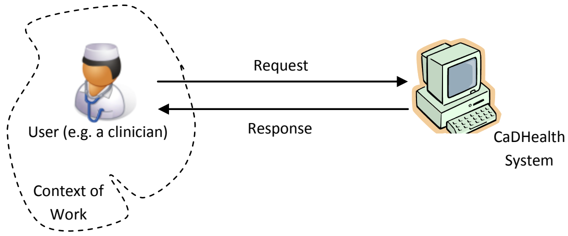

Figure 5.24: The reactive mode

Discourse Mode

The discourse mode (Figure 5.25) is a *collaborative mode* in which the system is used as a context-aware platform to engage a group of clinicians working across boundaries in a "discourse" on a clinical case. The discourse mode involves multidirectional (i.e. man-man and man-machine) interactions. It is user-driven, and involves both synchronous and asynchronous forms of collaboration as well as the ability to resolve conflicts of opinion among the group based on user context. An example of discourse mode of decision support is an online discussion of physicians in different hospitals and regions about the most effective and efficient therapy to a certain diabetic patient.

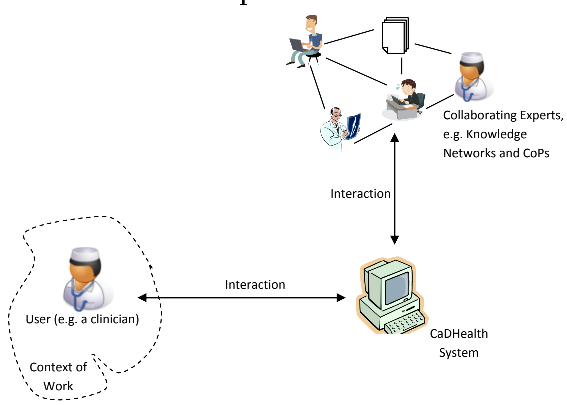

Figure 5.25: The discourse mode

Proactive Mode

This is a proactive and event-driven mode (Figure 5.26) of decision support, in which the system detects changes in its environment of use, e.g. in a patient's condition, and sends information rich content to alert a clinician for actions/decisions. Proactive decision support is multidirectional (i.e. man-man and man-machine), and involves both synchronous and asynchronous forms of collaboration. An example include a monitor attached to a patient sends an alert to his physician about changes in his medical condition, e.g. blood pressure.

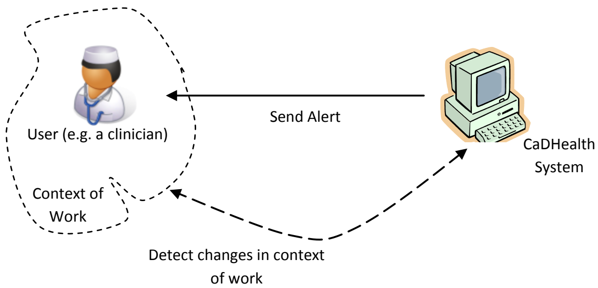

Figure 5.26: The proactive mode

Opportunistic Mode

The opportunisitc mode (Figure 5.27) is an event-driven model of decision support in which the system, based on its knowledge user's context of work, takes advantage of discussions among experts on communities of practice and social networks and retrieves information to suit a user's problem requirements. On the Web today, there exist large numbers of what (Gantt and Nardi, 1992) call "gardeners and gurus" – people who have particular technical and professional expertise and who are willing to share it with others. In opportunisitic decision support, the system basically acts a context-aware web crawler that gathers information from such network of experts, which is then sent as as rich content to alert a clinician for actions/decisions. Opportunisitc decision support is event-driven, multidirectional (i.e. man-man and man-machine), and involves mostly asynchronous form of interaction.

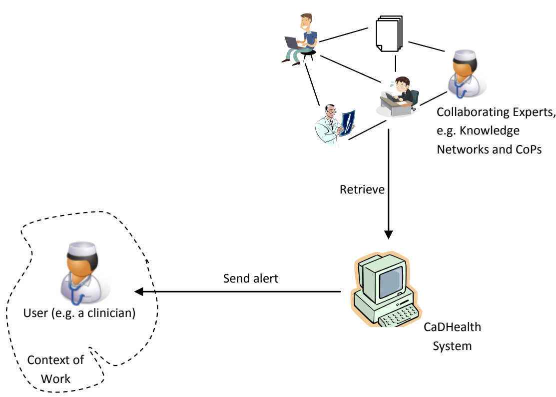

Figure 5.27: The opportunistic mode

5.10 Reasoning with Contextualised Knowledge

In this section, we describe the reasoning mechanism in CaDHealth, which uses the CBR methodology (see Figure 5.28). A key assumption of CBR is that, in real-world problem-solving, people understand new experiences in terms on past ones (Riesbeck and Schank, 1989, p. 25), which, according to (Kofod-Petersen and Aamodt, 2009), naturally lends the methodology to problems of reasoning about context and situations. The use of context to guide CBR has offered a new and powerful way of enclosing contexts with cases (Kofod-Petersen and Aamodt, 2009) and embedding cases in general domain models (Aamodt, 2004) in order to enhance the possibilities to simulate user behaviour and generate appropriate recommendations (Zimmermann and Augustin, 2003), enable intelligent situation awareness and decision support (Feng et al., 2009; Nwiabu et al., 2011), and facilitate knowledge-intensive reasoning in socio-technical systems (Öztürk and Aamodt, 1998; Aamodt, 2004; Kofod-Petersen and Aamodt, 2009).

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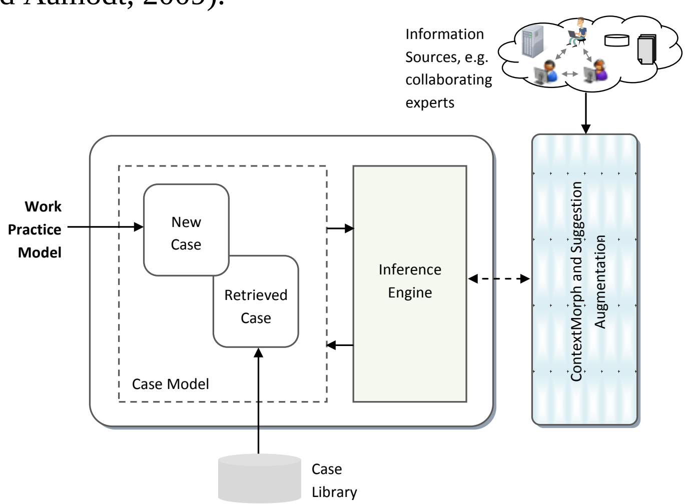

Figure 5.28: Context-aware case-based reasoning in CaDHealth

In applying CBR in this work, we are guided by a number of concerns that have, over the years, shaped research methodologies in CBR. Hence, in what follows, we will seek to provide answers to the following questions: How are the cases structured? How is the retrieval mechanism of the cases defined, and what are the selection strategies for finding similar cases? How are selected cases revised, enriched and adapted to suit the requirements of a new case? And finally, how are suggested cases stored in the case library? In addressing these concerns, researchers have variously sought to adapt the classical CBR cycle of retrieve, reuse, revise and retain (Aamodt, 2004). From a work practice-centred perspective, our approach is to author, structure and analyse cases in terms of the ontological, stereotyped and situated attributes describing a work context as the interactive, circumstantially adapted practice of people, set within an organisation's physical, socio-cultural and conceptual context, rather than just a well-defined flow of predefined processes

As noted in earlier, the PCA model generates a work practice model instance as a new case, which then becomes the input to the CBR component. From a practice-centred approach, this input denotes "contextualised pieces of knowledge representing an experience" (Kolodner, 1993, p. 13). In this sense, a case represents particular strategies for carrying out an activity in a given context, the tools for achieving the goals of the activity, and the circumstances and experiences that influence activity performance. In CaDHealth, a case model (see Figure 5.19) includes the activity being performed, the locality and time of work, available tools as well as descriptions of the socio-cultural contexts of work (Rosson and Carroll, 2002, p. 39). In other words, cases in the case model have domain, context and situation features. Past cases are retrieved from the case library, and consist of a finite history of time space information about the work situation in a particular context (Nwiabu et al., 2011, p. 12) as well as abstract rules of the domain of work. Case model ensures that both the new and retrieved cases adhere to the same representational format. The case structure reflects the practice-centred approach proposed in this work, i.e. representations of work settings in terms of the vocabularies of the ontological, stereotyped and situated factors describing a work setting based on attribute-value pairs, i.e. intensional descriptions (Cunningham, 2009). The classes are defined as a couple of problem and solution parts. Researchers in CBR recommend that vocabularies for describing cases must be rich enough to be expressive, but limited enough to allow efficient recall (Kolodner, 1993; Bello-Tomás et al., 2004).

Next, the case structures are passed onto the inference engine (see Figure 5.28). The retrieved cases are used to suggest solutions that are reused, tested and adapted to suite the new problems described by the user's work setting. We use *similarity matching* – a widely used reasoning mechanism in the CBR research community, which involves matching the work practice instance against a retrieved case for similarity measures based on a number of attribute values. Since the early days of CBR research, a number of insightful similarity measures have been developed, ranging from the traditional mechanism where similarity is assessed based on feature-value descriptions of cases that use similarity metrics to advanced methodologies employing knowledge-intensive similarity mechanisms, e.g. compression-based similarity (Cunningham, 2009) for excellent overviews of similarity measures in CBR (Kolodner, 1993; Bello-Tomás et al., 2004; Aamodt, 2004). In modelling the similarity measures between two work contexts in CaDHealth, we adopt a well-known definition of similarity metrics known as the local-global principle (Richter, 2008). The local-global principle is generally used in ontological CBR systems (Assali et al., 2010) and in object-oriented case structures, e.g. myCBR[38]. According to this principle, it is possible to compute the similarity between two objects – where one object represents the case (or part of it) and the other represents the query (or part of it) – by specifying a local part that considers only local similarities between single attribute values, and a global part that calculates the global similarity for whole cases based on local similarity assessments. As noted earlier, every case describing a work setting (see Figure 5.29) includes, as a key part, a set of user queries for which support is sought. For each simple attribute, a local similarity measure is used to express its influence on the utility estimation; and for each complex attribute, a global (object) similarity measure is applied. The final similarity value is obtained as an aggregation function computing the final similarity based on the local similarity values and the defined attribute weights. The local-global approach appears pertinent to our work because of its suitability for handling complex case representations consisting of numerous attributes with different value types[39] such as in a work practice description.

From a practice-centred approach, the similarity computation of two instances of clinical work settings be reduced to three components: *a concept-based similarity* (Assali et al., 2010, p. 107), which focuses on ontological descriptions of concepts and their relationships in the activity domain, *a role-based similarity*, which seeks to identify attributes (e.g. artefacts) that have the same role and considers them as corresponding attributes (Assali et al., 2010, p. 109), and *a context-based similarity* that seeks to obtain a representation of a real-world setting by identifying a finite set of attributes with associated constraints on the attribute values (Jurisica, 1994). The constraints on attribute values are specified either as "allowed"

[38] http://mycbr-project.net/

[39] In this work, we assume the existence of a set of local similarity measures for each of the work practice attributes, although, in CBR systems, local similarity measures are generally not defined for attributes, but rather for data types that may be assigned to attributes.

values (e.g. values which should be present if the attribute matching is to occur) or "prohibited" values (e.g. values considered, but which should not be present if the attribute matching is to occur). Here, we do not claim to define new similarity measures. We use the measures and definitions presented in the literature that we found pertinent to our work.

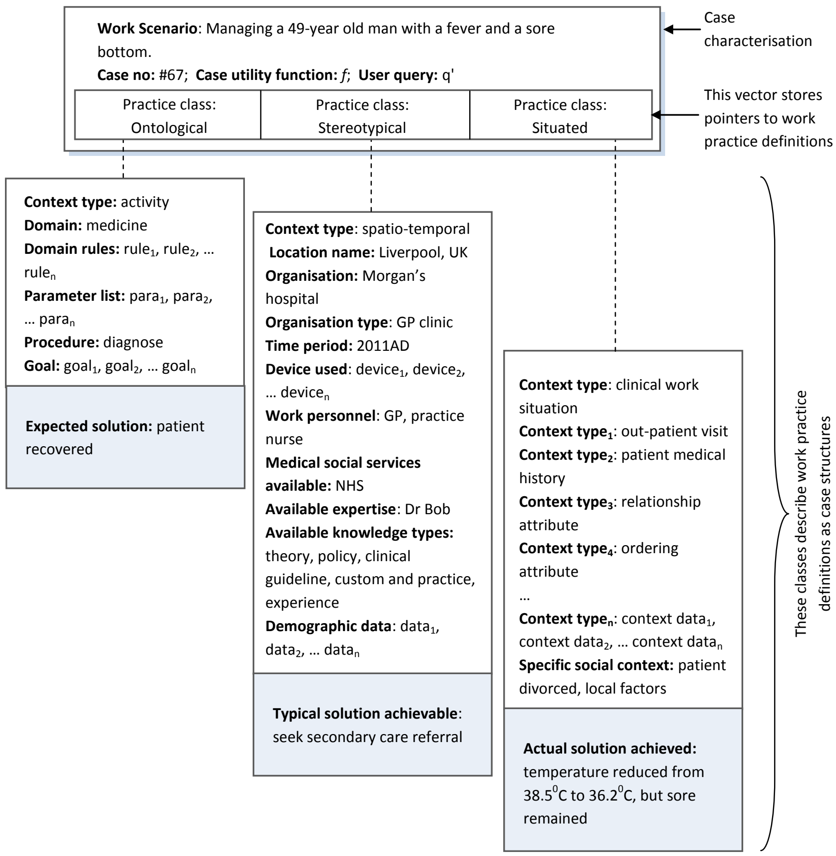

Figure 5.29: A case structure representing work practice as a contextualised work setting

Concept-based Similarity: Within a single conceptual domain, the similarity between two concepts is defined by how closely they are related on an ontological hierarchy.

Role-based Similarity: Let W, W' represent two work settings. For each entity, $a \epsilon W$, we consider that its corresponding entity in W', denoted by a' is the entity with which a has maximum similarity (Assali et al., 2010). However, it is not always possible to achieve maximum similarity (Assali et al., 2010, p. 109). For such situations, e.g. where a and a' are different but could perform similar roles, say by virtue of how a' is used in W' as an improvisational tools for performing the role, role-based similarity asserts that, a and a' are similar by role correspondence.

Context-based Similarity: Similarity matching between two work settings is context-based if the similarity changes with (explicitly stated) context. See (Jurisica, 1994) for a theory of context-based similarity.

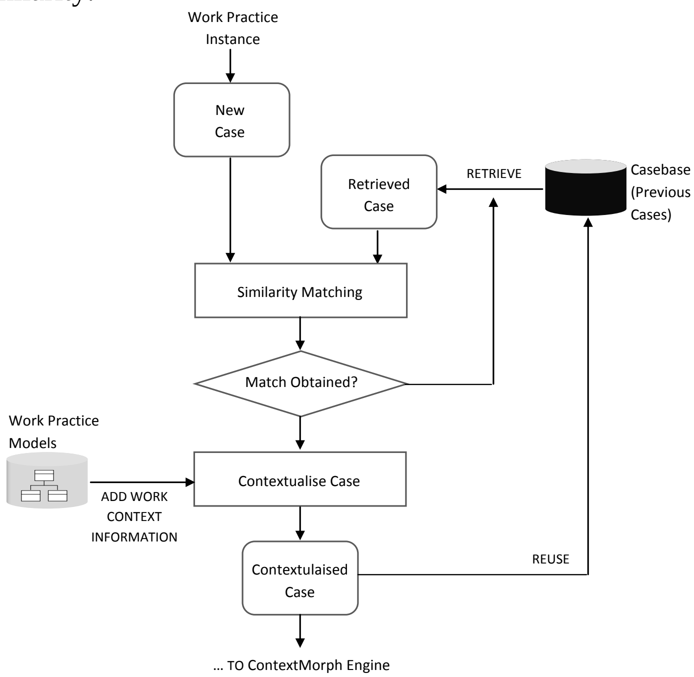

Figure 5.30: CBR process in CaDHealth

Since our aim is not to develop a CBR system, but rather to apply CBR – as a reasoning mechanism – in developing a practice-centred DSS, we have, for the sake of simplicity, adhered to the rapid prototyping method proposed for such situations where CBR applications are not to be developed from scratch (Stahl and Roth-Berghofer, 2008). This method follows the similarity definition in myCBR tool, and uses a straightforward case representation structure with a case base D made up of $(W_i)_{i\epsilon[1,|D|]}$ samples described by a set of features F with numeric features normalised to the range [0, 1]. In this representation, let q, W be instances of a clinical query and clinical case, where $W = W_1, \ldots, X_n$ and each W_i is described by a vector $(W_{i1}, \ldots, W_{1|F|})$ of numerical features representing some object. Assuming that the case representation consists of n number of features with feature weights x_i, the similarity between q and W can be computed as follows:

$$Sim(q, W) = \sum_{i=1}^{n} x_i \times Sim_i(q_i, W_i)$$

The feature-specific local similarity measure is given by Sim_i, and Sim represents the global similarity measure (Stahl and Roth-Berghofer, 2008). It is common for local similarity measures to be represented as similarity tables that simply evaluate all pairwise similarity values for symbolic features or *difference-based similarity functions* that map feature differences to similarity values for numeric features. Figure 5.30 shows a diagrammatic representation of the CBR process in CaDHealth. Like the traditional CBR cycle, it is assumed that a matching case will be found from the casebase of previous cases.

5.11 ContextMorph

This section describes the final stage in the PCA process model, which is concerned with using the knowledge acquired from the reasoning process to enable context-aware cross-boundary decision support. To achieve this, we propose ContextMorph. We introduce ContextMorph as a technique for *context morphing*, i.e. for modeling information interchange and decision support across clinical work settings and disparate practice systems. In principle, context morphing aims to generate contextually enriched knowledge in order to adaptively support decision in a specific work context. In practice, the technique aims to explicate the forms of work practices in a specific work setting, and consequently tailor an information item (which we refer to as a suggestion), which originates from a different work setting, to fit into the practices and problem-solving patterns in the user's work context in a way that accommodates for both institution-specific and situation-dependent variations in care.

Typically, when people provide suggestions toward assisting other people, e.g. in online forums, they usually provide the information item in a general context or, at least, in terms of their own peculiar contexts and experiences. As has been argued in this work, people in different work settings, e.g. clinicians – owing to differences in work culture, available resources and expertise, patients' needs and institutional agenda – have evolved work practices that conform to their work contexts and seek to address their peculiar issues. We posit that in order to be effective, a suggestion needs to adapt to the various ways by which a user works. As a result, our context morphing approach aims to re-structure (i.e. *customise*) the information content of a suggestion in order to add value to the ways by which clinicians often contextualise problem-solving procedures in order to accommodate for specific local contexts and peculiar patient-centred needs (Suchman, 1987; Harrison et al., 2010; Gabbay and le May, 2011). To achieve this, the ContextMorph technique focuses on the following actions:

- **Improvise**: What resources, tools, expertise and standardised services does the user lack? How do they make up for them by dint of their work practices? How can the suggestion provided help them in doing this in relation to their overall work goal and expected solution.
- **Influence:** What internal (person-related and organisation-dependent) and external (e.g. regional policies) factors has shaped the user's decision making? How do the factors affect decision quality? How can the suggestion provided help ensure quality?
- **Augment:** How can the suggestion enrich the user's work practices and existing information towards achieving the overall work goal and expected solution, and vice versa?
- **Explain:** How can the suggestion help offer an explanation or justification for the user's work practices (Kofod-Petersen and Aamodt, 2009)?
- **Apply:** Here the suggestion is directly applied to user work context without any action on it. This occurs where the work context of the suggestion provider and that of the user are similar.

Our idea of ContextMorph draws from the concepts of morphological analysis (Zwicky, 1969; Ritchey, 2006), medical knowledge morphing (Abidi, 2005) and GoalMorph (Vukovic and Robinson, 2005). Morphological analysis provides an approach for modelling complex real-world problems and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes (Zwicky 1969). In real-world problem situations, the contributions of hitherto trivial elements and external factors can often become significant, and any model that fails to appropriately consider them will hardly capture the true state of the system being modelled. Morphological analysis has been applied in modelling various complex problem domains, such as socio-technical systems (Ritchey, 2006). Whereas Knowledge morphing and GoalMorph aims to generate verified "morphed" knowledge from multiple, and heterogenous, knowledge artifacts (Abidi, 2005) and to construct context aware goals and reformulate failed goals into problems that to be solved respectively, our aim in ContextMorph is fuse context elements from disparate work settings in order to adapt an information item to specificity of a work context. The concept of ContextMorph is also analogous to the much-researched concept of information enrichment (Belotti et al., 2005;

Anya et al., 2008). However unlike traditional information enrichment where more information is added to an existing information item to make it more meaningful, the purpose of ContextMorph is to adapt an information item or a suggestion to specific context of work by adding contextual information to it; the ultimate goal being to facilitate cross-boundary decision support. Another related initiative, which encourages knowledge sharing based on the context of person to person interaction, is the OpenKnowledge project[40]. The framework supports peer to peer knowledge sharing and decision support, not by sharing their asserted statements, but by sharing their interactional models.

5.11.1 Modelling ContextMorph

At the core of ContextMorph is the notion of a *suggestion. W*e define a suggestion as *an information item that gives a clue to a decision maker as to the most appropriate set of solutions to a problem*. Drawing upon this, we define ContextMorph as *the intelligent and automatic process of fusing contextual information items that may exist differently in different work settings in order to ensure that a suggestion originating from one work context is adapted to more effectively support problem-solving and decision-making in another work context*. Central to the concept of ContextMorph is the need to identify and categorise various contexts and patterns of working existing in different organisational settings. The ultimate goal is to provide a mechanism for enabling an information item retrieved from a certain repository or a suggestion emanating from a collaborating expert in a certain work context, known as the *provider context*, to be effectively applied to support problem-solving and decision-making in the user's context of work, known as the *consumer context* (see Figure 5.31).

In Figure 5.31, the concept of ContextMorph is modelled based on the extended version of activity system proposed in this work. The figure depicts cross-boundary decision support using ContextMorph as a knowledge exchange process that takes an ecological view of the contexts of work of the knowledge (suggestion) provider and receiver. ContextMorph seeks to compute the extent to which a suggestion, which has been utilised in problem-solving in a context, can be applied to support a similar problem in another context (Porzel, 2011).

[40] http://www.openk.org/

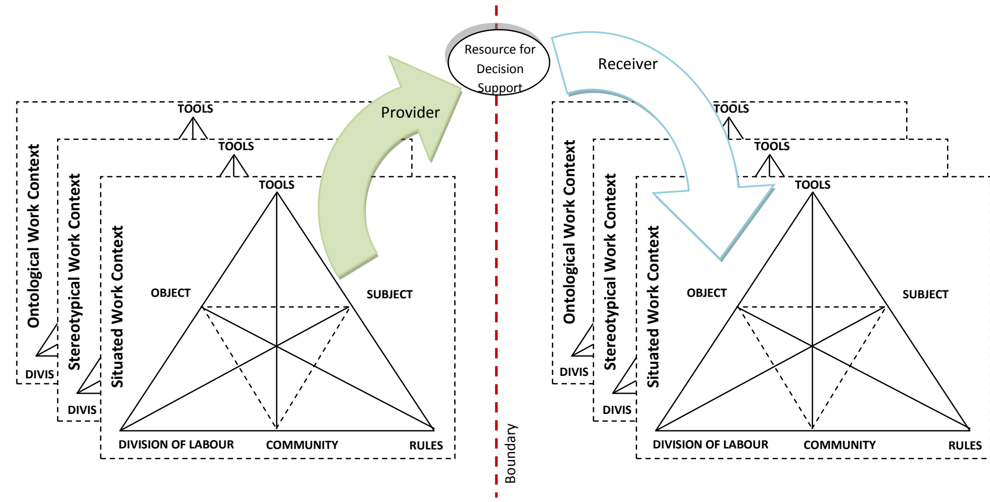

Figure 5.31: ContextMorph for practice-centred cross-boundary decision

The context morphing process reconciles any differences between the contexts of use of the suggestion provided with the user's context of work by *aligning contextual elements* between the two work settings based on the classes of practice (see Figure 5.32). OP and OP' denotes the ontological practices of the user and provider respectively; TP and TP' denotes the stereotyped practices of the user and provider respectively; and SP and SP' denotes the situated practices of the user and provider respectively. As shown in the figure, ContextMorph further takes as input a *morphing reference*, e.g. clinical guideline, patient-centred needs, work goal or work context information, against which the disparate contextual elements are reconciled, i.e. their similarities are matched. In (Tawfik et al., 2012), we found out that although differences in clinical practices across boundaries are associated with differences in local work contexts, they are nonetheless moderated by morphing reference objects, e.g. adherence to best practice guidelines and the need for patient-centred care (see also Chapter 4).

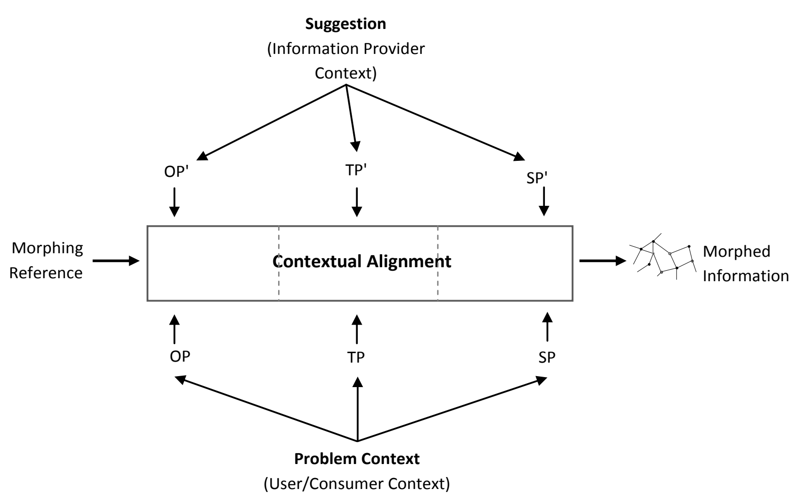

Figure 5.32: Conceptual model of ContextMorph

ContextMorph Engine

We describe the architecture of ContextMorph (see Figure 5.33). It consists of a suggestion profiler, a suggestion augmenter and a morphing engine comprising a knowledge fusion module and a contextual alignment section. Basically, the goal of the ContextMorph engine is to augment and adapt suggestions to support decision-making in specific contexts of work. This entails complex steps that involve determining how concepts in the suggestion map to issues (and concepts) in the user's problem situation, and generating a confidence rating required to ascertain which suggestion is most appropriate to a given context. There are two primary inputs to the ContextMorph engine: *a contextualised case* and a suggestion. A contextualised case is somewhat similar to a solved case in traditional CBR (Aamodt, 2004), and is the product of the similarity measure between a work practice instance and a retrieved case.

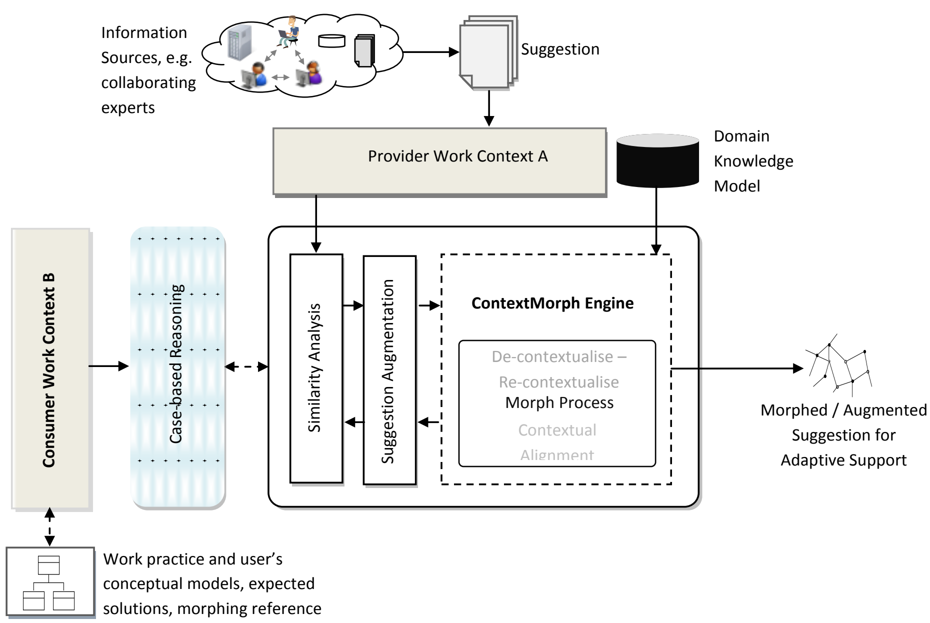

Figure 5.33: Context-aware decision support – the ContextMorph engine

The suggestion reflects also the work practices in the provider work context A. As the suggestion is entered into the engine, it undergoes *similarity analysis*. Similarity analysis is the process of generating a confidence rating about the use of a suggestion in B by extrapolating information from the suggestion based on existing information about the suggestion provider and known information about the use of the suggestion in related cases. The goal of this process is to determine if a suggestion is applicable to a specific problem context, and, subsequently, estimate a user's level of confidence in applying the suggestion.

Similarity analysis uses three techniques: *profiling*, *domain knowledge* and *stereotyped situational analysis*. The techniques of similarity analysis will be explained details in Chapter 6. Here, we define *profile as a subset of context that refers to a suggestion provider*; and the process of profiling involves such probing questions as:

- What is the information content of a suggestion?
- Who is the provider? What is their level of expertise with respect to current user problem?
- In what other case(s) has the suggestion been applied to? What was its role and impact factor?
- How does the case differ from current user problem with regard to contexts of work? What "boundaries" are to be crossed in adapting the suggestion to suit the context of current user problem?
- Does the suggestion conform to any known best practice model? What underlying theoretical or empirical assumptions does the suggestion embody?

Following similarity analysis, both the suggestion and the contextualised case are passed into the *suggestion augmentation* unit. During suggestion augmentation, the key concepts in the suggestion are identified, using formal concept analysis. The concepts are enriched with more useful perspectives about B by fusing them with information about the beliefs of the workplace and the user's work goals in order to further determine their suitability in B. Later, the enriched conceptual structures are passed onto the ContextMorph engine. At the core of the ContextMorph engine are two related processes: *de-contextualisation and re-contextualisation*, which are aimed to transform, i.e. *morph*, the knowledge in the suggestion (represented by the enriched conceptual structures) from A to a form that is clinically pragmatic for the consumer's work context in B (see Figure 5.34). The ContextMorph process is formalised using the Dempster-Shafer method (Kłopotek and Wierzchoń, 2002) in order to map the evidence of the suggestion from A to practice system of B (i.e. the beliefs, practices, tools and circumstances in B; the formalisation process will be further described in Chapter 6.

Suggestion Customisation: De-contextualisation and Re-contextualisation

Broadly speaking, ContextMorph is a customisation technique: a suggestion provided from outside of a work setting A is “contextually tweaked” to suite the context and goals of another work setting B (see Figure 5.31). This customisation is achieved via a two-stage process of *de-contextualisation* and *re-contextualisation*, and is based on the notion of boundary levels of work practices. De-contextualisation involves the processing of abstracting a work process by extracting peculiar issues of the activity performed in order to generate a relatively generic model of it that can be reused in a different work context. The reverse process, known as re-contextualisation includes developing work process instances adapted to the situations of a specific work context (Brézillon, 2011). During de-contextualisation and re-contextualisation, a *morphing reference* (see Figure 5.32), which we define as a "tool", for moderating variations in how a given problem is solved across work settings (Abidi, 2005; Tawfik et al., 2012). The use of a morphing reference helps ensure quality and resolve any conflicts between the provider and consumer contexts. Examples of a morphing reference include adherence to best practice guidelines, the need for patient-centred care (work goal) or evidence-based research.

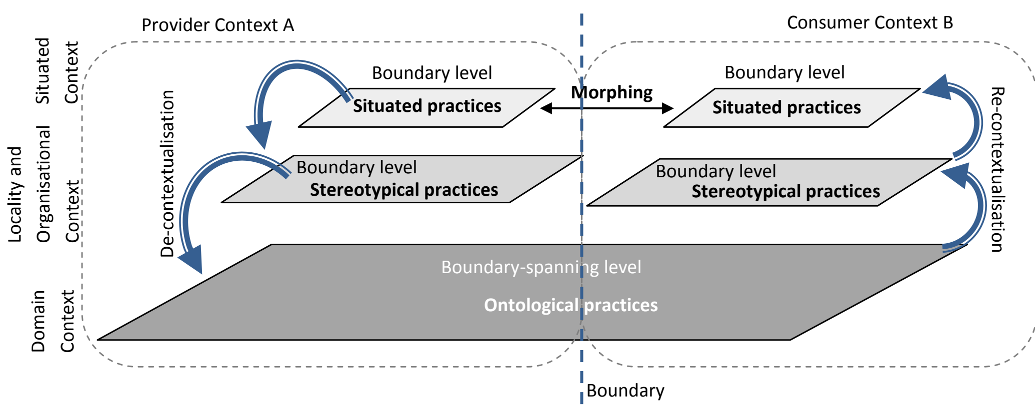

Figure 5.34: De-contextualisation and re-contextualisation

As shown in Figure 5.34, de-contextualisation is performed on the suggestion provider’s context of work so as to validate the suggestion against domain rules and standard protocols, whereas re-contextualisation occurs with respect to user work context by seeking to integrate the suggestion with the user’s contextual information. The base-level ontological practices are necessary to ensure consistency in results and quality of work across boundaries. In order for clinicians working in different work settings to share knowledge to support each other’s decisions, their mental models of the task to be supported need include a significant degree of similarity (Alavi and Leidner, 2001). This similarity is achieved by the ontological practices denoting formal knowledge about the domain of work that is usually acquired through training.

ContextMorph and Cross-Boundary Decision Support in CaDHealth

This section seeks to provide a bird's eye view of the whole process of cross-boundary decision in CaDHealth. Figure 5.35 illustrates the use of PCA and ContextMorph in enabling cross-boundary decision support among three work settings – hospitals A, B and C – denoted as practice systems.

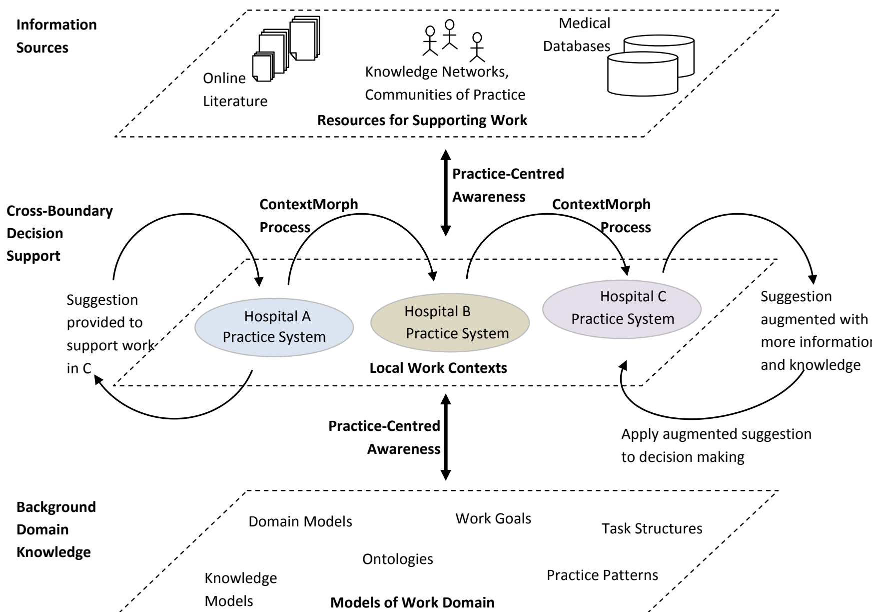

Figure 5.35: Cross-boundary decision support in CaDHealth

To fully understand the proposed conceotual framework, we provide in Figure 5.36 an illustration of how the framework is used to enable cross-boundary clinical decision support from user query to augmented suggestion for decision support. The first step is the specification of the problem to be solved as user query. The query is processed and the systems generated practice cues as an initial step towards making sense of user problem and work context. This is followed by a characterisation of the problem space at the ontological, stereotyped and situated practice system levels leading to "a comprehension" of user work situation and specific requirements. This is realised via the perception, conceptualisation and stereotyping cycle. The system specification of user (Bob's) situation and need is generated in the form of work practice models. Next, available collaborating agents, e.g. Mr Smith, provide experts suggestions aimed to help Bob in solving his problem. The system builds a model of the suggestion provided in relation to the provider's context of work. During ContextMorph, as described earlier, the suggestion provided is *morphed* (i.e. transformed) to suit Bob's prevailing work context, practices and problem requirements.

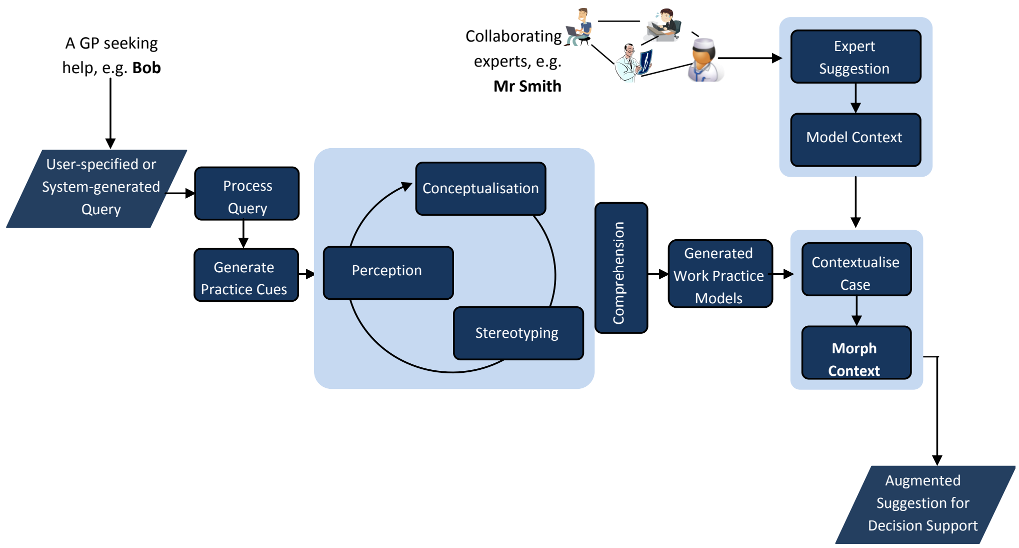

Figure 5.36: DSS Process in CaDHealth. The decision support process is applied in the context of the usage scenario described in Section 5.3.

5.12 Summary

One of the benefits of our modelling approach is that it offers newer and more broad-based perspectives for gaining deeper understanding of people's interaction with technologies in real-world problem-solving. Although by integrating context into a combined model of CHT with SAW, the proposed model has provided novel ways of highlighting the nuances in real-world problem-solving across work settings and enabling sense making of work activities beyond what are offered by existing workflow-based models, it does not, as abstractions, replicate all of the aspects of the knowledge, experience and behavior that clinicians bring to bear on the decisions "in practice". For example, the CaDHealth does not sufficiently support learning "on the job", and does not take account of the influence of body language, emotions and expressions on decisions. However, it allows for the use of logical reasoning (domain rules and ontologies), probability factors (for stereotyping) and situatedness (case-based reasoning) to enable reasoning about work contexts. These will be further described in the next chapter with aiming of defining more formal models for building computer applications based of this approach.

6
System Formalisation and Prototyping

[Design] constitutes an intervention in the background of our heritage,
Growing out of our already existent ways of being in the world
And deeply affecting the kind of beings that we are.
In creating new artifacts… it attempts to specify in advance
How and where breakdowns will show up in our everyday practices
And in the tools we use,
Opening up new spaces in which we can work and play.
Ontologically oriented design is therefore necessarily both reflective and political,
Looking backwards to the tradition that has formed us
But also forwards to as-yet-uncreated transformations of our lives together.
Through the emergence of new tools,
We come to a changing awareness of human nature and human action,
Which in turn leads to new technological development
The designing process is part of this 'dance'
In which our structure of possibilities is generated.

Terry Winograd and Fernando Flores, Understanding Computers and Cognition, 1987, p. 163

6.1 Introduction

In this chapter, the concepts proposed in the previous chapter are formalised and applied to the design of CaDHealth – a prototype e-health system that offers a unifying structure allowing clinicians to make sense of work situations across regional and workplace boundaries for effective clinical decision support in e-health. At the core of our formalisation approach is an attempt to build a formal theory of work practice as a representation of a clinician's local work environment, contexts and practices. This chapter introduces PracticeFrames – a data structure, which draws upon our proposed work practice model, and is based on the idea of *frames* (McCarthy and Hayes, 1969) with the goal of representing work practices as a combination of the ontological, stereotyped and situated factors that influence decision-making in a clinical work environment.

In prototyping CaDHealth, we aim for 1) the provision of *practice-centred awareness information* so as to enable a collaborating expert across a user's work boundaries to gain knowledge of the user's practices and work situation beyond existing workflow-based approaches and 2) the provision of *decision support information*, which involve enriching a cross-boundary suggestion to adaptively support user decision. Our goal is achieve a tight coupling between a clinician's work practices and a system's model of these practices, and thus provide system designers with methods to generate accurate descriptions of how clinicians reconfigure their organisation and tools in order to actually get work done "in practice" and the factors influence those actions (Fafchamps et al., 1992).

6.2 Formalisation of Practice-Centred Awareness

We describe a formal expression for translating the work practice and PCA models into software. We aim is to show how the models can be used as a basis for developing a formal, machine deployable specification of a clinical work practice by developing a formal construct linking together actions, activities, artefacts and the socio-cultural contexts of work. A major challenge here is that the formal expression must be ultimately grounded in procedures and services for real systems in order to be meaningful (Fox, 2011). From a software design point of view, such a formal expression may be presented top-down or bottom-up. However, for the sake of simplicity and in accordance with the practice-centred perspective adopted in this work, we have sought to formalise the expression as an n-ary relation depicting the interactions among elements in a local work environment – which we refer to as a *work setting* – modelled on three distinct levels of details, namely the ontological, stereotyped and situated levels. In what follows, we describe the formal expression using both logic and ontology-based formalisms. Although our formalisation approach hardly captures all aspects of system design from a practice-centred approach (for example, see Chapter 4), it represents a foundation for analysing, in more details, the wide range of contextual issues and functionalities to be considered when designing systems from practice-centred and socio-technical design approaches.

Figure 6.1 depicts an illustration of a formal model of practice-centred awareness and decision support. The starting point is a given *real-world clinical work setting W* in the application environment which triggers some more or less abstract information need based on either an automatic *context-driven percept p* of *W* or a *user query q*. We define a percept as a representation of a particular attribute of the current state of a work setting (Bordini et al., 2007, p. 69). The task of CaDHealth is twofold: 1) to generate *practice-centred awareness information a* aimed to help the suggestion provider (e.g. a human or a software agent in another world state *W′*) to become aware of *W* (i.e. the user's context of work) based on the activity being performed, patient's needs, available tools, resources and strategies, and the socio-cultural work contexts and practices in *W*, and, as a result, provide a more informed *suggestion s*, and 2) to generate a corresponding *output o* to enable the user to make the most effective decision adapted to *W*. When *o* is generated in response to *q*, decision support is said to occur in reactive or collaborative mode, but in proactive or opportunistic mode if it was in response to *p* (see Section 5.5.1). For example, in a traditional clinical problem-solving scenario, *q* is a query on an unsolved problem situation *W* for which a solution is required. *s* may denote a "second opinion" from a clinical expert in a different work setting *W′*, *a* may include system generated information aimed to inform the expert of user’s work practices and the problem situation in *W*, and *o* may be the description of suitable solution or a solution method in response to *q*.

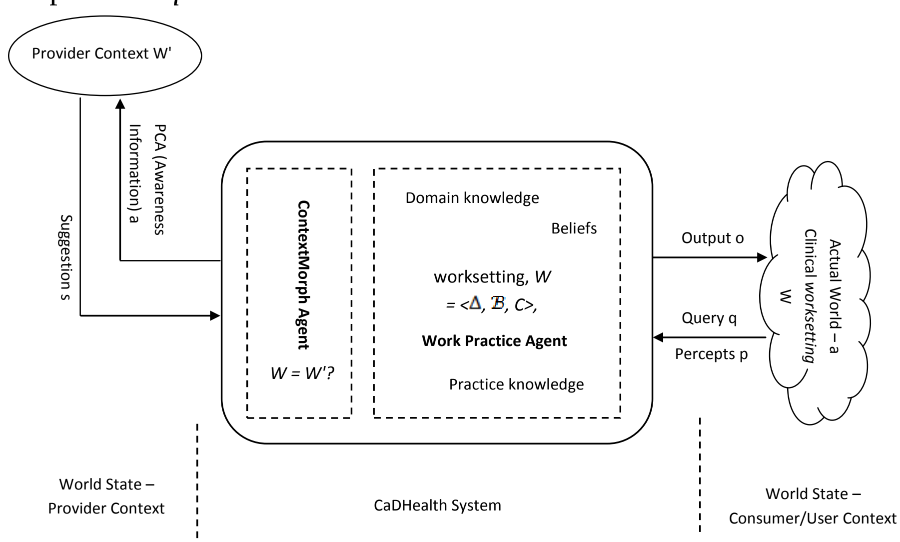

Figure 6.1: A formal model for practice-centred cross-boundary awareness and decision support

6.2.1 Specifying Work Context

Any expression of work practice must embody assumptions for describing the work performed, its spatio-temporal organisation, the artefacts used, the situation within which work unfolds, and the socio-cultural contexts of problem-solving including informal beliefs, institutionalised policies and strategies that develop over time. Hence, for a model of an e-health system to have the capability to enable decision support based on awareness of work practices, it has to be specified as a systemic organisation of actions (i.e. task methods) that give rise to activities (Allert and Richter, 2008), and relevant elements of the context of work that depict viable ways *of doing things* within a work setting. Such *a practice-centred system can be modelled as a work setting characterised by a set of axioms describing elements of the setting.* Elements of a work setting may include entities that execute actions (or tasks), individuals participating in the activity and their roles, the location and time of work, the work performed including rules, motives and expected outcome, and the contexts of problem-solving including circumstances and available knowledge and artefacts, available means, strategies, beliefs and the socio-cultural milieu in which work unfolds.

We define work context elements as the set of items $\{(a_1, v_1), (a_2, v_2), \ldots\}$ used to describe a *work setting W* in relation to a work process, such that $a_i, v_i \subseteq W$. The sets a_i and v_i are partial descriptions of W, where a_i is the set of context attributes, and v_i is the set of corresponding values of a_i. A context attribute-value set may be depicted as a simple "label" with an associated value (Brézillon, 2007) e.g. <"temperature", "34.80C">, or as a more complex structure that includes specifications for actions in particular settings or situational factors that influence action. For example, we can represent the fact that an activity is taking place at a hospital in Liverpool as the set <"ActivityLocation", "RoyalLiverpoolHospital">. A context attribute could specify an information item defining an element of a work setting, e.g. "NameOfClinician", NameOfActivity", "TimeOfActivity", "DevicesAvailableInActivityLocation", "RoleOfPersonInActivityLocation", "CurrentOrganisationalRules". A particular context attribute can assume several values within the duration of an activity, or across several activities, but each context attribute has at least one value at any given moment. To denote the possible range of values that any context attribute can assume, we associate to each a_i a function called valueOf, where $valueOf(v_i) \neq \{\emptyset\}$. The function valueOf takes its values in $P(Va_i)$, where $P(Va_i)$ is the power set of Va_i and Pa_i is the set of parameters required to compute the value of a_i. For example, the context attribute "RoleOfDevice" taking iPhone as "NameOfDevice", will return the range of roles that iPhone can play, including "making calls", "browsing", "route navigation" and "watching movies".

In cross-boundary decision support, a collaborating expert or an agent seeks to make sense of a user's work context and problem situation with regard to the user's query or system perceived information known as percept (see Figure 6.1). To represent a user's work context including query and precept, we introduce the term, *requisite*. The *requisite*, *r* is the problem requirement of the activity at hand in a work setting for which the user requires information to support their decision. Put succinctly, we view requisite as the set of information that enables the collaborating expert to gain awareness of the user's work setting and problem requirements. An example of a requisite is determining the most effective way to manage cancer after chemotherapy. Within a work setting, it is not all context attributes that are relevant for a requisite. Determining the relevance of an attribute has been a key issue in context modelling. In related work, such as (Brézillon and Brézillon, 2007; Bucur et al., 2006; Turner, 2006), the notion of relevance is largely understood by determining the attributes that are involved in establishing a "focus" for the activity and is often calculated by defining a set of relevant attributes for any instance of work or focus. We will follow a similar pattern, but will differ by defining sets of relevant attributes at the three major levels of a work setting or practice system (see Chapter 5), namely the ontological, stereotyped and situated levels.

Let $isRel(a_i,r)$ denote a predicate stating that the work context attribute a_i *is relevant* for the requisite r. At the ontological level , we define the *Ontologically Relevant Attribute Set, ORAS(r)* as the subset of the context attributes a_i in *W* that are relevant for the requisite *r* based on the domain knowledge and specifications of the activity in *W* whose problem requirements are denoted by *r*. Let's the domain knowledge types for this activity be represented by the set$\mathbb{D}$, then $ORAS(r) = \{a_i \subseteq \mathbb{D} \mid isRel(a_i, r) = true\}$. In defining $\mathbb{D}$, we used the faceted approach for domain analysis (Giunchiglia et al., 2012) in which a domain is defined as a 5-tuple, $\mathbb{D} = <id, FL, K, \{P\}, \{F_P\}>$, where: id is a string denoting the name of the domain, FL is a 4-tuple $<C, E, a_i, v_i>$ of mutually disjoint sets, where *C* is a set of classes, *E* is a set of entities, a_i is a set of attributes, and v_i is a set of values. K is a set $2^{\mathbb{D}^n}$ of all possible n-ary relations on $\mathbb{D}$: *{is-a, instance-of, part-of, value-of}* that collectively impose a relationship structure on the entities of the domain; is-a: C→ C such that element of C can be associated to zero or more elements of C; instance-of: E→ C such E is an instance of C; part-of: E → E such that each element of E can be associated to zero or more elements of E; valueof: a_i,→ v_i such that each attribute in a_i can be associated to one or more values in v_i. In this work relations are defined on the basis of the roles and role types that can be assumed by entities in the domain. Each P in {P} is a pair <S, T> of sets of basic actions $\{(S_1^P, T_1^P), (S_2^P, T_2^P), \ldots\}$, such that $S_i^P, T_i^P \subseteq \mathbb{D}_P$ where $\mathbb{D}_P$ is a set of all domain-specific actions allowed in performing the given activity. The sets S_i^P, T_i^P can be regarded as partial descriptions of states of activities of the various facets and scenarios involved in performing the activity as defined in the domain. S_i^P describes the state before an action is performed, and T_i^P is the description obtained after the action is performed. In an academic conference publication example, states of activities would include write a paper, submit the paper to a conference, have the paper reviewed, etc. Each F_P: <S, T> → $\{C \cup E \cup a_i \cup v_i\}$ is a mapping function that associates each action in the sets S_i^P, T_i^P to an element in $\{C \cup E \cup a_i \cup v_i\}$.

The faceted approach allows us to analyse a given domain (the subjective logical model of the world) in relation to the various ways by which the model could be applied in different real-world work settings (the objective physical world) that constitute the facets, instances or scenarios of use of the logical model. Our goal is to define the domain in terms of the *mandatory, optional, or alternative characteristics* of entities, actions, activities and practices in the system. For example, teaching as a pedagogical activity in the domain of education can be realised by different means depending on the context; children in a remote third world country could be taught multiplication by counting sticks, whereas their age mates in the Westminster Area of London use computer-controlled toys. Identifying the classes, types and relations is crucial aspect of modelling a domain particularly in the object-oriented paradigm. Classes can be thought of as a description of the elements of a domain together with their attributes and the actions they can perform. Classes are an abstract specification (at least at design time) and are instantiated, during program execution, into individual objects. A type, like a class, is an abstract specification for “a set or collection of entities that exist or may exist in some domain of discourse” (Sowa, 2000, p. 98). At this stage, our concern is to find out what exists in the domain, what their types are, what roles they can assume (including which entity constitutes the subject or object and what artefacts could be used), and what actions and activities the entities can participate in. Other potential approaches for analysing work domain include formal concept analysis (Priss, 2006) and ontologies used as computational artefacts providing formal descriptions that allow the encoding and reuse of the key concepts of a domain. Dasmahapatra and O'Hara (2006) report that ontologies intended to support clinical practice can only be understood within the context of their intended use and that standardisation of concepts is needed to harmonise variabilities across clinical work settings (Porzel, 2011, p. 36). In defining the *ORAS(r)*, references are not made to either location or time of work since emphasis is on making sense of r from the perspective of domain conceptualisations.

At the stereotyped level, we begin to bring in the elements of location and time. We aim to identify the set of possible situations[41] in a given location and time of work. Our approach draws from the formal model of stereotyping described in (Lehmann, 1998), which is an extension of non-monotonic logic. We want to draw conclusions about what is most likely to be true of the states of activities in a work setting W by considering what is already known about W. We refer to this as the *stereotypes* S_W. S_W is modeled as a subset of W, the set of all situations in which the S_W holds. For example, the African child stereotype could be represented as the set of all models in which children are malnourished and live in war situations. A key challenge here is to identify the best stereotype that is both a member of W and consistent with the domain-specific definitions represented by the set$\mathbb{D}$. We define the most likely state of activities in W to be members of the intersection $S' = \mathbb{D} \cap W \cap S_W$. We do not expect S' to be a non-empty set so as to avoid drawing contradictory conclusions (Lehmann, 1998). In this work, we allow the function that defines S' to pick a non-empty intersection. We, therefore, define the *Stereotyped Relevant Attribute Set, TRAS(r)* $= \{a_i \subseteq W \mid isRel(a_i, r) \in S'\}$. An example is to represent a stereotyped situation in which a clinician performs diagnosis, and if the fact that the clinician can improvise is consistent with all knowledge in $\mathbb{D}$ then we can conclude that the clinician works in technologically less developed region; we denote this in first-order predicate logic, thus: $\exists(x): clinician(x) \wedge performs\_diagnosis(x) \wedge \mathcal{M}\ improvises(x) \rightarrow S'$, where S' = <ActivityLocation(x), "A less technologically developed region">, and $\mathcal{M}$ is a modal operator.

At the situated level, we will call an instantiation of W with instances of the work context attributes $a_i \in W$ the pair $<a_i, v_i>$ where v_i is the set of values $v_i \in P(Va_i,)$ of a_i at any given

[41] Roughly, we can think of possible situations as likely states of affairs

moment in the course of work. For example, <RoleOfPersonInActivityLocation, “GP”>, <NameOfActivity, “Chemotherapy”>, <DevicesAvailableInActivityLocation, (“thermometer”, “CT Scan”, Stethoscope”)>. Let’s calculate the set of situated context attributes (Giunchiglia et al., 2012) as $I = \{(a_i, v_i) \mid a_i \in W \wedge valueOf(a_i) = v_i\}$. The *Situated Relevant Attribute Set* for the requisite *r* is calculated as the set of context attributes relevant to r. This is obtained as a function from the set of possible situations in TRAS to the set of admissible relations in ORAS. Hence, $SRAS(r) = \{(a_i, v_i) \mid a_i \in (ORAS(r) \cup TRAS(r)) \wedge (a_i, v_i) \in I\}$. For example, given a requisite r = “whether to prescribe a particular or not”; ORAS(r) = {<NameOfDrug, “Chloroquine”>, <UseOfDrug, “TreatMalaria”>}. Let’s assume that for a particular clinical case, the TRAS(r) = {<AllergicToDrug, “Yes”>, <AvailableAlternativeDrugs, “None”>, <EpidemicsInTheRegion, (“Malaria”, “Yellow Fever”)>. Hence, the SRAS(r) could be {<Suggestion, “Reducing dosage of Chloroquine could prevent itching allergy”>}. As shown in the preceding discussion, the work context problem requirements for an actual work setting is a factor of the ontological, stereotyped and situated work contexts and practices. In the next section, we describe a formal model of work practice as “a frame” containing the items defined in this section.

6.2.2 Framing a Work Setting

We construct a specific structure within which we will be able to describe the formal elements of a work context (as defined above) and their relationships at three levels: 1) the *micro-, the meso- and macro-levels*. Our goal is to construct a “frame” (or facet) of how agents build a sense of what they do in terms of actions, activities and practice. At the micro-level, the goal is to understand “the what” of a work process, i.e. the task performed. Hence, we define the entities in a work setting and their relations that give rise to actions (and task methods). At the meso-level, sets of actions are structured in a manner that describes the performance of activities. The goal is to understand how work is performed including who (people) and what (tools) are involved. Finally, at the macro-level, we seek to understand where and when a work is carried and how it is actually performed. This includes analysis of expressions of individual and collective intentions, beliefs, socio-cultural factors, and changing work circumstances inter-relate to give shape to particular ways of doing things – i.e. the practices – in a work setting (see Figure 6.2). Our goal in this approach is to construct an understanding of people's "ways of doing work" (Bødker, 1991) by depicting the three levels at which "the doing" is realised within a work setting, namely as an action, as an activity and as a practice.

In this work, we distinguish three main categories for "framing" (representing) a work setting, namely *entities, roles and context*. Entities are the elements of a work setting, and are similar to context elements in classical context modelling. An entity, according to (Dey and Abowd, 2000) is "a person, place, or object" that is considered relevant in a work setting, including physical and conceptual elements in the work setting. Relations between entities are dependent on work context attributes. An entity, such as a person becomes a member of a work setting by virtue of the specific role(s) that the person can assume in the performance of activities in the work setting. For example, the person Bob is a member of a clinical work setting by assuming the role of a GP. In a home setting, Bob could assume the role of a father or husband.

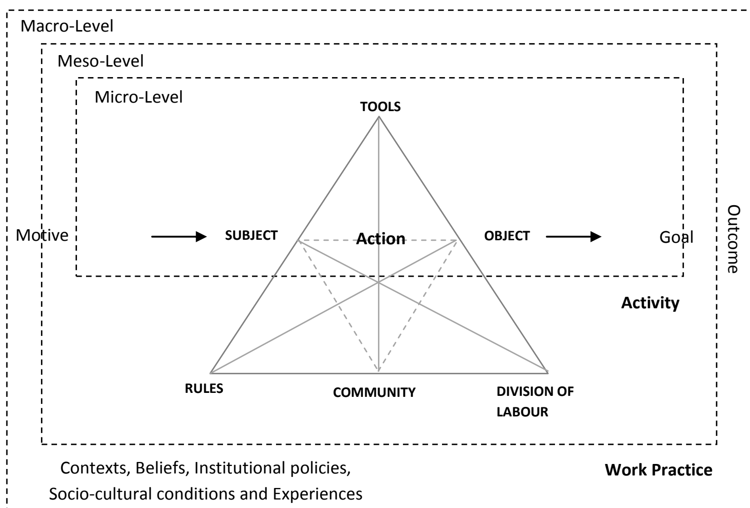

Figure 6.2: A model of work practice based on CHT's activity system

We identify three types of entities used to model a work setting; they include *ontological entities*, which become part of an action as a result of the domain definition of the action, e.g. domain-defined concepts and data, etc.; *stereotyped entities*, which exist as a result of a stereotype, e.g. entities created based on institutional policies, services, strategies, circumstances, beliefs, work culture, experience, etc.; and *situation entities*, which are actual entities perceived as a result of situations in a work setting, e.g. a physical object. Virtually any identifiable thing – physical or conceptual – in a work setting can be described an entity. An entity has an *entity type*, which refers to the natural existence of the class of "a thing" or a concept, e.g. person, tool, etc. The definition of an entity type is similar to a class construct in object-oriented modelling – class definitions lie outside of the context of any relationships, and instances of a class keep their types throughout their lifetime. An entity is equivalent to an instance of a class. Entity type is the default or natural type (Allert and Richter, 2008) of an entity since it is the type associated to the entity independent of its participation in a relationship. When an entity engages in a work process, it assumes a *role*. Hence, a role is not an intrinsic attribute of an entity, but rather an interpretation assigned to the entity by virtue of its role in the system (Crowley, 2006; Allert and Richter, 2008). *Role types* specify the type of roles that an entity assumes in a work setting, e.g. staff, patient, guideline, etc., and thus act to select an entity from the available set of entities for a particular work process. Role types could be defined normatively – based on a domain, as a stereotype – associated to a certain place and time, or contingently upon changing circumstances. We refer to them respectively as *normative (ontological) roles, stereotyped roles* and *circumstantial (situated) roles*. Normative roles describe relationships between entities based on domain specification, i.e. they *describe work as it should be done*; stereotyped roles *describe work as it likely to be done in a certain place and time*, and circumstantial roles describe entity relationships based prevailing local circumstances of work, i.e. they *describe work as it is actually done*. Role type is as fundamental in object-oriented modelling as entity type; however, role type is less known in object-oriented modelling compared to semiotics, linguistics and semantics where it plays a major role. In linguistics, for example, there is a common theory of formal languages, integrating role type as a fundamental concept complementing the concepts of predicates and objects (Allert and Richter, 2008).

Normative, stereotyped and circumstantial roles play a vital role in determining how entities relate with one another in the process of work execution; this relationship is not defined a priori, but is rather a product of the ontological, stereotyped and situated states of entities in a work setting. The contingent factors that define entities and their roles in a work setting can be referred to as context. *Context type* refers to the purpose that an element serves in a work setting. As a result of the nature of context (Dey and Abowd, 2000; see also Chapter 5), there is no standardisation of context types, and may include location, time, organisation, policy, etc. As shown in the previous section, context is modelled as *context attribute*, *attribute type* and *attribute value*, where attribute type refers to the kind of value that a context attribute can take. E.g. the context attribute “Year 2011” takes a temporal type. The behaviour of an entity in a work setting is dependent on the roles that the entity can assume, which in turn is dependent on context and available context types, i.e. the underlying rationale that informs the assumption of a role by an entity, and which reflects the central issues and socio-cultural factors of a work setting.

6.2.2.1 Micro-Level Model

The lowest form of a work practice is given by *an action*, which involves a change in the state of entities in a work setting. An entity, e.g. a human subject or an autonomous agent, consciously applies a set of operations (see Table 3.1) that may involve the use of other entities, e.g. tools in order to effect a (purposeful) state change on another entity (see Figure 6.3). State change in a work setting occurs when an entity assumes a role, which is triggered by motive, oriented towards a goal and invariably shaped by context. However, at this level, we want to ignore the role of context (as we move on to the macro-level, this role will become more apparent). See Figure 6.2. We want to show that when an entity assumes a role and effects a state change, an action is performed (see Figure 6.3). For example, when a person entity A, in a clinical setting, administers medication to another person entity B, an action C occurs. We distinguish between *possible actions* (actions that ought to be performed) and *actual actions* (actions performed in reality). Possible actions are represented as pairs *(U, V)* of sets of axioms, such that elements of *U* constitute partial description of the initial state before the action *(U, V)* is performed and *V* is the partial description of (expected) result of the action. When an entity assumes a role in a real work setting to perform an action, we denote as an actual action using the predicate *act (E, r, U, V)*, which reads an agent *E* of type entity assumes a role *r* and performs the action *(U, V,)*, i.e. a change of state from *U* to *V*. *F* represents a set of related actions $\{(E_1, r_1, U_1, V_1), (E_2, r_2, U_2, V_2), \ldots\}$ directed toward a goal.

Whereas several work, e.g. in object-oriented modelling, model entity type as an unary predicate and role type as binary predicate, for example, a clinician-patient encounter modelled as a binary relation; in this work, we model role as n-ary predicate depicting an actual work setting in terms of the clinician, the patient, and rules and device used, e.g. guidelines, medical equipment, etc. In the foregoing example, the action C emerges out of the n-ary relation between A, B and the devices used including the medication administered and available guidelines. Note that the ontological practice system includes specifications of the action performed, e.g. A should be a trained nurse or doctor. In some work settings or geographies, it is acceptable that A is a nursing assistant or another paramedical staff; i.e. the stereotyped practice system specifies the action as it is typically performed in the area, e.g. based on the available medications in the area. The situated practice system accounts for the action as it is actually performed in a given situation, e.g. that A is actually a trained care assistant.

Roles types are dependent on work settings. For example, an entity of type: person visits a clinician and assumes the role type: patient; he gets well and resumes work as a teacher in an educational work setting and assumes the role type: teacher; at home, the same person assumes the role type: father. Normative roles are usually defined at the ontological level, e.g. trained nurses give medication or paracetamol reduces fever. However, circumstances in an actual work setting (e.g. lack of trained healthcare personnel) might mean that a care assistant assumes that role. The idea of entity types and role-based modelling allows an entity to assume different roles within different practice systems and equally enables the description of a practice system in different contexts.

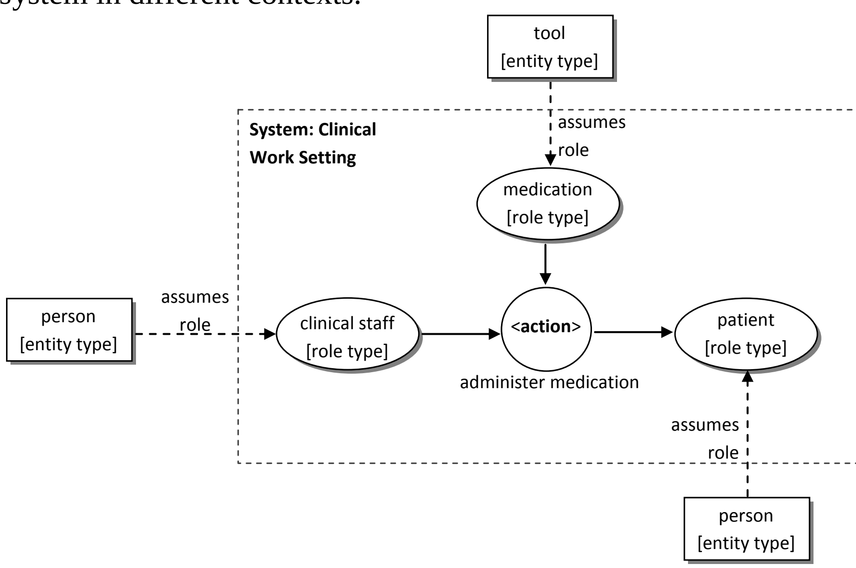

Figure 6.3: A formal model of action as a 3-ary relationship in a work setting showing entity and role types

6.2.2.2 Meso-Level Model

The second level of the formal model of work practice is the meso-level, and has as its main element *an activity*. We model activity as a logical collection of related actions that incorporates the people, tools and resources needed to get a certain part of work done (Geyer et al., 2006, p. 720). As a result, performing those actions is affected by the roles of other elements within the activity system, such as community and division of labour (see Figure 6.2). For example, in a family setting, the activities of a person of role type: mother towards another person of role type: child is affected by the presence (or absence) of an instance of role type: father. In a clinical work setting, carrying out diagnostic activities is affected by available devices, i.e. instances assuming the role type: tool.

In defining activity, we assume a set of elements of an activity system (Engeström, 1987; Kaptelinin and Nardi, 2006) represented as $\{(S_1, O_1, T_1, R_1, C_1, D_1), (S_2, O_2, T_2, R_2, C_2, D_2), \ldots\}$ such that $(S_i, O_i, T_i, R_i, C_i, D_i \in \Delta_{AS,}$ where Δ_{AS} is an activity system. An activity is formally represented as $\Delta = <\Omega, F, C_i, g>$, where Ω represents the processes enacted by a set of agents E_i belonging to Δ_{AS}. We assume that E_i and S_i refer to the same set of entities denoted as the subject(s) in the activity system. F is a set of related actions $\{(U_1, V_1), (U_2, V_2), \ldots\}$ executed by virtue of E_i assuming a set of roles r_i (as defined at the micro-level structure), C_i is a set of context items, e.g. a finite set of constraints over a work setting or a finite set of trigger conditions for actions in the action model (e.g. the motive for an action), g is the goal of activity. The combination of actions into activities is not additive and, conversely, an activity cannot be decomposed into its constituent actions without losing information. As indicated in literature (Allert and Richter, 2008; Balzer and Tuomela, 2003), the process by which actions yield activities, and activities in turn are manifested in forms of work practices is not linear, nor is the organisation of actions into activities or the historical process of constructing practices a quantitative one. This resonates with key assumptions of CHT, since work organisation in actual practice is shaped by situated and socio-cultural factors that reflect the ecological nature of the system within which work unfolds.

We posit that the elements of Δ can be sub-categorised into three broad classes, namely the ontological, stereotyped and situated classes. In taking this position, we have assumed that work activities consist of 1) an immensely complex and multi-faceted interaction between elements of a domain, 2) stereotyped factors of the space and time of work (e.g. the kind of technologies available for cancer diagnosis in Nigeria in 2011), and 3) the socio-cultural and contextual elements of the work environment (e.g. the attitude of a clinician or the economic status of a patient). Hence, we can define activity at the ontological, stereotyped and situated levels. At the ontological level, entities of Δ_{AS} assume domain-defined roles in order to perform actions specified at the domain level $\mathbb{D}$, C_i is defined with respect to *ORAS(g)*, where g is the goal of activity (or *requisite* in cross-boundary decision support). At the stereotyped and situated levels, entities of Δ_{AS} assume roles and actions defined with respect to stereotypes of a region and prevailing circumstances of an actual work situation respectively. At the stereotyped level, C_i is defined with respect to *TRAS(g)*, and with respect to *SRAS(g)* at the situated level. Hence, activity is obtained as a union set $\Delta = \Delta_{ontological} \cup \Delta_{stereotyped} \cup \Delta_{situated}$, where $\Delta_{ontological}$, $\Delta_{stereotyped}$ and $\Delta_{situated}$ denote the ontological, stereotyped and situated representations of activity respectively.

6.2.2.3 Macro-Level Model

The macro-level provides a further level of abstraction for the concept of work practice. In particular, we aim to enrich the activity model (as defined at the meso-level) with elements of the environmental, situational and socio-cultural characterisations of a clinical work space (see Figure 6.4). We begin with a set E of elements of *work practice* denoting the complete state of the universe of clinical problem-solving at an instance of time and place. Work practices are equivalent to the notion of situation in situation theory (Barwise, 1989; Devlin, 2006) or situation calculus (McCarthy and Hayes, 1969). They are taken to be actual parts of the world (of work), which correspond to everyday notion of a situation, and are thus treated as first-class objects (Barwise, 1989, p. 179; McCarthy and Hayes, 1969). Like situations, the universe of work practices can never be completely described; we can only give facts about a work practice in relation to given work processes and goals. Such facts can be used to enable individuals to make sense of a problem space for cross-boundary decision support, or to deduce facts about a given work practice. As depicted in Figure 6.1, E is formally described in order to obtain knowledge of the contextual items in W that are perceived as p or that could serve as parameters in a *query* q to be processed by a computer-based system, which subsequently generates the *PCA or awareness information* denoted as a.

We represent the set of elements of work practice as a triple $E = \langle \Delta, \mathcal{B}, C \rangle$, where Δ is a finite non-empty set of activities $\{\Delta_1, \ldots, \Delta_m\}$ in a work setting. $\mathcal{B}$ is a finite set of axioms $\{b_1, \ldots, b_m\}$ denoting the assumptions that influence ways of doing in the work setting, including world knowledge, behavior patterns, logistics and circumstantial factors that affect work as well as beliefs and intentions (Mora et al., 1999) obtainable in the work practice. It represents the social cognitive system of the work setting, including organisational policies and strategies. C is a finite non-empty set of items $\{c_1, \ldots, c_m\}$used to characterise the environment of work, including the identities of entities, e.g. persons in a work setting, the geographical location and time of work, problem-solving strategies, resources, etc.; C may be of multiple types, and may include contextual, situational, conceptual, physical, stereotyped, spatio-temporal, or social entities. The definition of *W* offers a rich model for describing contexts of work in terms of the activity being performed (e.g. writing an academic paper), the way it is performed (e.g. the artefacts, technologies and tools used), and the reason it is performed that way, captured in terms of the belief systems (e.g. the view of publications as a criterion for promotion in a university), socio-historical information that influences performing this activity in a particular place and time and which confers on it a certain stereotype (e.g. institutional policy), and lastly the contextual and situational features that characterise the environment of work (e.g. university has low research grants). Figure 6.4 depicts the relationship among action, activity and work practice, on different levels of emergence, within a macro-level model of work practice.

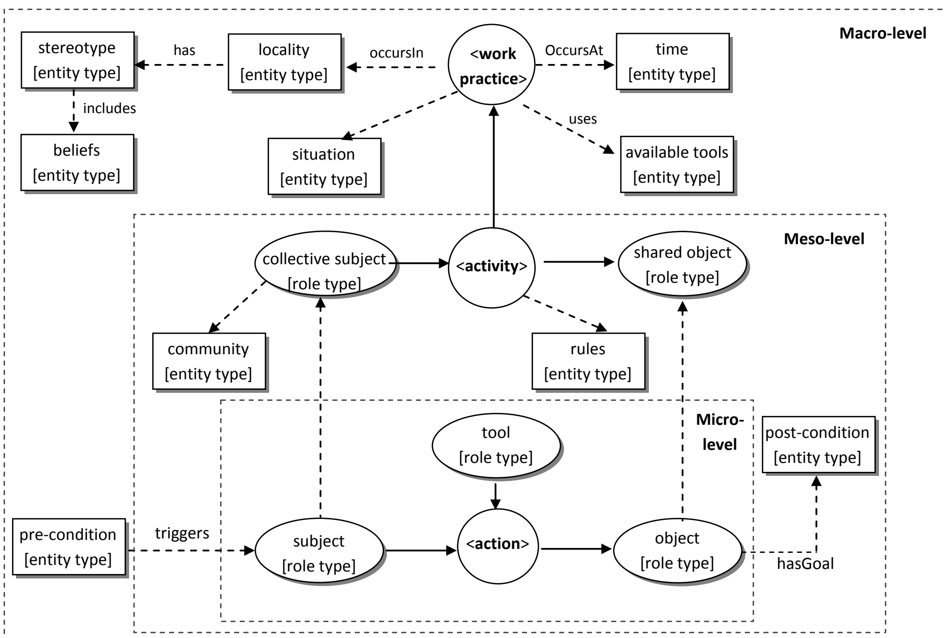

Figure 6.4: Enriched activity model showing the roles of work practice elements at the macro-level

As noted earlier, an entity assumes a role to perform an action at the micro-level model. At the macro-level, however, there is a system-level cause-effect chain and inherent synchronisation processes that influence or constrain how work is actually realised. Work is thus accomplished when entities (or more specifically agents) use available resources in order to attain a given goal (Allert and Ritcher, 2008). At the macro-level, therefore, we seek to highlight the informal, circumstantial, and located behaviours by which work is realised through the synchronisation of actions of entities in *W*. This synchronised influence on work processes is made possible through collective beliefs and desires of agents that describe their knowledge of the world, or what (Balzer and Tuomela, 2003, p. 17) referred to as “shared we-intention”, which is the reason work practices become routinised or stereotyped. In this work, we have assumed for the sake of simplicity that the set $\mathcal{B}$ represents all the variable factors that influence actual work processes in the real-world, and we seek to formalise those variable factors based on event calculus (Quaresma and Lopes, 1995).

6.2.3 Representing Work Practice

In order to represent work practices and how they shape actions and activities variously across work settings, we need to have a logical formalism that relates actions and activities (defined at the micro- and meso-levels respectively) to the variable factors influencing work across instances of place and time (defined at the macro-level). In this work, we use a modified version of the event calculus (Quaresma and Lopes, 1995), which allows us to identify a work setting as a coordinate in a spatio-temporal space, i.e. to describe work situations in relation to instances of place and time. Let us assume a form of such logical formalism called *WorkPracticeDescription (WPD),* in which we are given a work description at the domain level, called the *OntologicalPracticeDescription (OPD),* and a description of the world at a certain place and time, called the *StereotypedPracticeDescription (TPD),* and we are asked to determine what the world will look like as a result of performing the work description in the context of a given situation, called the *SituatedPracticeDescription (SPD),* within *TPD*. Our goal is to get a pragmatic description of the work situation and its problem requirements, denoted by *requisite r,* in a manner that enables a remote agent to gain awareness of *W* for cross-boundary decision support. This requires us to specify the context attributes that obtains, as well as the actions that are executed, at *W*.

The predicate *obtainsAt(E, W)* defines the practice *E* that is true of a work setting *W*. Section 6.2.2 shows the derivation of *E* from low-level actions that occur when entities assume roles. The predicate *isDefinedIn(E,* $\mathbb{D}$*)* means that practice *E* is defined in domain $\mathbb{D}$; *happensAt(E, G, t)* means that practice *E* occurs at organisation *G* at time period *t*; *hasBel(G, N)* means that organisation *G* has belief in proposition *N*; *hasStereotype(G, hasBel(G, N))* means that organisation G has as stereotype their belief in N; *hasCircum(W, K)* means that a work setting W has a circumstance K.; an activity object, e.g. a patient, could have a circumstance, expressed as *hasCircum*(O_i, *K*). To express that an activityΔ requires a tool T_i, we introduce the predicate *req*(Δ, T_i). Other predicates include *locatedAt(G, R)* meaning that organisation G is located at region R; *hasPolicy(R, L)* meaning region has policy L; and *isaffectedBy(E, L)* meaning practice E is affected by L. Any WPD can be specified based on the three descriptions of type *OPD*, *TPD* and *SPD*. Assume that *OPD* is given by the predicate *isDefinedIn*(E, $\mathbb{D}$), *TPD* given by *happensAt(E, hasStereotype(G, hasBel(G, N)), t)*, and *SPD* given by *hasCircum(req*(Δ, T_i)*, K)*. Then any *WPD* can be given by the axiom:

$$\forall(x) \rightarrow WPD(x) \rightarrow obtainsAt(OPD, W) \land \\ obtainsAt(TPD, Region) \land obtainsAt(SPD, W)$$

As an example, consider a simple domain-level definition of a tiger as a large carnivorous cat species[42]. Hence, at the OPD level we can say that: $\exists(x) large(x) \land carnivorous(x) \land cat(x) \rightarrow tiger(x)$. We denote this as description d_1. However, if Benjamin tells you that during his trip in India, hiking in the jungle, he saw a tiger, you will assume he saw a large frightening animal, yellow with black strips[43]. Therefore, the *TPD* could be defined thus: $\exists(x)\ isFrightening(x) \land hasYellowWithBlackStrips(x) \rightarrow tiger(x)$. However, not all tigers are such. Some tigers are small, white or albino. The use of the stereotype that says that tigers are big, dangerous and yellow with black stripes could have been triggered by a certain motivation, e.g. to view tigers as frightening animals. If you have had a visit to the kanchanaburi temple[44] in Thailand, you might begin to construct a stereotype that relates tigers to a cat stereotype as friendly social animals expressed as: $\exists(x) friendly(x) \land social(x) \rightarrow tiger(x)$. In constructing an awareness of any actual situation, this work argues as a central point, for a formal description such as *WPD* obtained as a semantic distance (Lehmann, 1998) between the sets *OPD*, *TPD* and *SPD*. In order to make sense of an actual situation where one saw a big cat with white stripes in a friend's house, one may begin to draw from the domain definition of a tiger as a cat, large and carnivorous, as well as the India and Thailand tiger stereotypes. Note that often stereotypes

[42] http://en.wikipedia.org/wiki/Tiger
[43] This example draws upon Lehmann's idea of stereotypical reasoning (Lehmann, 1998)
[44] http://www.visitkanchanaburi.com/tiger.htm

are constructed from more than one source, for example, our knowledge about a work situation could be derived from knowledge of policies of the work organisation or local laws of the town where the organisation is located.

6.3 Clinical Work Practice Ontology

Since a major goal of this research work is to investigate the design of e-health systems for cross-boundary CDS based on the realities of the work settings in which the systems would operate, we further investigated a formalisation of the proposed PCA model from the approach of a formal ontology. This was considered necessary in order to 1) to provide a formal approach for describing "the things" that exist in a work setting, 2) to represent located problem-solving as entities, relationships between entities, and their evolution over time as practices; 3) to enable automated "reasoning" over work practices (even if possibly only approximately); and 4) to allow a cost-effective implementation of the proposed practice-aware cross-boundary CDS. In general, the ontology will be used by clinicians, e.g. for knowledge sharing and cross-boundary decision support, by hospital-based health information systems and by medical databases.

In computer science, ontologies are generally understood as "specifications of conceptualisations" (Gruber, 1993) about realities. They are generally regarded as a means of explicating knowledge and providing consensus about a given domain of work (Staab and Studer, 2004), and are used in organising information for human access and for knowledge exchange among software agents. Our aim here, however, is not to go into the detail of the process of ontology development[45], but rather to establish formal ontology as a starting point of a computational model of clinical work practice based on formal descriptions of domain concepts and common terms for the entities, artefacts, beliefs and prevailing circumstances of a work setting. In keeping with the underlying approach in this work, we investigate ontology from a cultural-historical theoretic perspective and, as such, emphasize the dynamic social relationships between individual processes in a work setting. From a CHT perspective, an ontology is viewed as an artifact capable of mediating human activity and, thus, becomes a result of the cultural-historical development of a work community. A key focus is to derive a

[45] See (Gómez-Pérez et al., 2004; Staab and Studer, 2004) for more in-depth discussion of ontologies and major issues of ontological engineering and development.

formal expression of real-world clinical practices and work situations in a commonly supported language with computer understandable semantics. In what follows, we briefly describe *WOrk PRactice ONtology (WOPRON)* as a formal model of a clinical work practice for PCA. We seek to support the claim that this ontology is a reasonable candidate for representing various instances of clinical work contexts across organisational and regional boundaries, and would, as a result, provide a basis upon which formal representations of arbitrary contexts of clinical work situations can be constructed for the purpose of designing computer systems for cross-boundary CDS.

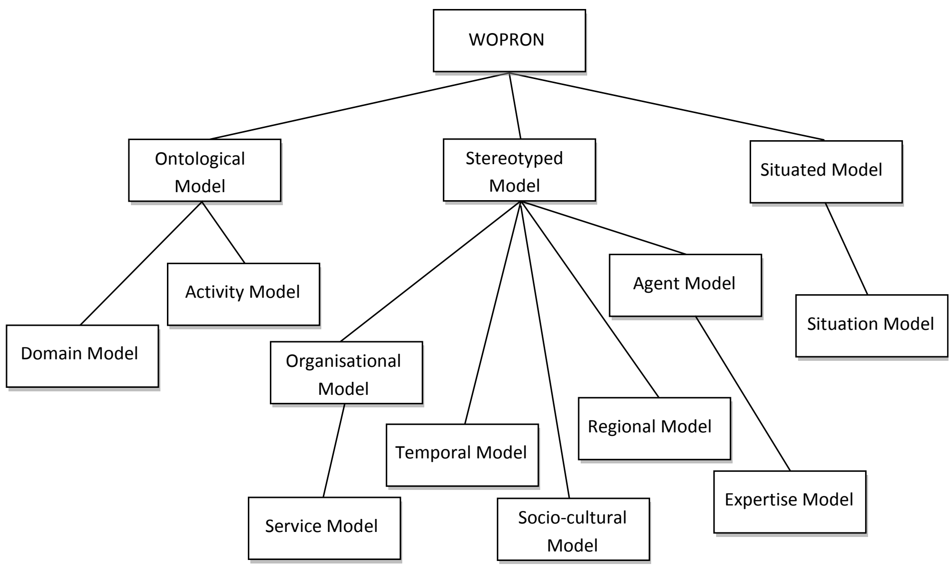

Figure 6.5: General model of WOPRON

6.3.1 Ontology Design

In designing WOPRON, we seek to enable the sharing of a common understanding of clinical work practices in a given work setting between a user (e.g. a clinician) and a suggestion provider (e.g. a human, a software agent or an autonomous system) in terms of: 1) the domain-based conceptualisations of an activity, 2) the spatio-temporal and organisational descriptions of work, and the local and socio-cultural elements of a work environment, and 3) the prevailing circumstances and situational factors about a clinical work situation. These correspond respectively to the ontological, stereotyped and situated views of clinical work practice.

WOPRON is design as a *loosely-coupled ontology* (Figure 6.5). To represent the real nature of work practice, an ontology has to be one that reflects the complex interdependencies among the operation of the real-world systems that are an inherent part of the broader health system. As shown in Figure 6.5, such ontology would incorporate models from multiple domains, e.g. a city's regional model and a clinical activity model. Healthcare stands together in a complex composite relationship with many other real-world systems, including drinking water systems, transportation, food production, housing, economy, social services, etc. that have far-reaching health effects (Tan et al., 2012). Any clinical decision-making process, as a result, would typically involve the consideration of numerous factors that lie outside of the health system.

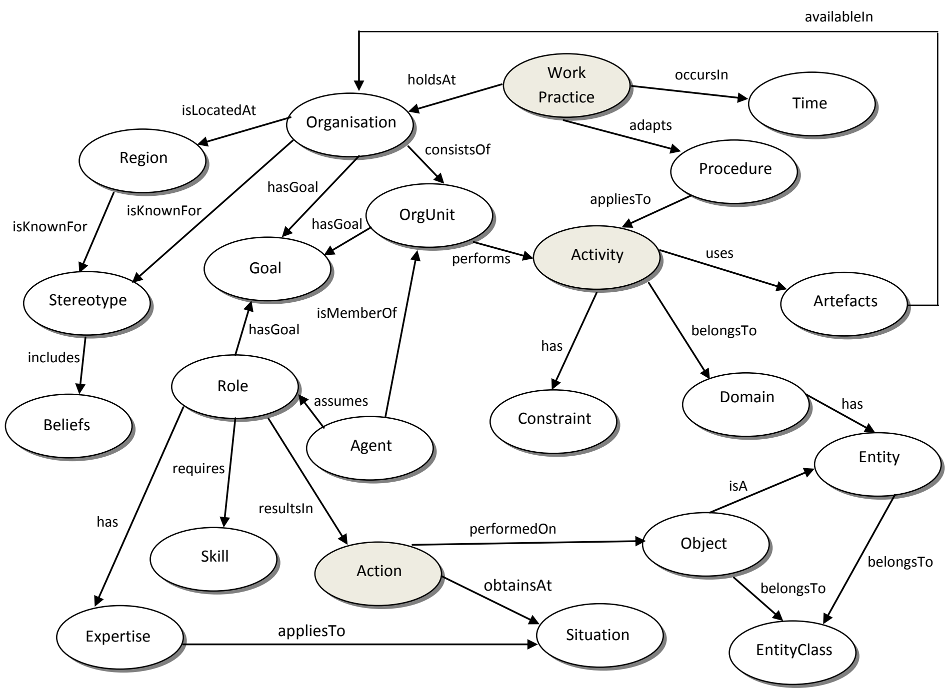

Figure 6.6: An integrated work practice model based on WOPRON

Figure 6.6 show an integrated model of WOPRON highlighting action (at the micro-level), activity (at the meso-level), and work practice (at the macro-level). In order to enable a formal approach for reasoning over work practices, the ontology was designed to provide a true representation of a clinical process as well as the complex situation of care. As a result, the ontology includes aspects of the domain, the organisation in which work is carried out, and the context of work in a formalised and structured format. Such a structured knowledge base allows the system to be more easily customized for different regions, hospitals and patients. Knowledge of the domains as well as organisational, regional and circumstantial factors provide metadata that can be utilized to enhance the description of work context and to build process and situation intelligence into the system. Figure 6.7 depicts the main portion of the WOPRON ontology we developed to satisfy these requirements. It is modelled using UML[46]. The "#Work Situation" class defines a work setting (context) to consist of a collection of goals. The "#Entity" class consists of objects (conceptual and physical) that have roles defined by the "#Role" class within a work setting. The "#Role Type" of an entity give rise to actions whose values are dependent on the "#ValueFunction" defined by the "#Work Practice" class.

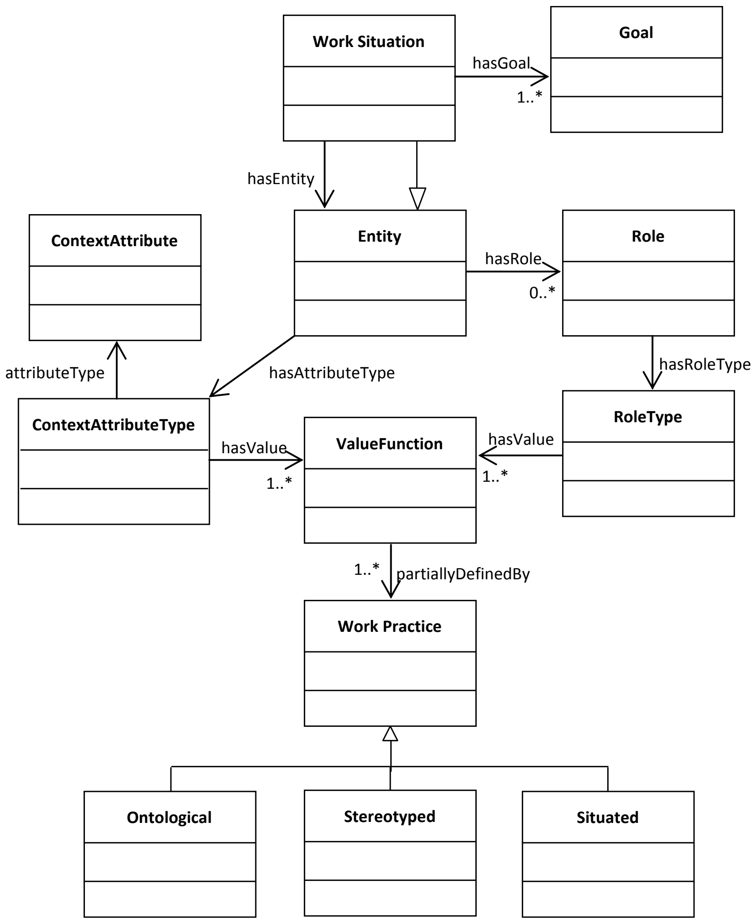

Figure 6.7: UML representation of WOPRON ontology

The development of the clinical work practice ontology proceeded over a period of about six months, and involved the consideration of a wide range of alternative approaches and tools. The most challenging aspect of the design, however, revolved around the problem of representing values of attributes and relations that not only evolve over time and space, but are dependent on personal circumstances and changing organisational work contexts. Where

[46] http://www.uml.org/

necessary, we will illustrate the various alternatives and how we have settled for our chosen options. The development process involves a number of stages. First, determine the domain and range of ontology. This involves defining the domain with the goal of providing answers to the questions that the ontology would cover and determining the potential uses of the ontology. We modelled the WOPRON ontology using Protégé ontology editor; Figure 6.8 shows a view of the concepts defined by the ontology.

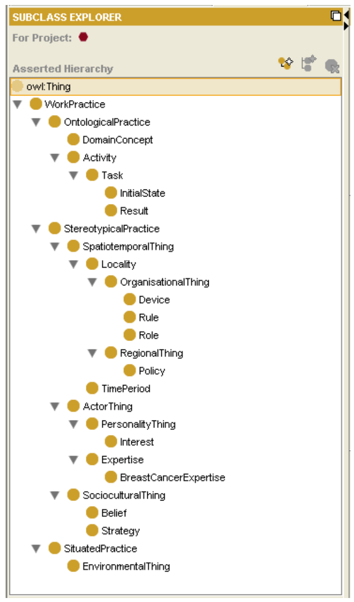

Figure 6.8: A view of the classes in WOPRON ontology in Protégé

Second, consider the use of existing ontologies. Our aim here is to investigate how much of available (ontological) knowledge can be used as input to generate the WOPRON ontology. An ontology for representing a clinical work situation should cover both domain and application-relevant knowledge which is specific to a healthcare organisation involved in the project and the circumstances prevalent in the place and time of work. Additionally, the usage of the ontology required a maximal coverage of the vocabulary used by clinicians as an inherent part of their reasoning "in practice". WOPRON includes a number of (sub) ontologies, e.g. domain ontology, situation ontology, organisation ontology and regional ontology. We define two of those, namely domain ontology and situation ontology.

The domain ontology is used to define all concepts that will be used by CaDHealth to describe a clinical work process. In our domain ontology, we define the “#Entity” class as a super class of all concepts, e.g. in our post-operative breast cancer case study, “#Hospital”,

“#Patient”, “#Oncologist”, “#Guideline”, “#Residential Home”, etc. are subclasses of entity. Classes “#Ontological”, “#Stereotyped” and “#Situated” are subclasses of the class “#Practice” (see Figure 6.7). We depict below (Listing 6.1) the OWL definition of some root and subclasses in our domain ontology. We have defined (i.e. declared the existence of) the root classes: “#Hospital”, “#Location”, “#Activity”, and “#Practice” with its subclasses “#Ontological”, “#Stereotyped” and “#Situated”.

Listing 6.1: OWL definition for work practice descriptions

```
...
<owl:Class rdf:ID="#Practice"/>
  <rdfs:subClassOf>
    <owl:Class rdf:ID="#Ontological"/>
    <owl:Class rdf:ID="#Stereotyped"/>
    <owl:Class rdf:ID="#Situated"/>
  <rdfs:subClassOf>
<owl:Class rdf:ID="#Hospital"/>
<owl:Class rdf:ID="#Location"/>
<owl:Class rdf:ID="#Activity"/>
...
```

In our situation ontology, we seek to encapsulate all information required to define and instantiate a clinical work setting. A system based on this model acquires the information by the perceiving the work environment in order to update its knowledge about the state of the environment. In our implementation, WOPRON is able to categorise perceived information into static information (information based on domain specification), derived information (information based on the stereotypes of the place and time of work), and perceived information (information based on prevailing or changing situation of entities in the work setting). Figure 6.9 shows an example of a work situation ontology model.

Listing 6.2: Context attribute definition for work practice descriptions

```
...
ContextAttribute rdf:ID="roleOfDeviceInWorkSetting">
   <nameAttribute>rolePlayed</nameAttribute>
        <normativeRole rdf: resource="#Ontological"/>
        <stereotypedRole rdf: resource="#Stereotyped"/>
        <circumstantialRole rdf: resource="#Situated"/>
        <valueType rdf: resource="#Role"/>
</ContextAttribute>
...
```

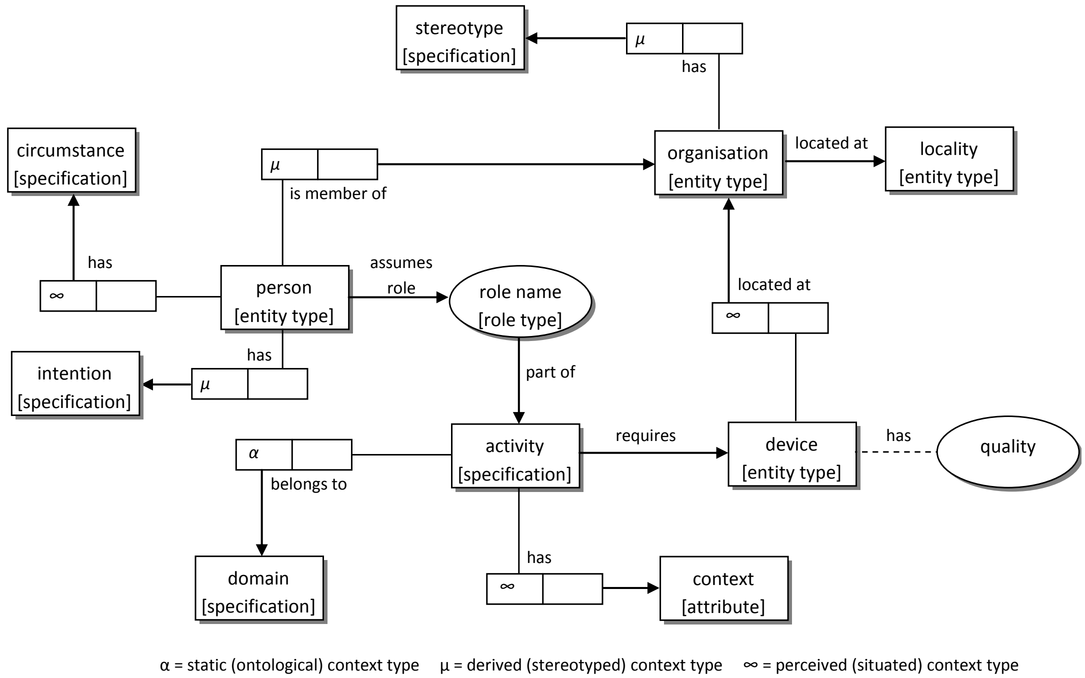

Figure 6.9: Example work situation ontology model

Given the structure, a "#Person" entity assumes a "#Role" to perform an action that is part of an activity. Actual performance of the activity is affected by the state of the work setting as perceived in a situation model. We present in Listing 6.2, a definition describing the role of a device used in a work setting. From the definition, the *valueOf* of a context attribute returns one or more values of type *valueType* that is dependent on the value of the normative, stereotyped and situated roles

6.4 PracticeFrame: Representing Work Practices

A central notion in the approach adopted in this research work is the concept of a work practice – a model of how people actually perform their activities within a physical and social environment – denoted as a work setting. To represent work practice in CaDHealth, we introduce a representational unit called PracticeFrame. A PracticeFrame is *a data structure containing the items for representing elements of a work practice in a computational system*. The aim is to connect together information used to describe work concepts and processes – at the domain level, as stereotyped schemas, and as actualised in a real-world situation – into a coherent whole capable of conveying awareness of the problem situation to an agent across the boundaries of the work setting. A PracticeFrame draws upon the notions of a frame

(McCarthy and Hayes, 1969), a *workframe* (Clancey et al., 1998), and a situation model (Endsley et al., 2003). It contains a state description of work practice, and specifies particular approaches and solutions to given problems in relation to prevailing real-world circumstances. PracticeFrame is depicted succintly as shown in Figure 6.10.

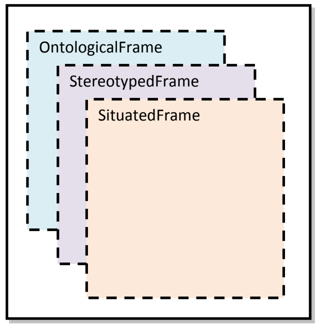

Figure 6.10: Overview of PracticeFrame structure

PracticeFrames are organised in a hierarchy that represents work process in terms of what is being done (the micro-level), how it is being done (the meso-level), and where, when and why it is done (the macro-level). It seeks to portray how actions are effected in executing the tasks that are part of activities within the context of work practices. It shows the various ways by which a particular task could be performed, and *why* an agent or a group has preferred a certain approach to others. A distinguishing feature of PracticeFrame lies in its potential to represent the evolution of a people's "way of doing" in a spatio-temporal space. That is, it represents a work setting in relation to the performance of an activity at a particular place and time, and views a workspace not only as a physical or mathematical concept, but also as an anthropological one (Resmini and Rosati, 2011, p. 68). The ontological, stereotyped and situated frames are sub-classes of the PracticeFrame. The ontological frame consists of actions as specified in the domain knowledge, for example, there are actions permitted in the course cancer treatment within the domain of medicine. The stereotyped frame includes stereotyped (i.e. likely) in the spatio-temporal context of work, for example, there are "likely" actions expected in the treatment of cancer as a result of being in certain places, e.g. in the UK where there is the NHS and in Nigeria where private hospitals are prevalent. The situated frame includes actual actions performed in the course of the cancer treatment.

Table 6.1: Example construct of a PracticeFrame

PracticeFrame

#Header_frame

work description: text
locality: name of place
time-period: date
name of organisation: name
requisite: set r of user queries and problem requirements
work goal

 # ontological_frame :

Δ_{AS} : set of elements of the activity system as defined by domain knowledge
ORAS(r): ontologically relevant attribute set with respect to r
C_i: set of domain context items, including required expertise, resources and problem-solving methods (PSMs)
set of domain specifications
set of domain entities
set of ontological roles
set of domain permissible actions

#Stereotyped_frame

Δ_{AS} : set of elements of the activity system as is likely obtained in the locality and time
SRAS(r): stereotyped relevant attribute set with respect to r
C_i: set of stereotyped context items, including availabilities, e.g. available expertise, beliefs, intentions, resources and PSMs
set of stereotyped entities
set of stereotyped roles
set of likely actions

#Situated_frame

Δ_{AS} : set of elements of the activity system as exists and perceived from the environment of work
SRAS(r): situated relevant attribute set with respect to r
C_i: set of situated context items, including available expertise, resources, patient's history, costs and PSMs
set of actual entities
set of actual roles
set of actual actions
set of percepts

#End

As shown in Table 6.1, a PracticeFrame consists of four sections, called frames. The first frame is header, which provides declarative information about a work setting and the problem being solved, including the place and time of work, and the work goal. This is similar to a header file in C language, for example. The remaining three frames describe the work setting and practices at the ontological, stereotyped and situated levels respectively. Figure 6.11 depicts PracticeFrame as a data structure; at the macro level, actions are represented as a vector storing pointers to the collection of actions in the PracticeFrame. At the meso and macro levels, PracticeFrame is described as class definitions.

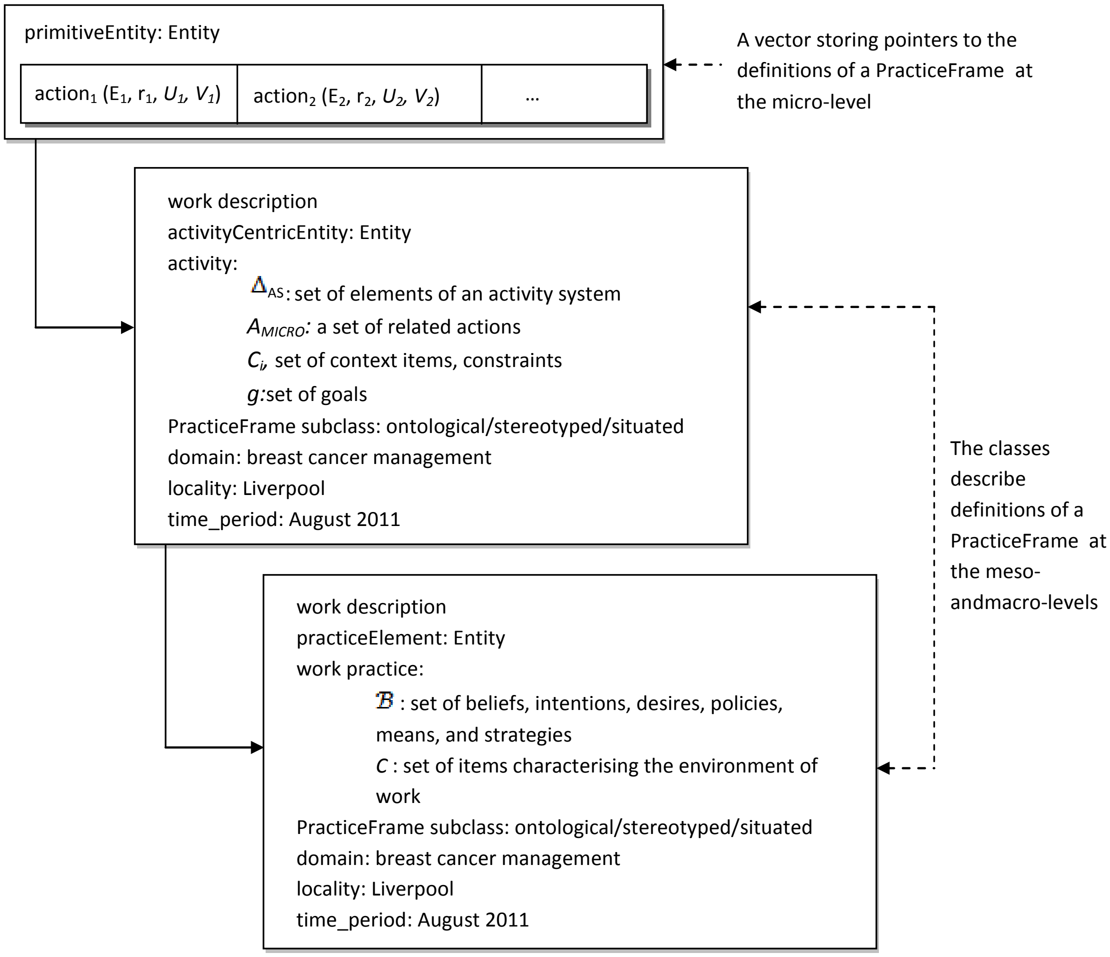

Figure 6.11: A data structure representing the relationship between action, activity and practice in a PracticeFrame

6.5 Formalising ContextMorph

In cross-boundary decision support, a remote agent (e.g. a collaborating expert) informally starts with two pieces of information: 1) information about a user's work setting and problem situation *W*, which is usually obtained from the user's query *q* or the system's precept *p*, and 2) information about the agent's own work setting *W'*. Such information could be represented as PracticeFrames. The challenge for the agent is to build an awareness (i.e. a representation) that is as close as possible to the real situation of work in *W*. In this section, we will formally describe a computational model of the process of constructing this awareness based on the concept of ContextMorph introduced in Chapter 5. The process involves a knowledge fusion, whereby the agent seeks to make sense of *W* based their own work situation in *W'* by aligning similarities and comparing differences between the two work settings in order to generate a representation of the context and problem requirements in *W*. This fusing process occurs at three levels, i.e. the ontological, stereotyped and situated levels (see Figure 6.12), and is aimed to enable the agent *to reason over the user's work practice* in three related stages that involve *ontological, stereotyped and situated reasoning* processes.

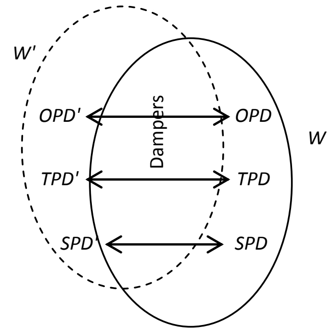

Figure 6.12: ContextMorph process showing the role of dampers

The user-centred study in Chapter 4 reveals that the difference in clinical practices and local work contexts between W and W' are moderated by two crucial factors: adherence to best practice guidelines and the need for patient-centered care. Taking a cue from (Schmidt et al., 2007), we refer to these factors as *dampers* on work practice variability. Dampers are essentially used as devices to modulate the degree by which local practices (e.g. improvisation techniques) deviate from domain rules. Dampers are usually boundary practices used to ensure standard across the local practices of multiple organisations (see Chapter 5). ContextMorph consists of two major processes: in the first process, the practice awareness information (PAI) is generated; in the second process, the suggestion provided by the agent is augmented and adapted to W. It is extremely help to view the first process as an association between the description of an actual work situation W, the set of all possible descriptions of such work setting within a given domain μ, the domain specifications about how the given problem is solved $\mathbb{D}$, and the damper (as the modulating device). The best description for W is the description closest to $d(WPD, \mathbb{D}) \leq d(\mu, \mathbb{D})$, where d is measured as the semantic distance between the sets OPD, TPD, SPD and $\mathbb{D}$.

Listing 6.3: Operations for PCA generation process

Require: parameter *W* is the information set describing the user's work setting or contextualised case
Require: parameter μ is the set of all possible descriptions of a given problem-solving situation within the domain $\mathbb{D}$
Require: parameter *r* is the problem requisite obtained from user query q or system generated precept
Require: parameter *damper* is a vector of string describing the coordinative artefacts and practice used for damping variability in work practice during ContextMorph
Require: parameter *W'* is the information set describing the remote agent's work setting
Generate *OPD, TPD, SPD*
  OPD ← getOntologicalPractice(string *W*, vector<string> $\mathbb{D}$ [domain], *ORAS(r)*)
  TPD ← getStereotype(string *W*, vector<string> organisation, vector<string> region, string history, *TRAS(r)*)
  SPD ← getSituatedPractice(string *W*, vector<string> precept, *SRAS(r)*)
Get *OPD', TPD', SPD'*
  OPD' ← getOntologicalPractice(string *W'*, vector<string> $\mathbb{D}$)
  TPD' ← getStereotype (string *W'*, vector<string> organisation, string region, string history)
  SPD' ← getSituatedPractice(string *W'*)
GENERALISE(*OPD', TPD', SPD') → WPD'*
GENERALISE(*OPD, TPD, SPD) → WPD*
DEFINE(WPD, $\mathbb{D}$) → {d | d ∈ $\mathbb{R}$, d(*WPD*, $\mathbb{D}$) ≤ d(μ, $\mathbb{D}$)}
COMBINE(*WPD, WPD', damper)* → [0,1] ⊂ $\mathbb{R}$
GENERATE_PRACTICE_AWARENESS_INFO(*WPD, WPD', r*) → *PAI*
return (*PAI*)

We define sets of operations for the ContextMorph process (see Listings 6.3 and 6.4). The operators act on partial descriptions of work practices. They include: GENERALISE(*OPD, TPD, SPD) → WPD:* takes three sets of partial descriptions of a work setting *W*, which are obtained on the functions getOntologicalPractice(), getStereotype() and getSituatedPractice() respectively. GENERALISE() finds the most appropriate set of descriptions *WPD* for *W*. DEFINE(WPD, $\mathbb{D}$) → {d | d ∈ $\mathbb{R}$, d(WPD, $\mathbb{D}$) ≤ d(μ, $\mathbb{D}$)}: determines whether a set of work practice descriptions for a work setting WPD complies with the specifications of the domain of work $\mathbb{D}$. COMBINE(*WPD, WPD', damper)* → [0,1] ⊂ $\mathbb{R}$: computes the similarity between two work practice descriptions by applying a similarity metric so as to combine the work practice descriptions using *damper* as modulator. MORPH_SUGGESTION(*WPD, sugg*) → {s | s ∈ 2^S, s ≠ ∅}: determines whether a suggestion *sugg* can be "morphed", i.e. transformed to the context and requirements of a work setting given by *WPD*. MORPH_SUGGESTION() yields a value s, which is element of the power set of S, where S denotes a dynamically defined set of items that ascertains whether *sugg* is morphable, organisation-specific, region-specific, or domain-defined, or whether the evidence in the suggestion is based on theory, research, experience, organisational or regional policy, custom and practice, or trial and error}. GENERATE_PRACTICE_AWARENESS_INFO(*WPD, WPD', r*) → *PAI:* generated

PAI for the remote agent, and AUGMENT_SUGGESTION(*WPD, sugg, r*) → *adapted_sugg:* augments sugg as a structure for supporting user decision.

Listing 6.4: Operations for the ContextMorph process

Require: parameter *W* is the information set describing the user's work setting or contextualised case
Require: parameter μ is the set of all possible descriptions of *W* within the domain $\mathbb{D}$
Require: parameter *r* is the problem requisite obtained from user query q or system generated precept
Require: parameter *damper* is a vector of string describing the coordinative artefacts and practice used for damping variability in work practice during ContextMorph
Require: parameter *W'* is the information set describing the remote agent's work setting
Require: parameter *PAI* is the system generated practice awareness information
Require: parameter *sugg* is the textual description of the remote agent's suggestion
Generate *OPD, TPD, SPD*
    OPD ← getOntologicalPractice(string *W*, vector<string> $\mathbb{D}$ [domain], *ORAS(r)*)
    TPD ← getStereotype(string *W*, vector<string> organisation, vector<string> region, string history, *TRAS(r)*)
    SPD ← getSituatedPractice(string *W*, vector<string> precept, *SRAS(r)*)
Get *OPD', TPD', SPD'*
    OPD' ← getOntologicalPractice(string *W'*, vector<string> $\mathbb{D}$)
    TPD' ← getStereotype (string *W'*, vector<string> organisation, string region, string history)
    SPD' ← getSituatedPractice(string *W'*)
GENERALISE(*OPD', TPD', SPD')* → *WPD'*
DECONTEXTUALISE_SUGG(*sugg, WPD')*   */* De-Contextualise sugg with reference to WPD'*/*
GENERALISE(*OPD, TPD, SPD)* → *WPD*
RECONTEXTUALISE_SUGG(*sugg, WPD)*   */* Re-Contextualise sugg with reference to WPD */*
DEFINE(WPD, $\mathbb{D}$) → {d | d ∈ $\mathbb{R}$, d(*WPD*, $\mathbb{D}$) ≤ d(μ, $\mathbb{D}$)}
COMBINE(*WPD, WPD', damper)* → [0,1] ⊂ $\mathbb{R}$
GET_DEGREE_OF_CERTAINTY(*sugg*) →{dc | dc ∈ [0,1] ⊂ $\mathbb{R}$
MORPH_SUGG(*WPD, sugg*) → {s | s ∈ 2^S, where S = {"organisation-specific", "region-specific", "morphable", "domain-defined", "theoretical", "research", "experiential", "policy", "custom and practice", "trial and error"}, s ≠ ∅}
AUGMENT_SUGGESTION(*WPD, dc, sugg, r*) → *adapted_sugg*
return (*adapted_sugg*)

6.5.1 Reasoning over Work Practices

Any subset of work practice descriptions may be applicable to multiple work settings. As a result, we need to consider sufficient attributes of each work setting in the ContextMorph process so as to infer a work situation with high degree of certainty. Usually, reasoning is performed over all possible descriptions μ of *W*, often referred to as the "frame of discernment" (Denoeux, 1999), in order to determine the description with the highest likelihood. In what follows, we further illustrate a formalisation of ContextMorph using the Demspter-Shafer theory (DST) of evidence (Shafer, 1990; Kłopotek and Wierzchoń, 2002). As noted in (Denoeux, 1999), DST allows dealing with absence of preference that results in indeterminacy due to limitations in available information and resources for problem-solving. In using DST, we assume that descriptions of work practices constitute “a structure of beliefs”, i.e. sets of organisational and situational issues that guide and shape problem-solving in a work setting. Generally, beliefs that influence decision-making in a clinical work setting are derived from three primary sources: the domain of work, the stereotypes about the work setting, and the circumstances of problem-solving in this setting. Any such description *WPD* is represented by a set of information items denoting a view of *W*. *WPD* contributes its impact by assigning a belief. This assignment is called the *basic belief assignment* denoted by the function $m{:}2^{\mu} \rightarrow$, [0,1], which assigns an evidential weight to $WPD \subseteq \mu$. So, according to WPD’s description, the probability of a description is given by a “confidence interval”: *[Belief(W), Plausibility(W)]*. The lower boundary of the interval is the belief measure, which accounts for all evidence that supports the claim that *WPD* is an actual description of *W*:

$$Belief(W) = \sum_{WPD|WPD \subseteq \mu} m(WPD)$$

The upper boundary of the confidence interval is the plausibility confidence, which accounts for all evidence that do not rule out the given description (e.g. domain specification that lends credence to a description):

$$Plausibility(W) = 1 - \sum_{WPD \cap \mu \neq \emptyset} m(WPD)$$

For each possible description, DST gives a rule for combining the evidence in the descriptions. According to this rule, the orthogonal sum m_1 and m_2 is given by:

$$(m_1 \oplus m_2)(A) = \frac{1}{K} \sum_{B \cap c = A} m_1\,(B) m_2(C)$$

Where K = $\sum_{B \cap c = A} m_1\,(B) m_2(C)$ for A $\neq \emptyset$ and m($\emptyset$) $= 0$.

Based on the computed belief attached to a WPD, a system is able to make a conclusion about the actual description of W using rules that seek to enable inferences based on what is known about the ontological, stereotypical and situated factors in W. This approach to reasoning over W directed towards action resonates with the idea of practical reasoning (Bordini et al., 2007, p. 39). Consider the rule in Listing 6.5:

Listing 6.5: An example rule for ContextMorph process

```
likely_factor (A, B)
        : = factor (A, B) [F ← DEFINE(WPD, 𝔻) | F ← percept]

likely_factor (A, B)
        : = factor (A, B) [dc ← GET_DEGREE_OF_CERTAINTY(sugg) ∧
        dc > threshold ∧
        ¬ in_conflict_with (damper)]
```

The first rule states that the most likely factor in a work practice description is the one defined based on WPD and domain specification $\mathbb{D}$, or the one perceived by the system. If the rule fails, then the likely factor becomes the one with the degree of certainty associated to it greater than a given threshold, and provided there is no strong conflict between the factor and the damper.

6.6 System Prototyping

Preceding discussions have focused on the main abstractions and mechanisms of the approach proposed in this work. In this section, we describe an end-user prototype application driven by this approach. We refer to the prototype as **C**ontext-**A**ware cross-boundary clinical **D**ecision support system in e-**Health** (CaDHealth). CaDHealth is designed as a *practice display system*. The content of the display is a visualisation of the PracticeFrame – a representation of located clinical problem-solving based on the ontological, stereotyped and situated work practice descriptions. The use of visualisation techniques or "displays" to represent knowledge (Novak, 2007), work contexts (Bardram et al., 2006), expertise (Huang et al., 2006), and awareness information (Dourish and Bly, 1992) at the interface level is not new. However, what is new, as far as we know, is the use of the approach to represent work processes at the work practice level. In designing CaDHealth, we aim to address the issues uncovered during the user-centred in Chapter 4. CaDHealth is developed as a frame-based representation of the situations and circumstances of a clinical work setting. To a large extent, the design was inspired by Gabbay and le May (2011)'s model of "clinical mindlines" as a representation of the situated, internalised and practice-centred guidelines that serve as a clinician's knowledge-in-practice-in-context (p. 101). As depicted in Figure 6.13, CaDHealth supports users in two principal ways:

- Through the provision of Practice Display: This describes the *practice information,* which the systems provides to a collaborating expert in a remote work setting to enable them to gain knowledge (i.e. awareness) of the user's work practice situation and patient's needs in order to enable them to offer appropriate suggestions, and
- Through the provision of Enriched Decision Support Information Display: The suggestion provided by a collaborating expert is *enriched by the system* by infusing into it more information (e.g. from the system database) and *morphed for contextual adaptability* in order to provide the user with context-aware information (and enriched suggestion) to support their clinical decision.

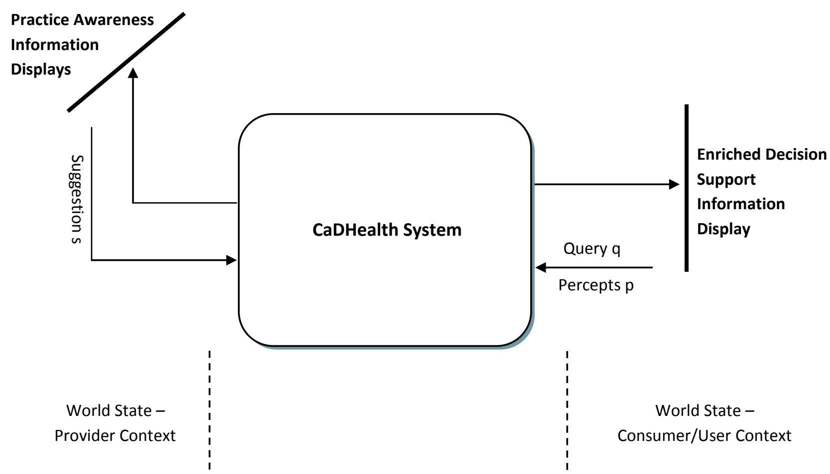

Figure 6.13: CaDHealth showing the two types of information provided for cross-boundary clinical decision support in e-health

6.6.1 CaDHealth Archtitecture

CaDHealth has been designed as an interactive practice information display system that allows clinicians to maintain awareness of work situations and problem requirements across work settings for cross-boundary decision support. From an HCI perspective, our task involves designing the system with the capability, 1) to enable awareness of work situation across regional and organisational boundaries, 2) to support clinical decision based on a wide raging factors that include cultural, circumstantial and interactional factors that influence how work actually gets done "in practice" as opposed to an abstract top-down functional model of an organisation's work process, and 3) to avoid supplanting a clinician's judgment.

CaDHealth is designed as part of a hospital's integrated e-health system[47] in order to portray the system's ability to illuminate the role of stereotypes, situated and interactional factors in clinical decision making. Secondly, such approach is necessary for standardising practices across regions and organisations, and by incorporating guidelines and evidence-based information (as dampers), it ensures that local work practices are clinically compatible and that their independent application does not compromise patient safety (IOM, 2001).

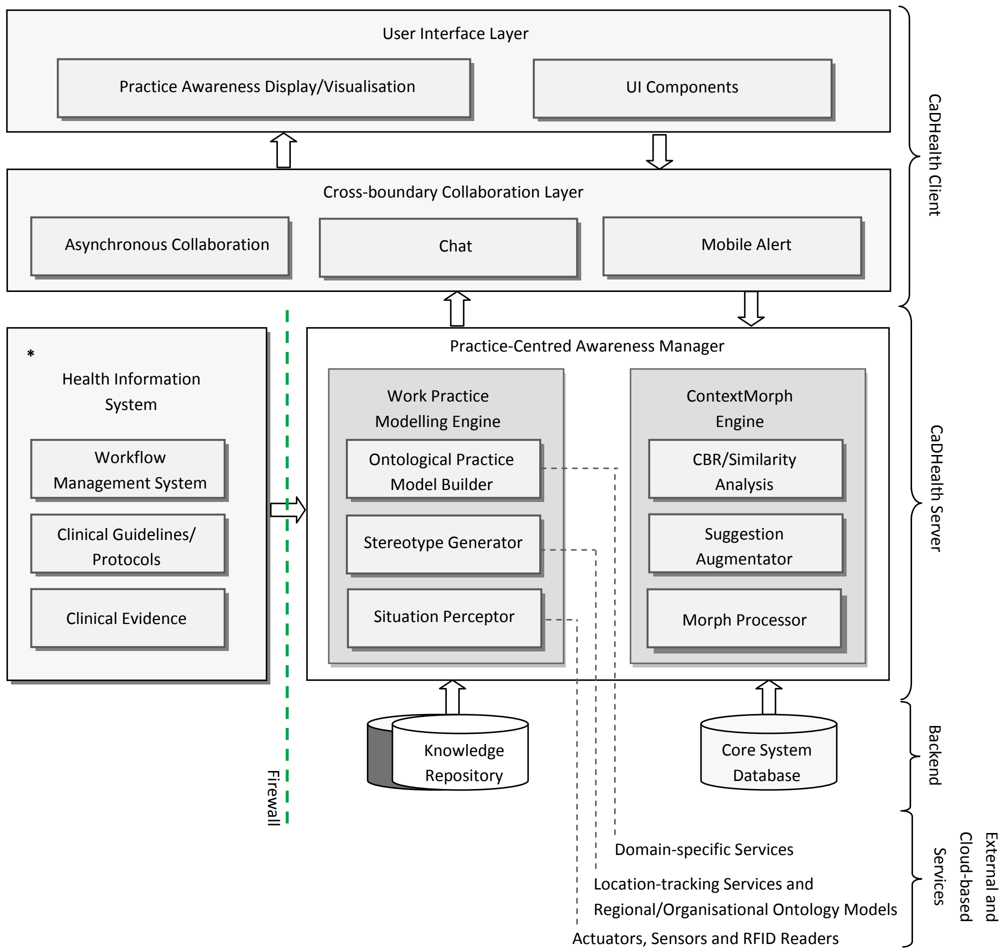

Figure 6.14: The system architecture consisting of the user interface components, the cross-boundary collaboration layer, and the knowledge layer. The component labelled Health Information System***** (HIS) denotes a hospital's existing HIS and is not part of the CaDHealth system.

The system architecture of CaDHealth is illustrated in Figure 6.14. The system consists of three main components: the CaDHealth user interface (UI) layer, a cross-boundary collaboration layer and the PCA Manger. The UI and the cross-boundary collaboration layers are designed as client-side applications, whereas the practice-centred awareness (PCA)

[47] The approach was largely informed by the outcome of the user-centred study reported in Chapter 4 where clinicians expressed preference for a cross-boundary decision support system that is integrated into their hospital's health information system or broader e-health system.

Manager, integrated into a HIS, constitutes the CaDHealth server. The backend include a knowledge repository and the core system database. The knowledge repository stores domain models and practice models and percepts, i.e. the semantic, practice and perceptual memories respectively; the core system database is the working memory and stores clinical work processes and practice-aware decision models. In addition to these components, the infrastructure is potentially able to connect to external and cloud-based services, such as location-tracking services, sensors, actuators, RFID (Radio-Frequency Identification) readers, situation models as well as regional, organisational and domain-specific services. Because CaDHealth is integrated into a hospital's larger HIS, the architecture includes a firewall, which ensures that 1) sensitive patient information, e.g. in patients' health record or a hospital's institution guideline, is *annonymised* before being used in cross-boundary decision support, and 2) only authorised and authenticated agents and services are granted access.

As shown in Figure 6.14, CaDHealth is designed following a multi-tier system architecture in which the client, server and backend sides as well as required external services could reside physically on different nodes on a network. However, the CaDHealth infrastructure is logically a peer-to-peer distributed system. What this means is that a component of the infrastructure, namely the PCA Manager, is deployed on all devices participating in the system setup. This implies that users and collaborating agents are able to participate in practice-centred cross-boundary decision support by sharing information (as peers in a distributed smart workspace) in the context of a user's work setting and problem-solving requirements. Essentially, the device that generates a percept within the user's work setting or that accepts user query in any cycle of cross-boundary decision support acts as the de facto server or "super-peer" (Bardram et al., 2012). Whereas a query-driven cycle, i.e. a cycle of decision support initiated by user query, follows the traditional request-response model, a percept-driven cycle follows an action-notify type of interaction, in which "perceived" changes in user work setting invoke appropriate handlers that ultimately result in alert messages for cross-boundary decision support.

The main components of the PCA Manager include the Work Practice Modelling component and the ContextMorph engine. The Work Practice Modelling engine organises a work description (WPD) into three constituent parts, namely domain factors, stereotypes about how the work is performed in the given locality, and perceived entities and their relationships within the work setting. The ContextMorph engine adapts a remote suggestion to user work setting using three low-level processes: similarity analysis, suggestion augmentation and morphing. The client end comprises two components: the cross-boundary collaboration layer and the UI layer. The collaboration layer handles interactions between user and collaborating agents across work boundaries, whereas the UI layer handles the visual displays of awareness and decision support information. The implementation processes and usage of the components will be described in details in the next two sections. The backend layer of CaDHealth comprises four distinct memories (see Figure 6.15).

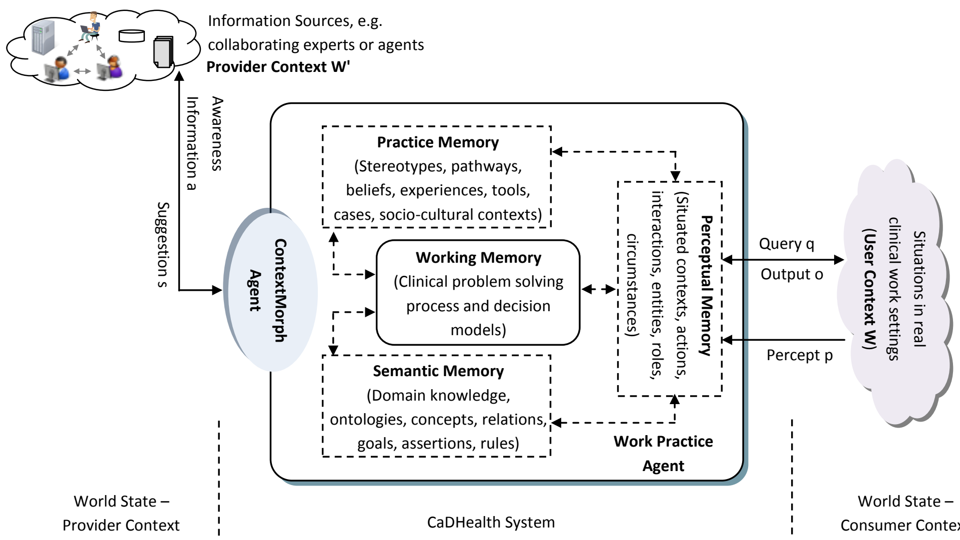

Figure 6.15: CaDHealth architecture illustrating the system memory

Our aim is to represent memory in CaDHealth as a “boundary artifact” that holds the state of a work process (Ackerman and Halverson, 2000, p. 63). As shown in Figure 6.15, the system memory includes *the working memory, the semantic memory, the practice memory*, and *the perceptual memory*. The working memory is the part of the system holds information that is actively in clinical problem-solving, reasoning and decision making, and makes it available to other parts of the system. An example of such information is a decision model. The semantic memory stores domain and concept-based knowledge related to a clinical work process. The third category of memory in CaDHealth, the practice memory, stores traces of an organisation’s past activities, practices (i.e. work approaches) employed to perform the activities, and experiences. The idea of practice memory resonates with Ackerman and Halverson’s (2000) notion of organisational memory. However, practice memory is more holistic in its approach since it embodies the ontological, stereotyped and situated factors of an organisational work process and patterns. Examples of information stored in the practice memory include practice models and their instances, e.g. work stereotypes, pathways, clinical cases, work experience information. The perceptual memory stores information about entities perceived in a work environment, their categories and relationships between them. As they noted, the representational state of a work context, as stored in the working memory, in moving across organisational and regional boundaries, must necessarily lose some of its context. As a result, the ContextMorph agent, performs the decontextualisation and recontextualisation processes required to ensure that sufficient details about user work context is passed across boundary to the remote agent and that the suggestion provided by the remote agent is adapted to suit user work context and problem requirements.

6.6.2 Proof of Concept Example

The central design objective of CaDHealth is twofold: 1) to facilitate awareness of work practices and contexts across organisational and regional boundaries and 2) to enable clinical decision support at the work practice level. To meet this objective, CaDHealth was designed to incorporate three components: *the practice display, the ContextMorph component*, and *enriched decision support*, and reflect the three steps involved in implementing CaDHealth. The practice display is generated by the work practice model. The ContextMorph compares the suggestion provider's work practice and that of the user, and transforms the suggestion to suit user work practice and problem requirements. The enriched decision support provides the user with a rich set of information to support their decision making. In what follows, we describe these components in details. However, we will do this in the context of the example scenario described in Chapter 5. The overall implementation is depicted in Figure 6.16.

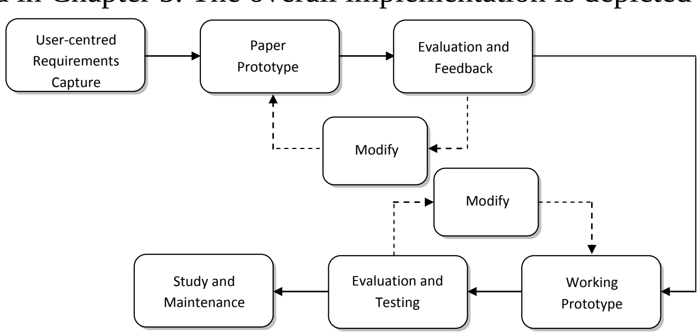

Figure 6.16: CaDHealth implementation process (Shneiderman, 1997)

Recall that in Chapter 5, we described a clinical work situation (in UAE) for managing a post-operative breast cancer patient. The MDT headed by Bob sought "second opinion" from a UK-based oncologist. Over a period of one month (in April/May 2010), we collected data on the case. The data included descriptions of work situations occurring in the course of providing care to the post-operative breast cancer patient, and were obtained by note taking. Elements of data included work context parameters as shown in Table 6.2. The data describing the context of clinical work situations include ontologically-related parameters (i.e. information obtained from domain specifications of the task of adjuvant therapy), information that could easily be perceived through available hardware sensors, cameras and actuators (e.g. location and time of work), and stereotyped information derived from organisational records and settings, e.g policies, guidelines and available resources for work. Figure 6.17 shows the core implementation architecture of CaDHealth.

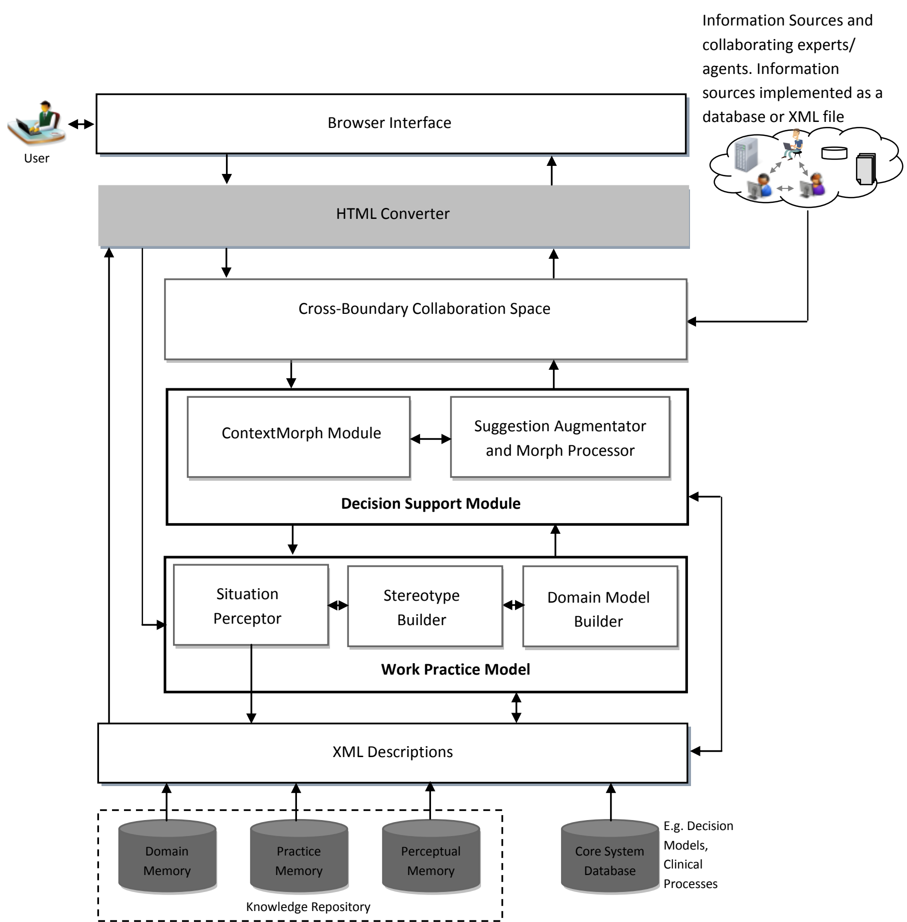

Figure 6.17: Core CaDHealth architecture

Table 6.2: Context parameters describing work situations and practices

Parameter	Sub-parameter	Description
Locality		The region or country where the activity is performed
Organisation		The hospital where the activity is performed
User		The user of the system
Role		The role of the user in the activity
Group		The group consisting of the user and other people involved in the work
Role		The role of the group
Ontologically-related parameters	Activity	The name and description of the activity being performed
	Problem-solving specifications	Domain specifications about the activity being performed
Stereotypes	Policies and guidelines	Norms (at the organisational and national levels) that govern how activities are actually performed
	Available resources	Descriptions of resources, e.g. laboratory services, diagnostic tools, etc., available for post-operative treatment.
Clinical case	Age	Age of patient
	Sex	Sex of patient
	Treatment history	Patient's treatment history with regard to present clinical case
Situational parameters		E.g. a patient's subsequent compliance with any treatment recommendation, risk of relapse, and potential side effects of any course of therapy on patient are usually take into account
Time period		The period (i.e. day, month and year, or just month and year) during which the activity is performed

A key challenge in this example scenario is to enable the system to generate a display of the clinical work practice for this case in such a way that the UK-based oncologist will gain sufficient awareness of the MDT's problem requirements and contribute appropriate suggestions to support their decisions on the case (see Figure 6.18). In the UK, the oncologist uses breast cancer adjuvant treatment guideline as described in (Garibaldi et al., 2012). From the guideline, the complex process of specifying the right course of adjuvant for a patient cannot be comprehensively captured by rules. As such, for the oncologist to gain an understanding of Bob's remote work setting and problem requirement using the guideline poses a challenge.

6.7 Work Practice Modelling Using Brahms

The work context parameters describing the clinical work situation are used in constructing the work practice model (see Figure 6.14). As noted earlier, the data describing the context of clinical work situations are obtained from three broad sources: domain-based specifications of the problem solution, organisational and regional stereotypes and percepts. Figure 6.18 depicts these sources in UML[48], and how the stereotypes (e.g. spatio-temporal associations), domain specifications and percepts (situated practice elements) for the work setting are mapped to entities that construct part of the *WPDs* The descriptions represent knowledge about the work setting and its problem requirement.

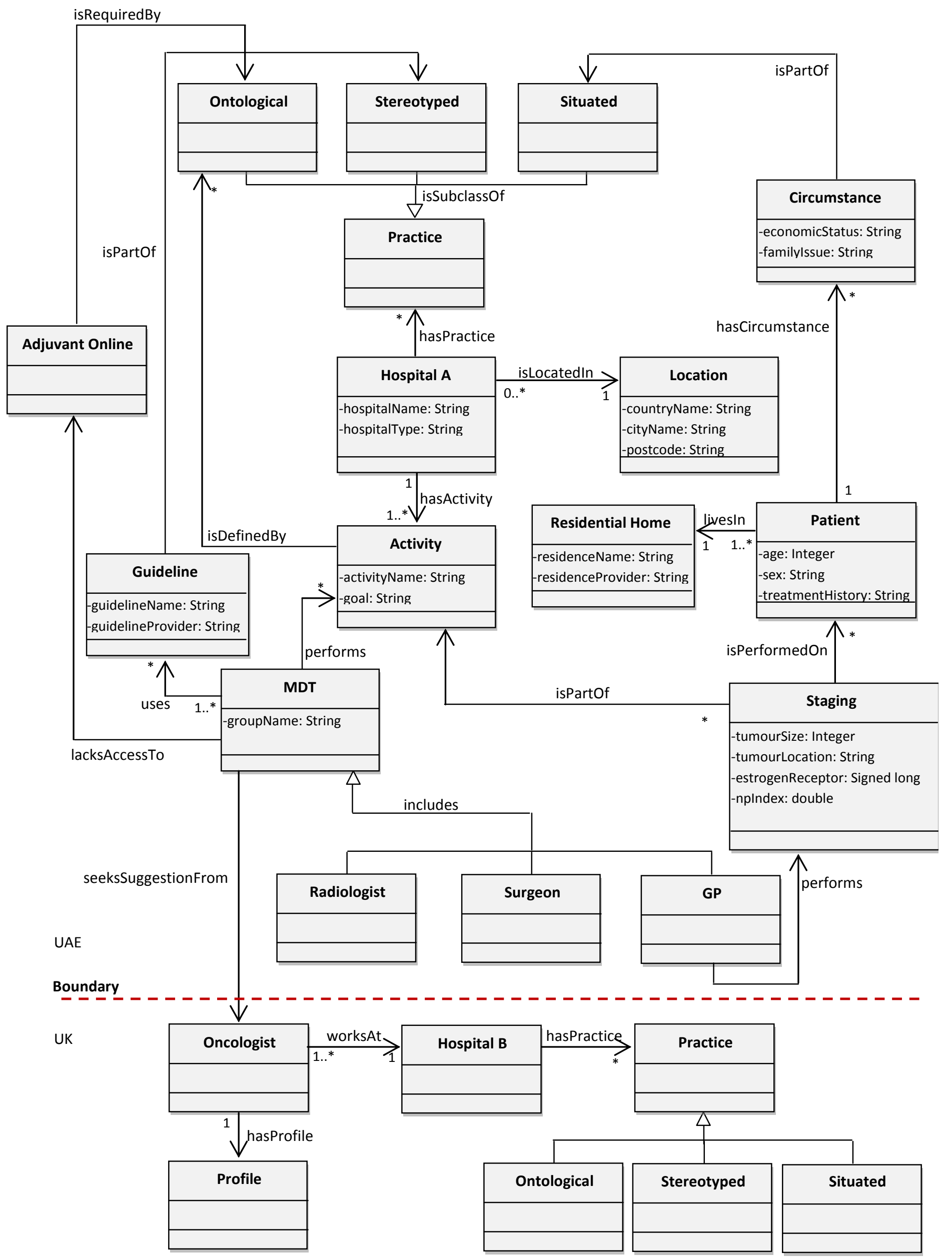

Figure 6.18: UML implementation of the proof of concept example scenario

48 http://www.uml.org/

The work practice modelling component was implemented in Brahms modelling environment[49]. Brahms is a modelling and simulation tool designed to model human work practice that emerges from real-world work processes in organisations (Sierhuis et al., 2009; Clancey et al., 1998). Brahms is an agent-oriented language with well-defined syntax and semantics, and is based on the theory of situated action (Suchman, 1987). The Brahms architecture is organised around representational constructs that include groups, agents, beliefs, activities, workframes, pre-conditions, actions, thoughtframes, etc. Our Brahms model was built around the three broad constructs: the ontological, stereotyped and situated levels (see Table 6.3) in order to effectively model a clinical work practice description. In modelling the scenario, a large number of agents are needed in order to realistically simulate a work practice description. The core agents of our model included Bob (the GP), the surgeon and the radiologist, who are members of the MDT. Other agents included the oncologist and Alice (the patient). Resources were modeled as objects. We represented the Brahms geography model as comprising spatio-temporal objects, and were depicted as mainly as stereotypes of the spatio-temporal space of work. The three main constructs were modelled as follows:

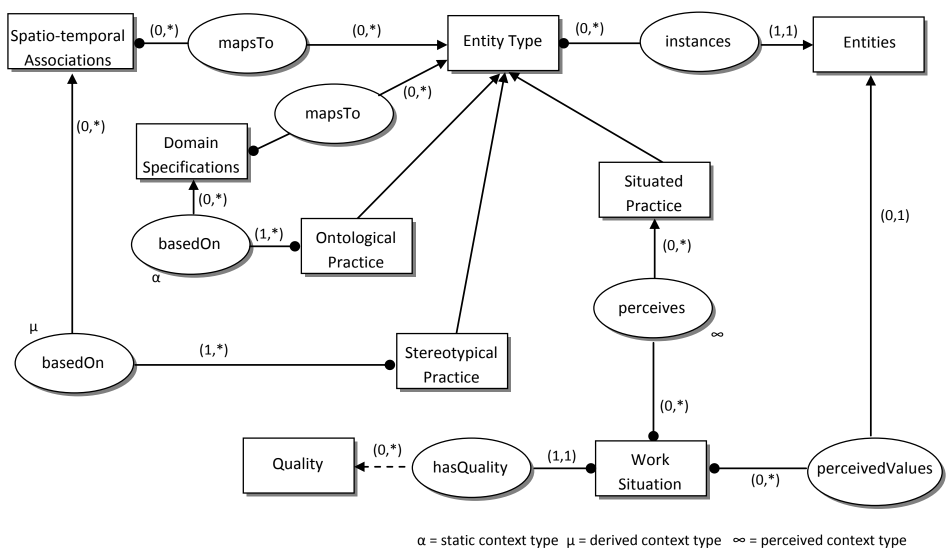

Figure 6.19: Example of how CaDHealth constructs practice knowledge about a work setting

Firstly, the ontological work practice construct is used to build conceptual entities that represent domain conceptualisations of a work activity (e.g. the idea of an adjuvant breast cancer therapy). Next, stereotypes are obtained as derivations of organisational policies,

[49] http://www.agentisolutions.com/brahms.htm

protocols and guidelines. Lastly, percepts are perceived through available hardware sensors, cameras and actuators. Percepts include information such as the locality of work, the user (i.e. Bob) and other members of the MDT group present in the work setting, the date and time of work, and the patient. Issues of generating percepts via hardware are considered as problems of engineering, and are not necessarily critical for testing the applicability of our method; what we have included here is a Brahms implementation for perceiving physical entities whose states change within a work setting (see Listing 6.6). This process is illustrated in Figure 6.19.

Table 6.3: Representation of MDT work setting based on Brahms constructs (Sierhuis et al., 2009)

MDT group consisting of
Users (agents) who work in
Organisation that is located in Region and carry out
Actions that are guided by rules (Guidelines), and are part of
Activities (e.g. Staging) that are shaped by
Work Practices that derived from
Domain specifications (**Ontological**),
Organisational beliefs and peculiarities (**Stereotypes**), and
Perceived Situations of entities in the work setting (**Situated**)

Listing 6.6: A procedure in Brahms for generating percepts

```
Object SituatedPracticeDescription instance of SPD {
        initial_percepts {
                detectable.host = "localhost";
                detectable.port = 9071;
                detectable.timeout = 6000;
                detectable.sensorID = "uae1774";
                detectable.sensorData = 30;
                detaectable.GPSLatitudeLocation = "24°00'N";
                detectable.GPSLongitudeLocation = "54°00'E";
                [...]
                work_setting.EnvironmentalContext = "Hospital Ward";
                work_setting.Clinician.Name = "Bob";
                work_setting.Patient.Age = 57;
                work_setting.Patient.Sex = "Female";
                (situatedPracticeDescription first_sub_activity getSituatedPractice());
                (getPercept());
} // SituatedPracticeDescription
```

CaDHealth minimises user overhead by automatically gathering work practice description information and building representations that correspond to the user’s work setting and problem requirements. The goal of the work practice modelling component is to incorporate into a post-operative breast cancer management task model assumptions about how to describe work situations, clinical work practices, including the effect of such factors as external domain services, logistics, organisational stereotypes, etc., which are normally left out by traditional approaches (see Listings 6.7 and 6.8). Along with these work descriptions, the actual goal of user problem, known as requisite, is stored in the work practice model.

Listing 6.7: A procedure in Brahms for stereotyped practice description

```
Object StereotypedPracticeDescription instance of TPD {
        stereotypes {
                work_setting.SpatialContext = "UAE";
                work_setting.TemporalContext = "AD August 2010";
                work_setting.Organisation.Name = "Morgan's Hospital";
                [...]
                work_setting.Clinician.Role = "GP";
                work_setting.Group.Name = "MDT";
                work_setting.Group.List = GroupList;
                work_setting.Group.NotAvailableRole = "Oncologist";
                work_setting.AvailableArtefact = AvailableArtefactList;
                work_setting.NotAvailableArtefact = NotAvailableArtefactList;
                work_setting.PrevailingPolicy = PolicyList;
                work_setting.GuidelineInUse = "NCCN;
                work_setting.LocalityWellnessRating = "Meduim";
                [...]
                (StereotypedPracticeDescription first_sub_activity getStereotypedPractice);
                (evaluateStereotypedPractice());
} // StereotypedPracticeDescription
```

Listing 6.8: A procedure in Brahms for ontological practice description

```
Object OntologicalPracticeDescription instance of OPD {
        domain_specifications {
                work_activity = "adjuvant therapy";
                work_activity.MedicalCase = "breast cancer";
                [...]
                work_activity.Requisite = r;
                work_activity.RequiredKnowledgeType = "Practice-based Research Evidence";
                work_activity.KnownKnowledgeSource = "NCCN | Cancer Reseach UK";
                work_activity.RequiredArtefact = ArtefactList;
                work_setting.Patient.TreatmentHistory = TreatmentRecord;
                (OntologicalPracticeDescription first_sub_activity getOntologicalPractice());
} // OntologicalPracticeDescription
```

As noted earlier, the situated, stereotyped and ontological practice descriptions are stored in the perceptual, practice and semantic memories. The working memory stores the sequence of tasks that is used to accomplish a given problem. In adjuvant therapy example, we have identified the actual sequence of tasks of the MDT corresponding to Alice's post-operative treatment. These include: 1) acquire patient's details, 2) acquire changes in patient's condition since surgery, 3) examine, and possibly change, medication scheme, 4) note changes, and 5) seek further referrals, which might include a "second opinion" from across work boundaries.

Listing 6.9: A procedure in Brahms for situated practice description

```
Object SituatedPracticeDescription instance of SPD {
        situational_specifications {
                work_activity = "adjuvant therapy";
                work_activity.MedicalCase = "breast cancer";
                [...]
                work_activity.Patient.Name = “Alice”;
                work_activity.Patient.Age=89;
                work_activity.Patient.Gender=Female;
                work_activity.Patient.Circumstance=”lives alone”;
                work_activity.Patient.Circumstance=”has risk of fall”;
                work_setting.Patient.TreatmentHistory = TreatmentRecord;
                (SituatedPracticeDescription first_sub_activity getSituatedPractice());
} // SituatedPracticeDescription
```

As shown in Listing 6.9, the identification of the patient (in this case Alice) is acquired. Based on this, any changes in Alice’s condition are mapped out. Next, the medication and any new test are examined in relation to required domain information and prevailing stereotypes and percepts (as stored in the perceptual, practice and semantic memories). Once the working memory has been populated with “a working clinical case”, a *WPD* of the given work setting is generated. Figure 6.20 depicts the Brahms output of our example scenario model (in AgentViewer). It shows the work practice model of the WPD in Hospital B, a similar WPD in Hospital A, and a visual model of the use of a suggestion emanating from B in Hospital A.

Figure 6.20: An output of Brahms model of a work practice description illustrating the proof of concept example scenario.

In the next section, we will focus on how the Brahms model has been utilised in creating the practice display for the CaDHealth system. In CaDHealth, generated *WPDs* are stored in the core system memory (see Figure 6.14). Periodically, CaDHealth performs work practice model update by retrieving representations of *WPDs*, which match actual workflow processes and which are in turn stored in the core memory for further update.

6.8 Work Practice Visualisation

6.8.1 The Practice Display

The practice display in CaDHealth is a visual representation of a work setting generated in relation to a clinical case and based on a work practice description. The goal of the practice display is to present to a remote collaborating agent visual representations of a user's work setting (i.e. the PracticeFrame-based *WPD* of the work setting) for the purpose of enabling cross-boundary awareness. The display is dynamically configured based on real-time perception of which work context information is, with regard to user's problem *requisite*, relevant at the ontological, stereotyped and situated work practice levels.

The use of displays for visualisation is not new in IS and HCI research, and is considered a promising approach for supporting decision-making (Judelman, 2004). The technique has been applied by researchers to represent knowledge (Judelman, 2004; Novak, 2007), expertise (Huang et al., 2006), awareness (Dourish and Bly, 1992; Gutwin, 1997, p. 85; Bardram et al., 2006; Tadda and Salerno, 2010), context (Judelman, 2004, p. 80), and activity (Geyer et al., 2006; Rattenbury, 2008, p. 91). Generally, the method chosen for conveying awareness information greatly affects how well awareness can be maintained (Gutwin, 1997, p. 77) across boundaries of work. As (Endsley, 1995) puts it, "the way in which information is presented via the operator interface will largely influence [cross-boundary awareness] by determining how much information can be acquired, how accurately it can be acquired, and to what degree it is compatible with the operator's [work situation awareness] needs" (p. 50).

In designing the practice display, we encountered a number of challenges, notable of which is how to convey an accurate visual display of a work situation that accommodates the wide range of factors that can be classified as stereotypes, situational entities or that conform to domain specifications, and at the same time, can be termed to be organisation-specific or boundary-spanning. In using a practice display, a designer is bound to encounter the problem of where and how to locate practice awareness information. We have determined two basic dimensions that provide boundaries for these problems. These dimensions are drawn from 1) the class of the work practice information and 2) the capability of the work practice information to morph into forms that meaningfully adapt to different work settings. We refer to these two dimensions respectively as *class of work practice* and *level of work practice*. The concept of class of work practice enables the system to distinguish whether work practice information is ontologically defined, whether it is a stereotype of a specific work organisation, or a situational element of a work setting. On the other hand, level of work practice implies the likelihood of effectively utilising work practice information in a different work setting other than that from which it originated (see also Chapter 5). These two dimensions combine to form the matrix shown in Table 6.4. On one extreme of the division are situated-local practices, which are situation-dependent organisation-specific practices; they are extremely difficult to morph and adapt for decision support other work setting. On the other end are ontological-boundary practices, which essentially domain-based and work setting independent practices. They are easy to morph, and mainly act as dampers for ensuring standard across local practices during cross-boundary decision support.

Table 6.4: Location of work practice information based on class and level of work practice

		Class of Work Practice		
		Ontological Practice	Stereotyped Practice	Situated Practice
Level of Work Practice	Boundary Practice			
	Local Practice			

The practice display support users in three ways. First, it acts as a portal through which remote agents can access information about a user's work practice, problem requirements, and the changing configurations of user work behaviour. Second, it provides a mechanism for users to reflect on the organisations of their work setting and decision-making behaviours. Third, it acts as a view through which user relate system generated decision support information to their work situation and practices for effective decision support. The display provides support by leveraging on (prevailing) real-world descriptions of what is relevant to the user, thereby providing support in a context-aware manner. The computed relevance of a practice information item determines its size in the display – more relevant information items appear larger in the display and hence easier to access.

By providing a visual representation of the situations and context of user work setting, the practice display enables users to keep track of the organisation of their work space, practices and routines. This could lead to the “externalisation" (Nonaka and Takeuchi, 1995) of the interrelationship between the wide range of factors that define a user’s work practice (see Table 6.5) and their representation in Brahms in Table 6.6. However, achieving such a representation in the light of large amounts of information that clinicians consider “in practice” in enormously challenging. From a HCI perspective, the notion of practice displays enable 1) easy navigation through the wide range of factors that influence clinical work process and decision-making using mouse clicks, 2) changing the relevance of work context attribute within a work setting, and 3) adding, removing and editing practice elements in accordance with problem requirements and work practices.

Table 6.5: Factors considered in post-operative adjuvant therapy besides guideline-based factors

Factor	Value	Category
Cancer detection	Screen-detected, Non screen-detected	Ontological
Menopausal Status: Post-Op Node Status	Pre, Peri, Post	Ontological
(Path)	Negative, Positive	Ontological
Histological Type	Tubular, Colloid, Ductal, Lobular, Mixed, Metaplastic	Ontological
Extensive DCIS	Yes, No	Stereotyped
Clear Margins	Yes, No	Stereotyped
Patient Consent	Yes, No	Situated
Is patient able to attend annual mammography	Yes, No	Situated
ER Status		
Receiving Tamoxifen	Negative, Positive	Ontological
Risk category	Yes, No	Situated
	Low, medium, high	Situated

Figure 6.21 shows a practice display constructed based on the Brahms model. The three circles represent the three classes of work practice: the ontological, stereotyped and situated work practices. Each practice display representation contains icons of files, folders and shapes that represent the resources, people and information about a work situation and a user’s problem requirement. These icons and the information the represent are referred to as practice information items. Although, practice information items are generated by the system, they are based on what the user has manually specified to be true about their work setting. In addition to the visual representations, each practice information item has a textual label, which provides further information about the item, e.g the name, description, or Web address path.

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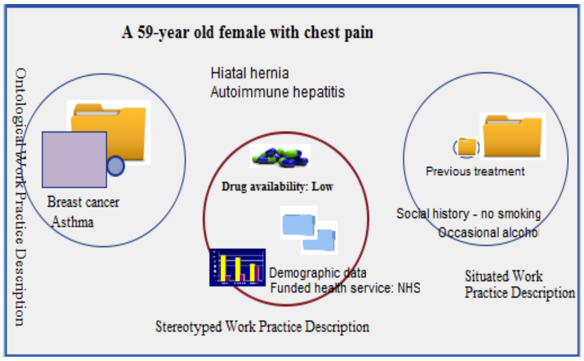


Figure 6.21: An example practice display (mockup) showing the three classes of work practice represented as circles. The size of a practice information item indicates its relevance.

The work practice display representations are updated once per day during offline calculation. In the display, only the most relevant practice information items are shown. The threshold that determines which information items to display is dependent on the most relevant information items for the work setting, which is calculated based on the values relevant attribute sets – *ORAS(r), SRAS(r)* and *TRAS(r)*, where r is user requisite

6.8.2 The ContextMorph Component

The ContextMorph component has been described earlier (in this chapter and in Chapter 5). Without repetition, we focus on its implementation in CaDHealth. In implementing ContextMorph, we introduce the concept of a *remote tele-pointer*. The idea of a remote tele-pointer draws on (Gutwin, 1997)'s use of tele-pointer, and is used here as a visualisation technique to enable the perception of work settings across boundaries by highlighting 1) how ontological, stereotyped and situated practices inter-relate to give rise a user's *WPD*, and 2) how the user's *WPD*, in turn, relates to the remote agent's own *WPD'*. Tele-pointers play a major role in conveying what a person is doing, primarily by showing how the person's actual practices (ways of doing) relates to how the work should be done (as defined at the ontological practice level).

6.8.3 Enriched Decision Support Component

Although research has shown that the cost of developing a user interface for DSS is up to 70% of the total cost of building the entire DSS (Sankar et al., 1995), developing interfaces that are both adaptable and consistent still presents a huge challenge. In CaDhealth, enriched decision support information is provided to the user as a set of options (together with explanations for their suitability to user work setting), from which user makes a choice. In socio-technical systems designs, particularly used for medical decision support, system generated decision options are always made flexible with low level of automation because of the risks and the inability of an automated decision aid to be perfectly reliable.

Table 6.6: Representation of practice-centred factors considered during ContextMorph depicted in Brahms

```
agent ::=
agent Bob memberOf {MDT}
   {organisation: morgan_hospital;}
   {location: liverpool;}
   {time_unit: number;}
   {display: literal-string;}
   {role: oncologist;}
   {device: NICE Guideline, UK}
   practice_frame {
        ontological:
                {conceptual_entities}
                {conceptual_relations}
                {activities}
        stereotyped:
                {available_resources}
                {stereotypes}
        situated:
                {perceived_entities}
                {perceived_relations}
}
```

6.9 A Scenario Example of Using CaDHealth

To clarify how CaDHealth is used to provide PCA of a clinical work situation to a remote collaborating agent and offer enriched information to support user decision-making based on the agent's suggestion, we describe in this section an example of the chain of events that are involved in the interactive use of CaDHealth to provide cross-aware support in clinical decision making. The activity diagram in Figure illustrates what occurs when an unknown clinical work situation is presented to the system, and includes the core functions of CaDHealth prototype. The functions are further described in Appendix C.

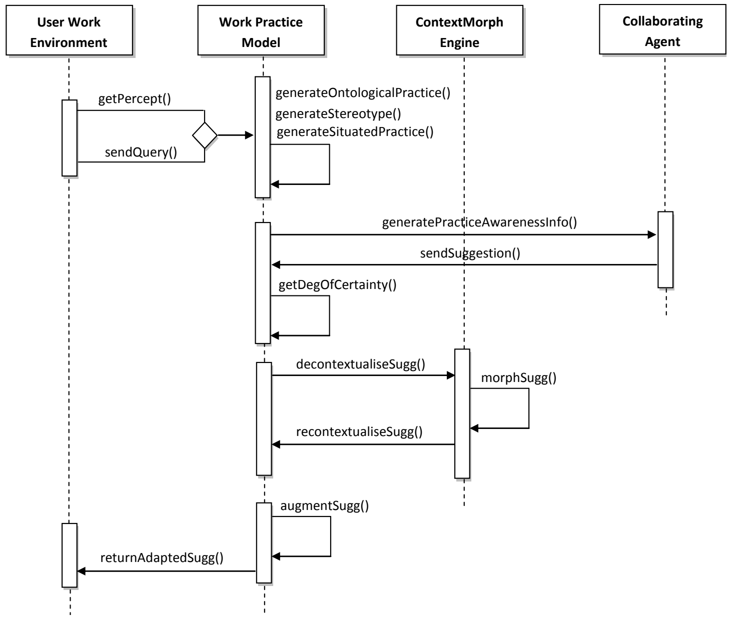


Figure 6.22: Activity diagram showing a decision cycle in CaDHealth

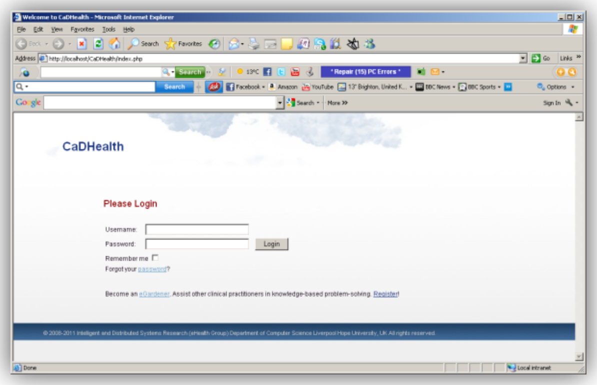


Figure 6.23: CaDHealth login screen.

The starting point for a cycle of decision support in CaDHealth occurs when a user sends a query seeking assistance from a remote agent or when the system automatically perceives a work environment and detects changes in entities' conditions that require further information. This is handled by the functions: getPercept() and sendQuery() respectively. The next step is to update the work practice model based on the new information contained in the user query or system generated percept. Recall that at design time, the functions: getOntologicalPractice(), getStereotype() and getSituatedPractice() were used to construct the initial *WPD*. During update, the functions are re-run based on the new information. On ther basis of the new WPD, the system generates work practice awareness information by executing the function: generatePracticeInfo(), which is sent to a remote collaborating agent as practice display. When an agent sends a suggestion, CaDHealth executes the function sendSuggestion(), and consequently, determines the suggestion's degree of certainty by executing the function: getDegOfCertainty().In order to adapt the remote suggestion to user's work practice, the ContextMorph engine executes three functions: decontextualiseSugg(), morphSugg() and recontextualiseSugg(). Finally the work practice model executes the augmentSugg() function, and, by executing the function returnAdaptedSugg(), returns the enriched suggestion to the user for decision support (Figure 6.22).

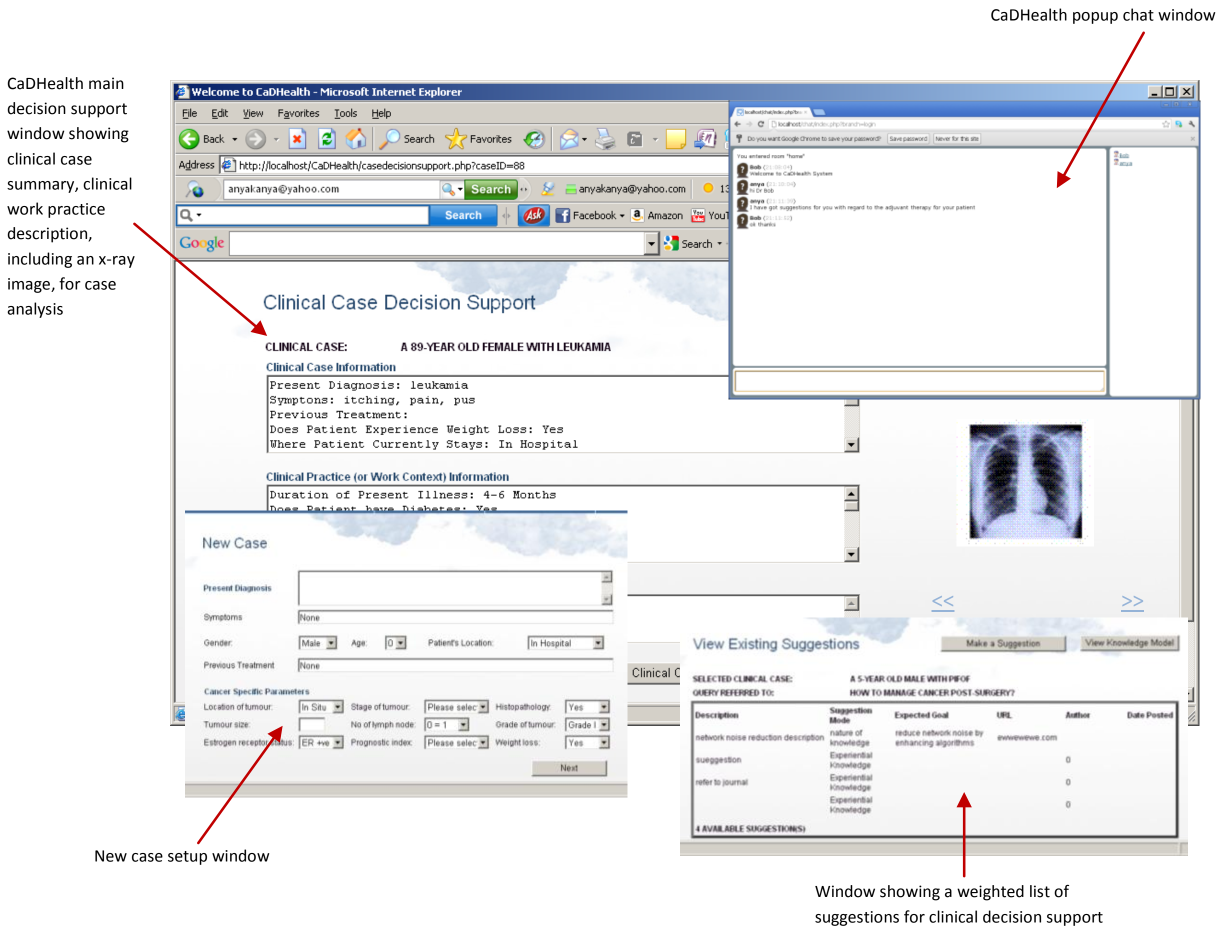
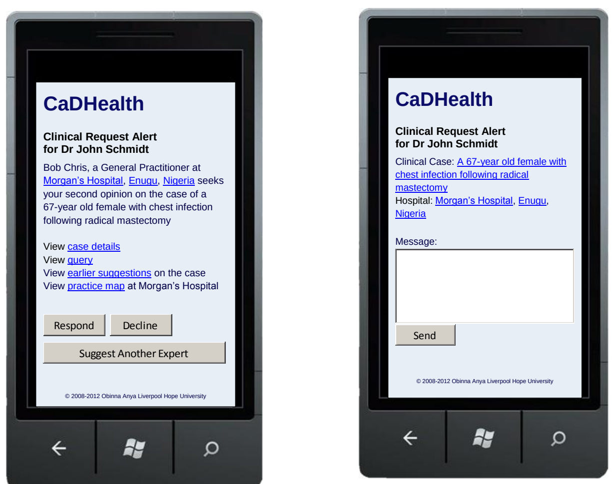


Figure 6.24: Different windows of CaDHealth

Note that CaDHealth is designed to be used by medical professionals, not patients, and in the context of chronic disease management as opposed to emergency situations – with the goal of enabling clinicians to obtain from across their organisational and regional boundaries peer opinion that would enable them to provide for their patients the best possible care tailored to their work practices and patients' needs. Hence, CaDHealth includes a log in interface as shown in Figure 6.23. After a successful login, the user is taken to the main window (see Figure 6.24). This window contains options for setting up a new case and viewing CaDHealth case analysis summary, for viewing ranked list of suggestions for decision support, and for chatting with remote experts. CaDHealth is able to generate practice-aware decision information and match information provided during new case setup to ontological, stereotyped and situated information obtained from the system database. During chat, CaDHealth is able to generate a suggestion from a remote expert's chat message by relying on the user's annotation of the chat message as well as on information obtained from work practice model for the particular clinical case.

Finally, we developed a mockup mobile phone interface for CaDHealth (Figure 6.25). It consists of a a request, i.e. alert message to a remote collaborating agent in (a), and a window for remote agent suggestion in (b).



a b

Figure 6.25: A smart phone (mockup) implementation of CaDHealth showing

6.10 Summary

This chapter presented the operationalisation of the concept of PCA and its application to cross-boundary awareness e-health decision support. We aimed to formalise an awareness of a work setting in terms of what the people do (actions), how, where and when they do it (activities), and why they do it the way they choose to (work practices). In this chapter, we proposed an ontology framework known as WOPRON for formalising work practices, and a frame-based representational unit for work practices known as PracticeFrame. A prototype application, known as CaDHealth, was developed to enable cross-boundary decision support in post-operative breast cancer therapy at the work practice level. Next chapter presents the evaluation of the prototype.

7

Prototype Evaluation

You're not thinking; you're just being logical.

– Neils Bohr (1885-1962), admonishing one of his students

7.1 Introduction

The preceding chapters have operationalised the concept of PCA and discussed the prototyping of CaDHealth as a proof of the concept of PCA for cross-boundary clinical decision support in e-health proposed in this work. As a result, we now have an infrastructure that allows us to look more closely at the hypothesis posed at the beginning of the thesis. In this chapter, we present the evaluation studies conducted to test the claim that supports for the maintenance of PCA in cross-boundary e-health, and to assess and validate the utility and usefulness of the CaDHealth prototype. The evaluations were primarily user-centred, constituting an essential step of the user-centred methodology adopted in this work.

Considering the numerous concerns in cross-boundary awareness and decision support, no single functional real-world test exists that can fully cover the entire architecture. As a result, we have adopted a multi-method evaluation approach with the aim of evaluating the system in terms of user acceptance, awareness and decision support as depicted in Figure 7.1. User acceptance was aimed to assess the usability of CaDHealth using a combination of questionnaires, interviews and observation, whereas awareness and decision support were evaluated as a measure of the accuracy of the system's awareness and decision support information using semi-structured interviews within the framework of Endsley's SAW evaluation technique (1995). In both studies, CaDHealth was evaluated with actual users (i.e. clinicians) in order to ensure generalisability of the results obtained and to see to it that the evaluation takes sufficient account of the socio-technical and local work context considerations that constitute the key elements of CaDHealth awareness information (Li, 2008; Catwell and Sheikh, 2009). Broadly speaking, we aim to assess how the use of CaDHealth enhances cross-boundary awareness and decision support by fitting into the existing structure of work practices and patients' needs of a clinical work setting (Chaiklin, 2007; Li, 2008; Yusof et al., 2008).

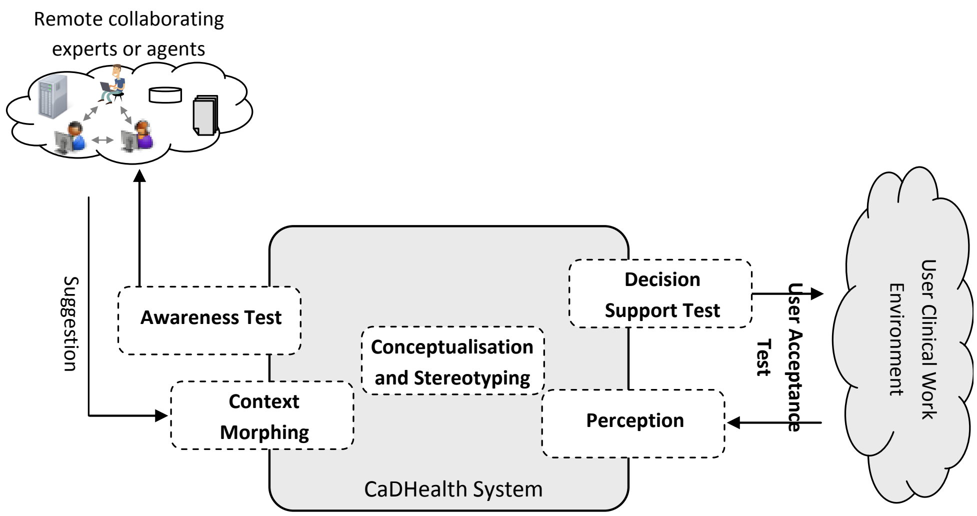


Figure 7.1: Overview of areas covered by evaluation approach

7.2 Methodological Approach

This work is evaluated using multiple techniques taken from usability engineering (Nielsen 1994), as well as standard controlled experimentation for HCI (Rosson and Carroll, 2002; Cairns and Cox, 2008) and awareness systems (Endsley, 1995; Endsley and Garland, 2000) that have been applied, to a large extent, in previous research to evaluate workspace awareness (Gutwin, 1997). These techniques come with strengths and weaknesses that potentially influence the validity of this evaluation study. In his framework of methods for the behavioural and social science, which also applies to HCI and e-health research, (McGrath, 1994) notes that "the meaning of research evidence, in any area of science, is inherently tied to the means and methods by which that evidence was obtained" (p. 152). He outlines the three "desirable features" of research evidence to include generalisability of the evidence across a population, precision of measurement of the behaviour in question, and realism of the context in which the measurements take place (p. 155). However, it is not always possible to maximise all three criteria, since any attempt to increase one tends to weaken the other. In adopting an evaluation methodology that employs experimentation as well as mixed methods surveys (Tashakkori and Teddlie, 2003; Creswell and Plano Clark, 2007; O'Cathain, 2009), we are supported by McGrath's (1994) suggested methodological framework for (evaluation) research study, which incorporates respondent methods, experimental methods, field methods, and theoretical methods.

Our usability evaluation is characterised by two forms of evaluation that have become predominant in HCI and e-health research literature, namely formative and summative evaluation (Scriven, 1967 cited in Rosson and Carroll, 2002, p. 228). Formative evaluation takes place during the system design process and its information is used to further shape the design activity whereas summative evaluation occurs at the end of system implementation and is used to measure if the final system meets its specified goals. As pointed out by (Glasgow, 2007), both forms of evaluation are common in e-health research. Usability evaluation was commenced quite early in the CaDHealth project. As illustrated in Figure 6.16 in Chapter 6, the first phase of this test was conducted to evaluate the paper prototype, whereas a second one focused on assessing the working prototype. The paper prototype provided us an obvious opportunity to collect data for improving the design of the working prototype. In using controlled experimentation, our focus was to concoct a work situation or context like a laboratory experiment, by making it as much like some class of actual behaviour setting as possible (Gutwin, 1997, p. 147). Though critics have pointed out the failure of controlled experimentation to account for the actual ways in behaviour or awareness (Gutwin, 1997, p. 153) is influenced by the real-world, the extent to which a study resembles a real work environment remains a matter of the research design.

7.3 Evaluating User Acceptance

Evaluating user acceptance, also known as usability, is considered one of the major approaches of validating prototypes in HCI and IS research (Shneiderman, 1997; Rosson and Carroll, 2002; Sharp et al., 2007, p. 591, 646). In e-health, usability is highly emphasized since e-health is considered to denote "not only a technical development, but also a state-of-mind, a way of thinking, an attitude …" (Eysenbach, 2001). Hence, an implementation of a context-aware e-health system designed from a practice-centred approach cannot be considered complete without a way of measuring its effectiveness and usability in the context of the already existing clinical work settings in which it is to be deployed (Chaiklin, 2007). It has been pointed out that existing frameworks for evaluating ISs might not, as a result, suffice for emerging healthcare systems; and alternative frameworks have been proposed (Yusof et al., 2008; Bardram, 2008; Li, 2010), including those that incorporate measures for evaluating usability in the context of what (Yusof et al., 2008, p. 386) call “a technological, human and organisational fit”. The usability evaluation was conducted to provide objective measurements on the usefulness and ease of use of our architecture (specifically, in relation to the issues that emerged out of the user-centred study reported in Chapter 4) while, at the same time, investigate the detailed user reaction to the system and the user interface in a more qualitative fashion (Rosson and Carroll, 2002, p. 227; Bardram, 2008).

Using the quantitative measures of perceived usefulness and ease of use, we are able to demonstrate that CaDHealth provides considerable usability and user experience with regard to enabling cross-boundary clinical decision support in e-health at the work practice level. The theoretical importance of perceived usefulness and perceived ease of use as determinants of user behaviour and system acceptance, particularly in the human factors tradition, is well indicated by several lines of research (Davis, 1989; Shneiderman, 1997; Nielsen 1994; Tullis and Albert, 2008; Kofod-Petersen and Aamodt, 2009). Davis (1989, p. 333), for example, reported in two separate studies that perceived usefulness was significantly correlated (r=.63) with self-reported current use, and that perceived ease of use was correlated (r=.69) with self-predicted future use.

7.3.1 Formative Evaluation

Evaluation of the paper prototype, which we refer to in this evaluation study as mock-up prototype, followed the heuristic evaluation method, and was conducted informally by interviewing potential users and observing their reactions during two separate testing sessions in the UK and the UAE that involved 3 and 1 clinician(s) respectively. The technique consists in asking the participants to assess the prototype GUI design using heuristics as guidelines while performing scenarios, and interviewing them at the end of each scenario. The outcome of this phase of the evaluation confirmed that clinicians liked the system, and were intrigued by the idea of a cross-boundary decision support system with the ability to deliver work context information. In addition, they indicated preference for a user interface that can depict awareness information visually, and for CaDHealth to be integrated into a hospital’s existing clinical system for ease of access. They also showed preference for mobile alerts, but would rather they remained less intrusive and do not interfere with normal clinical activities. In utilising the data gathered from this phase of the evaluation, we were guided by the following key questions, which derive from the views of usability experts (Tullis and Albert, 2008, p. 46):

- What are the most significant usability issues that are preventing users from completing their goals or that are resulting in inefficiencies?
- What aspects of the prototype work well for the users? What aspects do they find frustrating?
- What are the most common errors or mistakes users are making?
- What usability issues would probably remain after the final prototype is launched?

7.3.2 Summative Evaluation

Evaluation of the working prototype followed a multi-method approach (Bardram, 2008), and included observational study, the use of questionnaires, interviews and an experimental study, which enabled us to obtain different perspectives and ensure good usability (Sharp et al., 2007, p. 614; Röcker, 2009). Observation, questionnaires and interviews tested usability, whereas the experimental study was designed to evaluate accuracy. Using the test scenario depicted in Figure 7.2, we described to the participants the idea behind CaDHealth, and explained the need for conducting the survey. The sequence diagram shows the messages and methods calls flowing between the CaDHealth components involved. The participant commenced the use of CaDHealth by setting up a clinical case on CaDHealth. A clinical case consists of non-confidential information about a patient, such as age, sex and previous treatment. Based on the case information as well as system captured information, such as social and geographical information about the workplace and area, user query, etc., the system generates a work practice model specific to the clinical case and user problem requirement. First, the system searches its database for any matching suggestion to user query; otherwise, the Work Practice Model initiates cross-boundary suggestion and generates practice awareness information for the collaborating expert. In this scenario, the user and the remote expert engages in message exchange using CaDHealth chat tool. Next, the Work Practice Model extracts a suggestion the collaborating expert's key chat message. This suggestion is decontextualised, morphed and recontextualised by the ContextMorph Engine, and subsequently augmented by the Work Practice Model. Finally, the augmented suggestion is returned to the user for contextualised decision support.

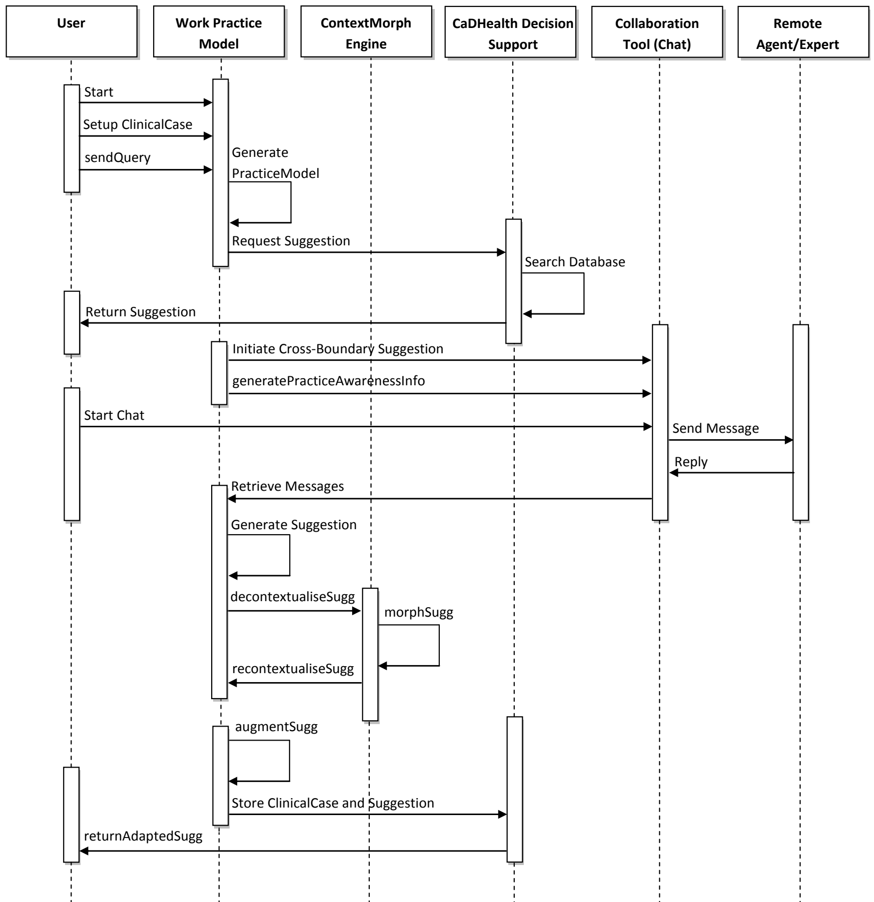


Figure 7.2: A sequence diagram for CaDHealth evaluation scenario

The overall aim of the study was to gather information about how the addition of PCA via practice displays would enable individuals working independently across boundaries to provide suggestions to support one another's decisions in a manner that adapts to user work situation and problems requirements. More specifically, we aim to validate the claim about the effects of PCA on cross-boundary decision support. It was, as a result, expected that *the quality of cross-boundary decision support will increase with the addition of practice-centred awareness information to the system interface*. Overall, the study was experimental, but largely informal without so much control on the situation or the task. Allowing the evaluation process to proceed as normal allowed us to simulate as much as possible a real-world clinical context, and to identify relevant areas of interest during the analysis rather than set out to answer a few specific questions beforehand.

7.3.2.1 Operative Measures for Usability

In this study, we used five operative measures to assess usability, and they include *completion time, perceived usefulness, perceived ease of use, strategy use and overall preference*. However, these measures were used to assess usability indirectly, since the construct is not directly observable. The reason for this, as noted by (Adams et al., 1995) is that awareness is difficult to measure. As a result, our evaluations have focused on measuring usability and utility rather than awareness. This creates three problems. First, awareness is a hidden mental process that provides few if any outward signs (Gutwin, 1997, p. 153). Second, people have difficulty reporting on their own awareness of what they do (see Chapter 4); one implication of this, as (Endsley, 1995) suggests, is that people rate their awareness higher if they have succeeded in a task, and lower if they have not, which may not always hold, particularly in terms of reporting on one's awareness of what another person is doing at a remote location. Thirdly, awareness knowledge is difficult to quantify. For example, if is difficult to describe in words one's awareness of a work situation, then it is even more difficult to assess the correctness and precision of such a description (Gutwin, 1997) let alone its effective value in enabling cross-boundary decision support.

In order to overcome these problems, we turned to three measures of groupware usability suggested by (Gutwin, 1997, p. 152), which fit well with our approach to CaDHealth evaluation. They include the *product, process and satisfaction measures* of groupware usability. The idea is that a participant's use of CaDHealth in facilitating awareness for cross-boundary clinical decision support will have observable effects on the product of clinical decision support, the process of clinical decision support and on the participant satisfaction. In particular, our measures were chosen for the following reasons:

- Completion time is a basic product of decision support performance. It assumes that there is a relationship between awareness information and the length of time of decision making.
- Perceived usefulness is a subjective measure of the degree to which a participant believes that using a particular system would enhance their job performance (Davis, 1989).

- Perceived ease of use is a subjective measure of the degree to which a participant believes that using a particular system would be free of effort (Davis, 1989)
- Strategy use is a qualitative measure that looks at the means and patterns by which work (or decision support) is realised. Strategy use is at the core of this work's research goal, and assumes that a more usable system will take account of, and support, the numerous strategies (i.e. practices) by which a participant seeks to realise work.
- Overall preference is a broad satisfaction measure based on a comparison between systems. It assumes that there is a relationship between overall usability and usefulness, and preference. In this study, overall preference is indicated by the quantitative measure, self-predicted future usage, as well as derived from the interview data analysis.

7.3.2.2 Data Collection and Participant Profile

Participants for the summative evaluation study were recruited using the *samples of convenience method* (Tullis and Albert, 2008, p. 17). Emails were sent out to clinicians who participated in the user-centred study reported in Chapter 4. Seventeen clinicians indicated their intention to participate in the study – 5 (29.41%) from the UK, 9 (52.94%) from the UAE and 3 (17.65%) from Nigeria. Two (11.76%) of the participants are consultants, 6 (35.30%) senior registrars, and 9 (52.94%) GPs. All participants are moderately skilled in using computer systems in daily clinical work. To quantify "moderately skilled", we conducted an initial study in which we observed the participants set up the same clinical case on CaDHealth, and calculated the amount of time it takes to complete the task. We found out all participants took between 5 and 7 minutes to complete the task in comparison with 3 master's degree computer science students at Liverpool Hope University, who took between 4 and 6 minutes to complete the same task.

No distinction was made between the sample three zones – the UK, the UAE and Nigeria – during data analysis. However, the evaluation procedure differs slightly across them. In the UK, the study was conducted during out of work hours, but at the participant's convenience. In the UAE, the evalutation was conducted in the participants' actual work environment. The survey was conducted at a time that would not interfere with the clinicians' normal work, and the participants were provided with separate monitors used primarily, but not exclusively, for demonstrating the prototype. The study was conducted online for the participants in Nigeria. Participants were given the web address of the CaDHealth prototypes, and were asked to assess the prototypes at a time that was convenient for them while the researcher interacted with them via Skype[50]. All evaluations were conducted individually with each participant, and were performed using the same clinical case scenario. Efforts were made to ensure that the effect on the system of the interrelationship among DSSs, users, user's organisation and working environment in a real-world clinical setting was effectively monitored by tweaking the scenario to reflect what normally obtains in each participant's local work setting. This allowed us to more effectively capture the participants' perceptions towards the user interface.

7.3.2.3 Evaluation Task

Participants were presented with a clinical task similar to a real-world situation (following the scenario described by the sequence diagram in Figure 7.2). A diabetic patient management application was used. The task was categorised into two:

- *Task 1* – **Cross-Boundary Awareness Task**: Find, on the practice display, information that enables you to gain more knowledge of a user's work situation and problem requirements about the use of Alpha-glucosidase inhibitors in lowering blood sugar in diabetic treatment.
- *Task 2* – **Decision Support Task**: Find the suggestions that most appropriately match user query about the use of Alpha-glucosidase inhibitors in lowering blood sugar.

The awareness task requires participants to build awareness of the work situation and practices about a clinical case based on the practice display and provide appropriate suggestions, whereas the decision support task enables participants to provide subjective assessement of the adequacy of the enriched information generated by CaDHealth for decision support.

7.3.2.4 Evaluation Procedure

This study adopted the *multi-method evaluation setup* for pervasive and e-health systems reported in (Bardram, 2008), where we:

- Observed the users while they perform the operations while thinking aloud
- Investigated perceived usefulness and usability based on a questionnaire, and
- Made a semi-structured follow-up interview.

[50] http://www.skype.com

A multi-method evaluation approach offered us an ecological perspective for assessing the performance and usability of CaDHealth based on a causal relationship between user goal attainment and system activity (Chandler, 1982; Li, 2010). The data collection method used is described below.

Each participant was introduced to the study, and guided through a tour of the system, its functions, and the practice displays that are part of the prototype configuration. The participant was then observed while they performed the two evaluation tasks using the two design interfaces of the CaDHealth prototype:

- *The mock-up prototype without practice display* and
- *The main prototype with practice display*.

The following questions were used to guide a participant's think aloud process while performing their task: Does the practice display provide the awareness information that I want? Is this information easy to interpret and apply? What clue does it give me about the remote user's clinical work situation, practices and problem requirements? Does it build the necessary background to enable us to easily share knowledge across boundary? How accurate is this information? Does practice display intrude on individual work, either by using up too much screen space or by distracting people from their tasks?

The time to complete the task was recorded with a stopwatch. At the end of the session, which took, on average, ten minutes, the participant was given a questionnaire that explored their experiences using CaDHealth. Finally, a short interview was conducted to investigate issues that arose during the session and to further explore particular responses on the questionnaire.

7.3.3 Design of Observation Study for Usability Evaluation

The observation study used a comparative technique (Blandford et al., 2008; Novak, 2007). In determining usability, this study examined three types of independent variables: 1) the CaDHealth interface type, i.e. whether or not a mock-up prototype without practice display or the main prototype with practice display was being used; 2) the task type, i.e. whether it is an awareness or a decision support task; and 3) the work practice information type, i.e. whether the suggestion provided was of the ontological, stereotyped or situated type of work practice. The dependent variables include task completion time, perceived usefulness and ease of use, self-predicted future usage.

All but the 3 participants from Nigeria took part in this study because of the difficulty in setting up an observation study where the experimenter and the participants are not in the same place.

7.3.3.1 Design of Observation Study

Using the evaluation tasks described in earlier, this study was designed to test whether the addition of PCA information would be useful in enhancing the quality of cross-boundary decision support of system interface. A within-subject experiment was conducted. All participants were tested individually where each participant performed the same set of tasks on both study prototypes: *CaDHealth mock-up prototype without practice display, and CaDHealth main prototype with practice display*. All tests were conducted using a laptop computer. It was explained that the aim of the study was to investigate user satisfaction and performance with the CaDHealth prototype by evaluating whether or not the addition of PCA information to a cross-boundary decision support tool increases the quality of decision support.

7.3.3.2 Task Completion Time Result

The primary aim, in measuring the task completion time, was to test whether participants would generally complete tasks more quickly using the main CaDHealth prototype with practice display than they would using the mock-up prototype without practice display. Completion times for the two tasks are summarised in Table 7.1, and depicted graphically in Figure 7.3 (with error bars indicated). The mean completion time for the awareness task was less when using the main CaDHealth prototype (2.71) than when using the mock-up prototype (3.59). For the decision support task, the mean completion time was also less when using the main CaDHealth prototype (1.91) than when using the mock-up prototype (2.72)

Table 7.1: Summary of task completion times (in minutes)

Task	CaDHealth Interface Type	N	Min	Max	Mean	SD
Awareness Task	CaDHealth Prototype	14	1.80	4.48	2.71	0.75
	Mock-up Prototype	14	2.20	5.02	3.59	0.82
Decision Support Task	CaDHealth Prototype	14	1.05	3.15	1.91	0.58
	Mock-up Prototype	14	1.86	3.85	2.72	0.61

A Wilcoxon Signed Ranks Test showed that participants performed both tasks faster when they use the main CaDHealth prototype than when they use the mock-up prototype as a result of the practice display, and that such difference is highly unlikely to have arisen by sampling error – for awareness task ($z = -3.233$, $p = 0.001$), and for decision support task ($z = -3.296$, $p = 0.001$). Indeed, for both awareness and decision support tasks, the median task completion ratings using main CaDHealth prototype (2.57 and 1.91 respectively) are lower than when using the mock-up prototype (3.26 and 2.65 respectively). Wilcoxon Signed Ranks Test (Cairns and Cox, 2008, p. 126) was considered appropriate because of the small size of the study sample ($N = 14$).

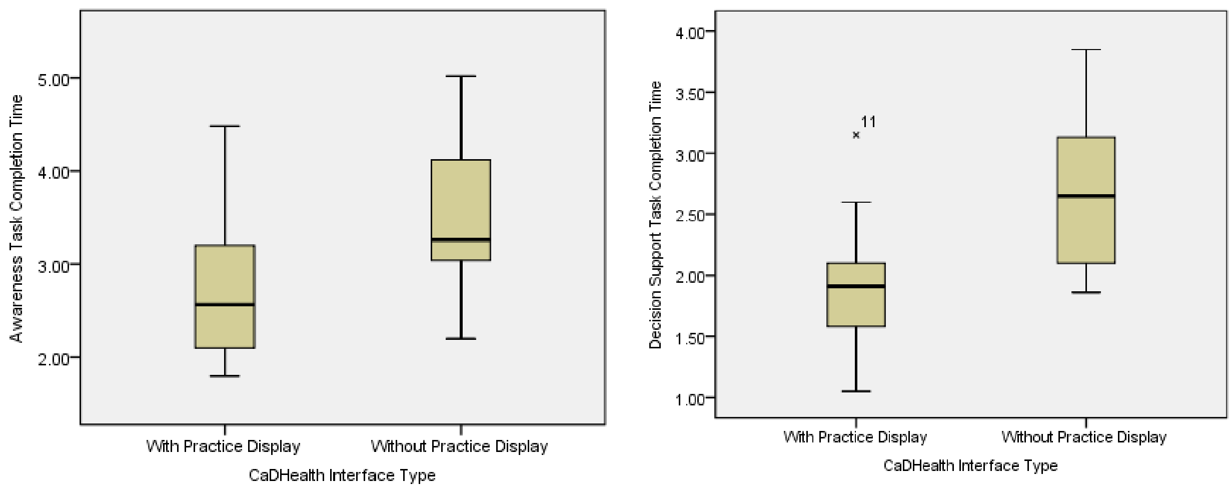


Figure 7.3: Mean task completion times (in minutes) for awareness and decision support tasks using CaDHealth main prototype with practice display and the mock-up prototype without practice display. Error bars represent mean ± SEM (standard error of measurement). N = 14; Wilcoxon signed Ranks test for awareness task ($z = -3.233$, $p = 0.001$); for decision support task ($z = -3.296$, $p = 0.001$). Since the participants performed the tasks differently in different situations, the error bars indicate the influence of such differences on participants' performance of the evaluation tasks, such as situation of work and level of expertise in participants' use of IT, etc.

7.3.4 Questionnaire-based Evaluation

Next, we discuss the questionnaire, which, as noted earlier, is completed by each participant at the end of the evaluation session. The primary aim of the questionnaire was evaluate the product, process and satisfaction measures of the system in terms of user perceived usefulness and ease of use. The questions were designed to reflect the core issues that emerged out of the user-centred requirements capture (in Chapter 4), the formative evaluation study as well as key recommendations of usability experts such as Nielsen’s usability heuristics (1994, p. 115), which remains to date the most widely accepted criteria against which usability is evaluated. We were able to use, with slight modifications, the validated questionnaire presented in (Davis, 1989. Emphasis was placed on those questions that highlighted the core functionalities of CaDHealth rather than trying to get feedback on all issues; this was necessary to avoid overloading the participants in the study. The functionalities were integrated into a representative and cohesive evaluation scenario (see Figure 7.2) that included only the issues that addressed the core focus of this research work. Table 7.2 contains the actual questions used. All questions were scored on a 7-point Likert scale, and responses were translated to interval scores using 1 to represent strongly disagree, 2 for disagree, 3 for somewhat disagree, 4 for unsure, 5 for somewhat agree, 6 for agree, and 7 for strongly agree. The questionnaire consists of 13 questions, and participants were asked to rate each question with regard to perceived usefulness, perceived ease of use and self-predicted future usage (Davis, 1989). The quantitative measure, self-predicted future usage, reports the participants' acceptance of CaDHealth as a measure of their intention to use the system in the future. Table 7.2 shows the questionnaire questions used to measure for self-predicted future usage. Open-ended questions were added to identify architectural and domain-related issues perceived by the participants to be supported well or poorly by CaDHealth.

Table 7.2: Descriptive statistics for perceived usefulness and perceived ease of use (on a 7-point Likert scale)

Variable Factor	**Question**	**N**	**Mean**	**SD**
Perceived Usefulness	Using CaDHealth in my clinical decision-making would enable me to accomplish more tasks quickly	17	5.65	0.70
	Using CaDHealth would make it easier for me to do my job	17	5.88	0.99
	Using CaDHealth would enhance my effectiveness at work	17	5.94	0.66
	Using CaDHealth would lead to improvement in my clinical decision making	17	5.88	0.70
	Using CaDHealth would increase my productivity	17	5.41	1.12
	I would find CaDHealth useful in my clinical work	17	5.88	0.86
	Average Perceived Usefulness Score	**17**	**5.78**	**0.53**
Perceived Ease of Use	I find it easy using CaDHealth to set up a clinical case, visualise the clinical case and obtain "second opinion" from remote experts	17	5.24	0.83
	I find learning to use CaDHealth easy	17	6.00	0.79
	I find my interaction with CaDHealth is clear and understandable	17	5.59	1.28
	It would be easy for me to become skillful at using CaDHealth	17	5.65	0.93
	I find CaDHealth easy to use	17	6.18	0.64
	Average Perceived Ease of Use Score	**17**	**5.73**	**0.60**

7.3.4.1 Analysis of Questionnaire Data

Initial exploratory analysis was performed to determine the specific tests to be performed in relation to the main prediction made at the start of this study (see Section 7.3.2). Mean and standard deviation response values are reported for each question and for each overall response average (see Table 7.2 and Table 7.3). In this study, the two key research variables: perceived usefulness and perceived ease of use were derived using appropriate tests of internal consistency and reliability with a Cronbach alpha coefficient of .68 and .66 respectively, which indicate a fairly internal consistency (Pallant, 2010), and are consistent with reports of similar studies (Davis, 1989). Correlation coefficients were computed between these variable constructs. Appropriate non-parametric tests were performed to determine whether our expectations are met; there was uncertainty as to whether the assumptions of parametric statistics are satisfied, given the fact that the data were not normally distributed owing to the small sample size.

Table 7.3: Descriptive statistics for self-predicted future usage (on a 7-point Likert scale)

Question	N	Mean	SD
Assuming a cross-boundary decision support tool like CaDHealth would be available on my job, I believe that I will use it on a regular basis in the future.	17	6.00	1.06
I would prefer using a cross-boundary decision support tool like CaDHealth to other tools like email for seeking "second opinion" from remote experts to support my clinical decisions.	17	5.94	1.09
Average Self-Predicted Future Usage	**17**	**5.97**	**0.74**

7.3.4.2 Results of Questionnaire-based Evaluation

The results of the questionnaire study indicate that participants found CaDHealth both useful (mean = 5.78, SD = 0.53) and ease to use (mean = 5.73, SD = 0.60). Participants showed a high-level willingness to use the system in the future (mean = 5.97, SD = 0.74); 35.3% of the participants indicated that it is strongly likely that they will use CaDHealth on a regular basis in the future, 41.2% agree that it is likely, 17.6% agree that it is somewhat likely, and 5.9% somewhat disagree. 35.3% strongly agree that they prefer CaDHealth to other tools like email for seeking "second opinion" from remote experts to support their clinical decisions, another 35.3% agree, 23.5% somewhat agree, and 5.9% somewhat disagree.

A correlation for the data revealed that perceived usefulness and self-predicted future usage were significantly related, $r = .69$, $N = 17$, $p < .01$, two tails. A similar pattern of correlation was equally found between perceived ease of use and self-predicted future usage, $r = .67$, $N = 17$, $p < .01$, two tails. See Table 7.4. We found p-values of 0.01 for the correlations, which indicate that the correlations could not have occurred by chance. It was concluded that usefulness and ease of use are important determinants of user acceptance. Hence, since most of the participants consider CaDHealth main prototype useful and ease to use, they are likely to use it in the future.

Table 7.4: Correlation between perceived usefulness, perceived ease of use and self-predicted future usage (on a 7-point Likert scale)

Variable		**Mean**	**SE**	**SD**	**N**	**Variable**		
						1	**2**	**3**
1	Perceived Usefulness	5.78	0.77	0.53	17			
2	Perceived Ease of Use	5.73	0.73	0.60	17	0.568*		
3	Self-Predicted Future Use	5.97	0.36	0.74	17	0.693**	0.674**	

* – Correlation is significant at the 0.05 level (2-tailed)

** – Correlation is significant at the 0.01 level (2-tailed)

The questionnaire responses were further analysed using one-way χ^2 (Chi Square) tests. The main variable constructs for this test are summarised in Table 7.5. The results indicate that the addition of practice-centred awareness information to the system interface led to significant increase in the expected number of participants that prefer the main CaDHealth prototype with practice display.

Table 7.5: χ^2 (Chi Square) analysis of main variable constructs

	χ^2	**df**	**p**
Perceived Usefulness	4.176	7	P < 0.759
Perceived Ease of Use	5.765	8	P < 0.674
Self-Predicted Future Use	8.588	4	P < 0.072

7.3.5 Interview-based Evaluation

In addition to the questionnaire survey, semi-structured interviews were carried with the aim of gaining more in-depth understanding of the strengths and weaknesses of the CaDHealth architecture, and obtaining more suggestions for improving user acceptance. In particular, we wanted to gain deeper knowledge about how well CaDHealth supports participants in their clinical decision-making at the work-practice level. This part of the evaluation study followed a socio-technical approach (Li, 2010), and uses CHT as the analytic framework. CHT provides a solid framework for assessing how varying contexts of work support or hinder the development of use by accounting for the dynamic nature of systems in use, right from motive formation to detailed user interaction with the system (Petersen et al., 2002).

Following Engeström's (1987) adaptation of the CHT theory, (Petersen et al., 2002) propose that ISs can be conceptualised in terms of how people learn and understand the use of new technologies. Their framework consists of four questions types, which we use as the primary basis for our analysis of the interview data. They include: i) "*what practices*", which describe the actions and purpose of design, ii) "*how practices*", which are ad hoc models describing the actual usage of the "what practices", iii) "*why practices*", which are general models and principles describing why a particular way of doing something is preferred, and offering explanations of how the system works, and iv) "*where practices*", which include the visions and imaginations that help redefine a person's behaviour or understanding of the change in the overall activity. The four questions also underline our use of PracticeFrame as a representational framework for work practices (see Chapter 6).

Using this conceptual framework and drawng from the grounded theory methodology (see Chapter 4), we analysed the interview data, looking through them repeatedly and noting themes (Tashakkori and Teddlie, 2003; Creswell and Plano Clark, 2007). We were particularly interested in the measure of participants' strategic use, and a number of the themes that emerged include clinicians' personal preferences as well as the policies, interests and values prevalent in their place of work. Our goal was to uncover the less explicit impacts that CaDHealth has on participants' work practices as it seeks to enable cross-boundary decision support within the context of the dynamics between the human, social and cultural environment in which the system is deployed. All 17 participants took part in the interview study. Each interview took about 5-10 minutes. All of the interviews were tape-recorded with the permission of the participant. Standard procedures were followed to maintain confidentiality of the interview data as well as anonymity of the participants.

The interview used primarily a clinical scenario based on the evaluation tasks and aimed to elicit the what, how, why and where questions of the CHT framework being used. The interview questions were developed with the help of two clinicians, and consisted of some core open-ended questions to allow respondents to explain their own views and experiences as fully as possible. By analysing the data collected, we were able to assess how well the practice displays represented a clinician's description of their work practice for cross-boundary awareness and decision support, and how CaDHealth appeared to support their decisions at the work-practice level.

7.3.5.1 Analysis and Results of Interview

The collection and analysis of data were done simultaneously according to the grounded theory approach. Open, axial and selective coding techniques were applied to data (Pace, 2004). The codes and emerging categories – specially the codes related to whether the practice displays showed information that correspond to the strategies that people use during decision making, whether the displays were easy to interpret in relation to the task of constructing awareness of a remote person's work situation, whether the displays intruded on individual clinical work, and how participants felt about the effect of the practice display in generating cross-boundary awareness and in decision support – were used to inform subsequent questions aimed to elicit user experiences. We discuss the themes identified from the analysis under two sub-headings:

Cross-Boundary Awareness

Participants reported that they found the practice display useful in helping them gain awareness of a remote person's work context and problem requirements. They indicated that the information presented on the practice display largely matched their strategies for problem solving, and that the task context model on the display accurately represented the information relevant to their work. Most of the participants noted that a striking feature of CaDHealth is the ability to use three broad categories work practice to identify how people generally derive capabilities for problem solving. Based on representations of the ontological, stereotyped and situated work practices on the practice display, the participants can easily know the what, where, when, how and why of clinicians' organisation of resources to achieve goals.

Practice-Centred Decision Support

One of goals of DSS evaluation is to determine whether the information presented by the system for decision support was the right information for the user. We asked questions about the type and amount of information provided by CaDHealth, how much of the information was provided by the system enrich the original suggestion provided by a collaborating expert, whether there was any conflict, and the strategy taken by the system to resolve the conflict was acceptable to the participant. Most of the participants agreed that the information provided by CaDHealth relates well to their clinical work practice and strategies for problem solving. They noted that a distinguishing feature in CaDHealth decision support approach was the representation of decision support in a manner that reveals the what, where, when how and why of their use of information in decision making.

7.4 Evaluating System Accuracy

Recent research in IS has highlighted the need to take user-centred evaluation beyond typical usability testing, particularly in the wake of new context-aware applications for decision support in complex and dynamic environments. As (Scholtz, 2006) has pointed out, a software application, in addition to being usable, must provide significant utility to the end user population. For a context-aware system designed from practice-centred perspective, a measure of this utility includes how much the system "fits" (Yusof et al., 2008) into an organisation's system of work practices for added benefits. Hence, having ascertained a measure of how well CaDHealth meets usability design guidelines, this part of the study has been designed to evaluate the utility of CaDHealth, in particular the practice display, with regard to enabling cross-boundary awareness and decision support at the work practice level. In this experimental study, participants were asked to gauge the utility and performance of CaDHealth in terms of *work situation classification* and *effectiveness of decision support*. Specifically, the particpants were to determine, 1) given a specific clinical task and work situation, if the system is able to construct a true representation of the situation, and, 2) given a user query based on the work situation and a suggestion, if the system is able to build an appropriate set of enriched decision support information. In addition, we estimate the effectiveness of the practice display in terms of the reduction in the cognitive load of the users.

We adopted the freeze-probe technique – the Situation Awareness Global Assessment Technique (SAGAT) proposed by (Endsley and Garland, 2000), which includes metrics for assessing work situation awareness based on direct measurements. The method has been criticized for trying to quantify a subjective phenomenon (Gutwin, 1997, p. 153), and because scenario freezes may disrupt performance. The method has, however, been applied with reported success in studies focusing on command and control performance (Endsley and Garland, 2000; French and Hutchinson, 2002), and, thus, has strong potentials providing valuable indications as to the effectiveness of an awareness system. Endsley found no significant differences in performance between simulation runs in which the scenario was frozen and those in which the scenario was not frozen. In using the SAGAT technique, our goal was to obtain a direct measure of the effectiveness of the use of CaDHealth in the context of the interrelationship among users, their organisation and environment of work. We did not use Situation Awareness Rating Techniques (SART) – another evaluation technique for SAW because of its subjective nature; the questionnaire and interview evaluation report earlier has enabled us to capture user subjective views. We evaluate this based on the three categories of PCA: the ontological, stereotyped and situated types.

7.4.1 Study Design

Two clinical experts participated in the study. Sampling was purposive and sought clinicians interested in research and cross-boundary clinical decision support who might critically appraise the tool and provide recommendations for its future enhancement. Participants were asked to monitor a simulation of a work practice display. SAGAT uses expert knowledge to develop questions and probes that assess a participant's awareness of a work situation (Scholtz, 2006). It involves freezing the simulation at random intervals during which participants are probed as to their perceptions of the user work situation at that time. Unlike the questions used in the usability study, the SAGAT questions were developed in consultation with clinical experts, so they are relevant to the user's task and more compatible with how clinicians represent clinical decision-making information during the scenario.

The responses to the questions are compared to the user work situations as represented on the work practice display at the time of the freeze. This comparison makes the technique less biased than subjective measures, self-rating or observer ratings of work situation awareness.

SAGAT contains a set of probes that are relevant to the three categories of work practice, namely the ontological, stereotyped and situated work practices identified in this work. In subsequent freezes, questions bordering on random subsets of the work practice categories are asked. Randomisation ensures that all aspects of user work situation, deriving from the ontological, stereotyped and situated factors that shape their problem-solving, are covered, rather than focusing only on supposedly significant questions (French and Hutchinson, 2002). SAGAT probes provide for an objective assessment of a work situation by allowing for detailed information about user work situation to be collected on an element by element basis, via the work practice display, that can be evaluated against reality (Endsley, 1995). Atotal of 47 work situations based on our evaluation scenario were collected. The goal of CaDHealth remains unchanged throughout the scenario.

7.4.2 Results

Since a primary role of CaDHealth was to classify a PCA information item into three categories of work practice, namely the ontological, stereotyped and situated work practice, the accuracy of this classification was used as a performance measure. The accuracy of the system was measured in terms of work practice classification by comparing the practice display information about a scenario with a participant's classification of the same scenario during a freeze. When the work practice category assigned by CaDHealth is different from that of the expert clinician, the specific classisfication is deemed inappropriate. As shown in Table 7.6, CaDHealth achieves a high accuracy of 92.56% (on average) in classifying work practice information items. This high level of performance is achievable as our approach for idenfying work practice information items makes the task of classifying work practice information is pretty straightforward.

Table 7.6: Prediction accuracy in work practice information classification

	Participant A		**Participant B**		**Classification Accuracy (%)**	
	Number of Predictions	**Numbers Correct**	**Number of Predictions**	**Numbers Correct**	**A**	**B**
Ontological Work Practice	24	24	21	20	100.00	95.24
Stereotyped Work Practice	14	12	16	15	85.71	93.75
Situated Work Practice	9	8	10	8	88.89	80.00
Total	47	44	47	43	93.62	91.49

7.5 Summary

The proof of concept prototype has been evauated using two key tasks: a cross-boundary awareness task and a decision support task. User-centred evaluation reveals that the incorporation of PCA into the design of e-health systems for cross-boundary decision support enhances system usefulness, acceptability and user adoption. A key strength of the evaluation procedure lies in the use of multiple methods that combined quantitative, qualitative and the situation awareness evaluation method of SAGAT in order to highlight deeper issues of perceived usefulness and perceived ease and their impact on user acceptance. This result is line with the central goal of usability testing (Davis, 1989; Dumas and Reddish, 1999), and previous studies (e.g. Davis, 1989) note that perceived usefulness is a strong correlate of user acceptance.

8

Conclusions and Future Research Directions

Like goals and methods, plans and actions,
theory's situated, not pure abstraction.
So make your theory a public way,
where passers by may pause and stay.

– Thomas Erickson, Theory Theory: A Designer's View

8.1 Conclusion

This thesis has investigated and critically analysed the concept of work practice as a design requirement for cross-boundary clinical decision support systems in e-health. The research was motivated by the general problem that knowledge sharing for cross-boundary decision support, particularly in the wake of new models of social interaction and pervasive collaboration among communities of practice (Wenger, 1998; Wenger et al., 2009), is ineffective and awkward because of the lack of a common ground (Kuziemsky and Varpio, 2010), which builds on shared local knowledge and has sustained seamless "second opinion" sharing in co-located work settings (Miller, 2010; Mejia 2007, 2010). As a result, it was hypothesized that an understanding, and a formal characterisation, of the types and dimensions of context in various healthcare work settings and a specification of how contexts of work are used and transformed to suit various clinical problem-solving situations, has the potential to contribute to the design of better cross-boundary decision support for future e-health work environments (Fernando, 2003; Experts Group, 2006).

This work has taken a practice-centred approach, and draws on ideas from CHT, situation awareness, HCI and context-awareness. Using this approach, the thesis has presented a coherent conceptual architecture for the design of context-aware e-health systems for cross-boundary clinical decision support, as well as a proof of concept prototype. A key focus has been to improve the design of cross-boundary clinical decision support systems for e-health through a novel approach for capturing, modelling, representing and prototyping work practices.

This chapter concludes this thesis, and in what follows, provides a summary of the research work, by taking a more detailed view of the results and contributions that emerged out of the research, and points out some directions for future research work.

8.2 Summary of Contributions

The central research question posed in this thesis is how e-health systems can be designed for cross-boundary clinical decision support in a manner that incorporates a practice-centred perspective in modelling context of work.

This question has been addressed by three main contributions that have been demonstrated in this work. Firstly, the work has identified, defined and incorporated practice-centred awareness as a design requirement for cross-boundary clinical decision support in e-health. This provides, for system designers, an alternative view on decision support in organisation that accommodates work practice as a fundamental part of the way that people work in the real-world. The second contribution is a coherent architecture based on the concept of work practice for the design of context-aware e-health systems for cross-boundary clinical decision support. The final contribution focuses on enhancing the usability of cross-boundary clinical decision support systems through the incorporation of PCA information in the form of a visualisation technique, which we refer to as practice displays.

This thesis has adopted a user-centred methodology, and, as such, these contributions have been realised within the four-stage research process of *user-centred requirements capture, conceptualisation, formalisation and prototyping*, and *evaluation* that represent chapters 4 to 7 of the thesis.

The user-centred requirements capture, which is reported in Chapter 4 and in (Tawfik et al., 2012), was aimed to garner a user-centred basis for the research work and, consequently, to further consolidate the notion of PCA as a design requirement for cross-boundary clinical decision support in e-health. The findings show that though clinical work practices are variegated (Schmidt et al., 2007) across regional and geographical work settings, they are moderated by adherence to best practice guidelines and the need for patient-centered care. We identified three classes of work practice – the ontological, stereotyped, and situated work practices, and showed that an awareness of them plays a crucial role in adapting information for cross-boundary decision support. Futhermore, we identified two levels of awareness – local and boundary awareness – and indicated their relevance in supporting cross-boundary decision support. The user-centred study employed a mixed method approach (Creswell and Plano Clark, 2007), including the use of a probed-based method (Graham et al., 2007; Boehner et al., 2007), known as the practice probe, which we have introduced as part of this work. As a result, we were equipped to define PCA as an understanding of a remote individual's local work contexts and problem requirements, including the ontological, stereotyped and situational factors that provide causal explanations for and influence how they utilise available resources, and contextualise plans and procedures to actually solve problems. We characterised PCA by relating the findings of the user-centred study to CHT and SAW.

Taking Engeström's activity system (1987) as a starting point, we translated the concept of PCA into a conceptual architechecture for the design of e-health systems for cross-boundary awareness and decision support. This process involved three steps. First, we extended CHT's activity system by dividing the activity system into three planes representing the three classes of work practice with the aim of illuminating which elements of the system (e.g. tools, subject, rules, community, etc.) influence problem-solving and how they achieve that, i.e. whether an element influences work as a factor of the domain of work, as an attribute of workplace or regional stereotypes, or as a result of prevailing situations of work. We referred to the resultant system as the practice system. We used the practice system to denote the ontological, socio-cultural, organisational and situational aspects of a work setting that involve not only actors and artefacts (Johri et al. 2007; Pipek et al., 2011), but also the interplay among system entities and the adaptive transformation of the system across time (Gay and Hembrooke, 2004, p.7; Kaenampornpan and O'Neil, 2005), as well as to underline one of the facts of the finding of our user-centred study that particular instances of work practice gain their meanings in relation to the ontological, stereotyped and situated factors of a work setting. Second, we integrated the practice system into Endsley's SAW model (1995) giving rise to what we call the PCA model. The suggested PCA model addresses the problem of cross-boundary decision support by using four layers that cover: perception of work situation, conceptualisation of work domain, stereotyping based on work locality, and comprehension of work status and problem requirements. The model captures the abilities that cross-boundary decision support systems must exhibit, by separating the four main functions into four layers that build on such classical models as CHT's activity system and Endsley's SAW model. Thirdly, we incorporated a context model into our PCA model in order to highlight the fact that the role of entities in a work setting and their relative weight in describing a situation need to be subject to prevailing practices, which form the integral problem-solving approaches of an organisation or group of individuals. We identified four modes of cross-boundary decision support, namely reactive, collaborative, opportunitstic and proactive support, and showed how the suggested PCA model could be applied in cross-boundary decision support by adopting CBR to enable reasoning across practice systems, and by using a technique, which we refer to as ContextMorph for modeling information interchange and decision support across clinical work settings and disparate practice systems.

In formalising and prototyping the suggested architecture as the CaDHealth system, we built on the idea of frames (McCarthy and Hayes, 1969) to derive what we refer to as the PracticeFrame with the goal of representing work practices as a combination of the ontological, stereotyped and situated factors that influence decision-making in a clinical work environment. The prototyping approach used in this thesis uses a visualisation technique, and contributes to research towards depicting human reasoning in context. Our approach allows the designer of cross-boundary decision support system to match visual displays to the information used in describing work situations and practices. Proposing a user-informed practice-centred approach for designing e-health systems for cross-boundary decision support, and demonstrating its usability through a multi-method evaluation procedure, is an important step for enabling cross-boundary decision support in future working environments. Enabling cross-boundary decision support in emerging working environments provokes a number of open problems, and this research work is not intended to provide a final conclusion, but rather should be understood as a clear step in a new direction of re-locating the place of the concept of work practice in technology design. It is also hoped to inspire more research attention on technology that can effectively accommodate work practice as the fundamental part of the way people work in the real-world.

8.3 Directions for Future Research

Although the work presented in this thesis has addressed a number of issues of awareness in cross-boundary e-health decision support, some issues have remained unconsidered. In this section, we briefly discuss three directions for extending the work described in this thesis.

- One of the key features of how clinicians work in the real-world is reflected in the complex interconnections between a large set of intricately connected subsystems. The task of deciding on a course of treatment for a diabetic patient, for example, is not just healthcare, but stands together in a complex relationship with many other real-world systems: transportation, social economy, food, housing, and education that have far-reaching health effects, but are not engaged or evaluated for those outcomes (Tan et al., 2012). In formalising our conceptual model of PCA, we chose to leave much of this complexity of our model. However, as argued by numerous theories such CHT, and evidenced in our user-centred study, such higher order patterns of relationships represent key components in people's mental models of their problem-solving and decision making. Hence, a system that can accurately track and leverage (possibly through visualisation) the complex patterns of relationships among subsystems that are exhibited in people's problem-solving could be a more responsive and semantically meaningful way of representing real-world working patterns than the approach currently used by our system. Such a system can draw upon such works as (Chaiklin and Lave, 1996; Engeström, 2000; Dourish, 2004; Allert and Richter, 2008; Wenger et al., 2009; Brézillon, 2011; Bardram et al., 2012; Tan et al., 2012).
- It is assumed that only a single suggestion from a remote agent or expert is provided to support user decision. This hardly reflects everyday work situation. It seems reasonable that there might exist situations where many suggestions are provided from different agents and experts, and that these suggestions might conflict with one another and with user requirement. In these situations, the system be able to construct a plan that will select the most effective suggestion(s) for the user, and provide explanations to justify the chosen options. Addressing this problem falls outside the scope of this thesis, but is required to achieve truly context-aware cross-boundary decision support and leverage on existing research in explanations systems in

intelligent systems. The literature is replete with researches we can draw from in investigating this (Burstein et al., 2010).

- The proposed system being the outcome of dominantly conceptual and research study will benefit from evaluation in a large-scale real-world healthcare setting. This is an important area that should be addressed. Even though the tests conducted as part of the work described in this thesis did evaluate various aspects of the system, from user acceptance tests to purely performance tests in terms of awareness and cross-boundary decision support, an e-health system for cross-boundary clinical decision support has not actually proven its worth until it is evaluated in situ. A real-world field evaluation would enable one to actually assess how well the system "fits" within the real-world socio-cultural work structure of a healthcare setting, and to broaden the understanding of how PCA plays out in a natural setting. In addition, PCA should be explored in other real-world work contexts other than healthcare.

8.4 A Vision for Future Clinical Decision Support in e-Health

As our work environment continues to grow in complexity, the amount of healthcare information available for clinical decision support, which currently doubles every five years, will continue to increase. The rise of pervasive digital infrastructures will equally lead to more ubiquitous and networked healthcare environment with more opportunities for seamless knowledge sharing across geographical boundaries. The approach proposed in this work posits that much of the intelligence that would consequently pervade our work environment can be found in models of human socio-interactional behaviours. By advancing knowledge of how people work in the real-world, it is argued that a practice-centred approach would create a roadmap for the re-design of legacy healthcare technologies to take account of work practice, for developing more useful and usable technologies for distributed decision support, and for effectively managing socio-technical work systems through practice-aware healthcare analytics, practice-aware interfaces and human-centred health informatics.

References

Aamodt, A. (2004) Knowledge-intensive case-based reasoning in Creek. In Funk, P., Calero, P. A. G. (eds.), Advances in case-based reasoning. European Conf., ECCBR 2004, LNAI 3155, Springer, 1-15.

Abidi, S. S. (2005) Medical Knowledge Morphing: Towards Case-Specific Integration of Heterogeneous Medical Knowledge Resources, IEEE Symposium on Computer-Based Medical Systems, IEEE Computer Society, 208-213.

Abidi, S. S. R. (2006) Healthcare Knowledge Sharing: Purpose, Practices and Prospects. In Healthcare Knowledge Management: Issues, Advances and Successes, In R. K. Bali and A. Dwivedi (eds.), Springer, 65-86.

Abbot, R. and Wallace, T. (2007) Decision Support in Space Situational Awareness. *Lincoln Laboratory Journal*, 15(2), 297-335.

Abowd, G., Mynatt, E. and Rodden, T. (2003) The Human Experience. *IEEE Pervasive Computing*, 2(2), 48-57.

Ackerman, M. S. and Halverson, C. A. (2000) Re-examining organizational memory. *Communications of the ACM*, 43(1), 58-64.

Adams, M. J., Tenney, Y. J., and Pew, R. W. (1995) Situation awareness and cognitive management of complex systems. *Human Factors*, 37(1), 85-104.

Adams, M., Edmond, D. and ter Hofstede, A. H. M. (2003) The application of activity theory to dynamic workflow adaptation issues, PACIS 2003, 1836-52.

Adams, M. (2007) Facilitating Dynamic Flexibility and Exception Handling for Workflows, PhD Thesis, Faculty of Information Technology, Queensland University of Technology, Australia.

Adelman, L. (1992) Evaluating Decision Support and Expert Systems, NY: Wiley.

Agostini, A. and Prinz, W. (1996) Contexts, Work Processes, and Workspaces. *Journal of CSCW*, 5(2-3), 223-250.

Ahern, D. K. (2007) Challenges and Opportunities of eHealth Research. *Am J Prev Med*., 32(5), S75-82.

Aiyedun, A. A. (2007) Medical Decision Support System Using Augmentable Guideline Engine, Master's Thesis, Computer Science and Engineering, University of Texas at Arlington.

Akman, V. (2000) Rethinking context as a social construct. *Journal of Pragmatics*, 32(6), 743–759.

Akoumianakis, D., Milolidakis, G., Stefanakis, D., Akrivos, A., Vellis, G., Kotsalis, D., Plemenos, A. and Vidakis, N. (2009) Virtual Operations in Common Information Spaces: Boundary Objects and Practices. *IFIP Advances in Information and Communication Technology*, 307, 207-216.

Alavi, M. and Leidner, D. E. (2001) Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues, *MIS Quarterly*, 25(1), 107–136.

Aldrich, H. and Herker, D. (1977) Boundary Spanning Roles and Organization Structure. *The Academy of Management Review*, 2(2), 217-230.

Aldridge, J. M., Fraser, B. J. and Huang, T. (1999) Investigating classroom environments in Taiwan and Australia with multiple research methods. *Journal of Educational Research*, 93, 48-57.

Allert, H. and Richter, C. (2008) Practices, Systems, and Context Working as Core Concepts in Modeling Socio-Technical Systems, Int'l Workshop on Philosophy and Informatics, WSPI'08.

Alsos, O. A. (2010) Awareness and Usability Issues in Clinical CSCW Systems, ACM Conference on Computer-Support Cooperative Work, Georgia, USA, 501-502.

Anderson, R. J. (1997) Work, ethnography, and system design. In: A. Kent and J. G. Williams (eds.) The Encyclopedia of Microcomputing. NY: Marcel Dekker, 20, 159-183.

Anderson, T. D. (2007) Settings, arenas and boundary objects: socio-material framings of information practices, Information Research, 12(4), [online]. Available from http://informationr.net/ir/12-4/colis/colis10.html. [Accessed on 03 Feb 2012].

Anya, O., Nagar, A. and Tawfik, H. (2008) An Approach for Enriching Information for Supporting Collaborative e-Work, Int. Conf. on Computational Intelligence ICCS08, LNCS, Springer, Part III, 5103, 419-428.

Anya, O., Tawfik, H., Nagar, A. and Amin, S. (2010) Context-Aware Decision Support in Knowledge-Intensive Collaborative E-Work, Int'l Conf.on Computational Intelligence, Amsterdam, LNCS, 1(1), 2281-2290.

Anya, O., Tawfik, H. and Nagar, A. (2011) Cross-Boundary Knowledge-based Decision Support in e-Health, Int'l Conf. on Innovations in Information Technology, Abu Dhabi, 25-27 April.

Appleby, J, Raleigh, V., Frosini, F., Bevan, G., Gao, H. and Lyscom, T. (2011) Variations in Healthcare: The good, the bad and the inexplicable, The King's Fund, UK.

Argote, L., Ingram, P., Levine, J. M. and Moreland, R. L. (2000) Knowledge Transfer in Organizations: Learning from the Experience of Others, *Organizational Behaviour and Human Decision Processes*, 82(1), 1–8.

Assali, A. A., Lenne, D. and Debray, B. (2010) Heterogeneity in Ontological CBR Systems, In: S. Montani & L.C. Jain (eds.), Successful Case-Based Reasoning Appl., SCI 305, 97–116.

Azudin, N., Ismail, M. N. and Taherali, Z. (2009) Knowledge sharing among workers: a study on their contribution through informal communication in Cyberjaya, Malaysia, *Int'l J. of Knowledge Management and E-Learning*, 1(2), 139-162.

Bai, G. and Guo, Y. (2010) Activity Theory Ontology for Knowledge Sharing in E-health, Int'l Forum on Information Technology and Applications (IFITA), 39-43.

Bainbridge, L. (1997) The change in concepts needed to account for human behavior in complex dynamic tasks, IEEE transactions on Systems, Man and Cybernetics, 27, 351-359.

Ball, M. J. and Douglas, J. V. (1995) Health information networks, Medinfo, vol. 8 pt. 2, 1465-9.

Balzer, W. and Tuomela, R. (2003) Collective Intentions and the Maintenance of Social Practices, *Autonomous Agents and Multi-Agent Systems*, 6(1), 7-33.

Bannon, L. (1995) The Politics of Design: Representing Work, *Communications of the ACM*, 38(9), 66-68.

Bannon, L. and Bødker, S. (1991) Beyond the Interface: Encountering Artifacts in Use, In J. M. Carroll (ed.), Designing Interaction: Psychology at the Human-Computer Interface, Cambridge: Cambridge Univ. Press, 227-253.

Bannon, L. (2000) Situating workplace studies within the human-computer interaction field, In P. Luff, J. Hindmarsh and C. Heath (eds.), Workplace Studies: Recovering Work Practice and Informing System Design, Cambridge University Press, 230-241.

Balogun, J., Gleadle, P., Hailey, V. H. and Willmott, H. (2005) Managing Change Across Boundaries: Boundary-Shaking Practices, *British Journal of Management*, 16, 261–278.

Bardram, J. E. (2009) Activity-based computing for medical work in hospitals, *ACM Transactions on Computer-Human Interaction*, 16(2), 1–36.

Bardram, J. E., Hansen, T. R. and Soegaard, M. (2006) AwareMedia: a shared interactive display supporting social, temporal, and spatial awareness in surgery, ACM anniversary Conf. on CSCW, ACM Press, Canada, 109-118.

Bardram, J. E. (2008) Clinical Proof-of-Concept - A Evaluation Method for Pervasive Healthcare Systems, In UbiComp '08 Workshop on Ubiquitous Systems Evaluation (USE '08), South Korea.

Bardram, J. E. and Hansen, T. R. (2010) Context-Based Workplace Awareness, *Journal of CSCW*, 19( )2, 105-138.

Bardram, J. E. and Hansen, T. R. (2010a) Why the plan doesn't hold: a study of situated planning, articulation and coordination work in a surgical ward, CSCW 2010, 331-340.

Bardram, J., Gueddana, S., Houben, S. and Nielsen, S. (2012) ReticularSpaces: activity-based computing support for physically distributed and collaborative smart spaces, CHI 2012, 2845-2854.

Barnes, B. A., O'Brien, E., Comstock, C., D'Arpa, D. G. and Donahue, C. L. (1985) Report on variation in rates of utilization of surgical services in the Commonwealth of Massachusetts, *J. of the American Med. Association*, 254, 371–375.

Barretto, S. A. (2005) Designing Guideline-based Workflow-Integrated Electronic Health Records, PhD Thesis, School of Computing and Information Science, The University of South Australia.

Barwise, J. (1989) The Situation in Logic, Stanford: CSLI.

Baxter, R. and Lyytinen, K. (2005) Information Technology Impact on Work Practices: A Study of 3D CAD Capabilities in Architecture, Engineering, and Construction, Case Western Reserve University, USA, Working Papers on Information Systems, vol. 5, no. 1, [online]. Available from http://sprouts.aisnet.org/5-17. [Accessed on 19 Nov 2011].

Bedny, G. and Meister, D. (1999) Theory of Activity and Situation Awareness, *Int'l Journal of Cognitive Ergonomics*, 3(1), 63-72.

Bedny, G. Z. and Karwowski, W. (2004) Activity theory as a basis for the study of work, Ergonomics, 47(2), 134-153.

Béguin, P. (2003) Design as a Mutual Learning Process between Users and Designers, *Interacting with Computers*, 15, 709-730.

Béguin, P. and Clot, Y. (2004) Situated action in the development of activity, 2(2), 50-63, [online]. Available from http://www.activites.org/v1n2/beguin.eng.pdf. [Accessed on 12 Jan 2012].

Belotti, R., Decurtins, C., Grossniklaus, M., Norrie, M. C. and Palinginis, A. (2005) Modelling Context for Information Environments, Ubiquitous Mobile Information and Collaboration Systems, LNCS, Springer 3272, 43-56.

Benerecetti, M., Bouquet, P. and Bonifacio, M. (2001) Distributed Context-Aware Systems, *Human-Computer Interaction*, 16(2-4), 213-228.

Benjamin, P. C., Menzel, C. P., Mayer, R. J., Fillion, F., Futrell, M. T., deWitte, P. S. and Lingineni, M. (1994) "IDEF5 Method Report", Knowledge Based Systems.

Benner, P., Hughes, R. G. and Sutphen, M. (2008) Clinical Reasoning, Decision making, and Action: Thinking Critically and Clinically, In: Patient Safety and Quality. AHRQ Publication No. 08-0043, [online]. Available from http://www.ahrq.gov/qual/nurseshdbk/. [Accessed on 12 Jan 2012].

Bentley, R. and Dourish, P. (1995) Medium versus mechanism: Supporting collaboration through customization, In: H. Marmolin, Y. Sundblad, and K. Schmidt (eds.), ECSCW '95, Dordrecht: Kluwer, 133-148.

Benyon, D. R. (1993) Adaptive Systems: a solution to usability problems, *Intl Journal of User Modelling and User Adapted Interaction*, 3, 65-87.

Bello-Tomás, J. J., González-Calero, P. A. and Díaz-Agudo, B. (2004) JColibri: An Object-Oriented Framework for Building CBR Systems, Advances in Case-based Reasoning, LNCS, 3155, 29-39.

Bellotti, V., Ducheneaut, N., Howard, M. and Smith, I. (2003) Taking email to task: The design and evaluation of a task management centered email tool, Conf. on Human Factors in Computing Systems, ACM, 345–352.

Berner, E. S. and La Lande, T. J. (2007) Overview of Clinical Decision Systems, In: Berner, E. S. (ed.), Clinical Decision Support Systems, Springer, 3-22.

Berner, E. S. (2009) Clinical decision support systems: State of the Art, AHRQ Publication No. 09-0069-EF, Rockville, Maryland: Agency for Healthcare Research and Quality.

Bettini, C., Brdiczka, O., Henricksen, K., Indulska, J., Nicklas, D., Ranganathan, A. and Riboni, D. (2010) A survey of context modelling and reasoning techniques, *Pervasive and Mobile Computing*, 6(2), 161-180.

Beyer, H. and Holtzblatt, K. (1999) Contextual design, *Interactions*, 6(1), 32-42.

Beyer, H. and Holtzblatt, K. (1994) Representing Work for the Purpose of Design, In L. Suchman (ed.) Representations of Work, HICSS.

Blandford, A. and Wong, W. (2004) Situation awareness in emergency medical dispatch, *Int'l Journal of Human–Computer Studies*, 61, 421–452.

Bødker, S., Knudsen, J., Kyng, M., Ehn, P. and Madsen, K. (1988) Computer Support for Cooperative Design, Conf. on CSCW, Oregon, USA, September 26-29, ACM Press, pp. 377-398.

Bødker, S. (1991) Activity theory as a challenge to systems design. In Hans-Erik Nissen, Heinz K. Klein, and Rudy Hirschheim (eds.), Information Systems Research: Contemporary Approaches and Emergent Traditions, North Holland, 551–564.

Bødker, S. and Christiansen, C. (2006) Computer support for social awareness in flexible work, *Journal of CSCW*, 15(1), 1–28.

Boehner, K., Vertesi, J, Sengers, P. and Dourish, P. (2007) How HCI Interprets the Probes, CHI 2007, ACM Press, New York, 1077-1086.

Boh, W. F., Ren, Y., Kiesler, S. and Bussjaeger, R. (2007) Expertise and Collaboration in the Geographically Dispersed Organization, *Organisation Science*, 18(4), 595-612.

Bonifacio, M., Bouquet, P. and Traverso, P. (2002) Enabling distributed knowledge management. Managerial and technological implications, *Novatica and Informatik/Informatique*, III(1)

Bordini, R. H., Hubner, J. F. and Wooldridge, M. (2007) Programming Multi-Agent Systems in AgentSpeak Using Jason, John Wiley & Sons.

Borriello, G., Stanford, V., Narayanaswami, C. and Menning, W. (eds.) (2007) Pervasive Computing in Healthcare, Pervasive Computing, IEEE Comp. Society, 17-19.

Bossen, C. (2002) The parameters of common information spaces: the heterogeneity of cooperative work at a hospital ward, ACM Conf. on Computer-Supported Cooperative Work, ACM Press, 176-185.

Böttcher, M. and Fähnrich, K. (2011) Service Systems Modeling: Concepts, Formalized Meta-Model and Technical Concretion, The Science of Service Systems, 131-149.

Boulus, N. and Bjorn, P. (2010) A cross-case analysis of technology-in-use practices: EPR-adaptation in Canada and Norway*, Int'l Journal of Medical Informatics*, 79, e97-e108.

Bourdieu, P. (1977) Outline of a Theory of Practice, Cambridge: Cambridge University Press.

Bowers, J., Buttton, G. and Sharrock, W. (1995) Workflow from Within and Without: Technology and Cooperative Work on the Print Industry Shopfloor, European Conf. on CSCW, Sept. 10-14, Stockholm, Sweden.

Bowker, G., Star, S. L., Turner, W. and Gasser, L. (eds.) (1997) Social Science, Technical Systems and Cooperative Work: Beyond the Great Divide, Hillsdale, NJ: Erlbaum.

Boxwala, A. A., Peleg, M., Tu, S., Ogunyemi, O., Zeng, Q. T., Wang, D., Patel, V. L., Greenes, R. A., Shortliffe, E. H. (2004) GLIF3: a representation format for sharable computer-interpretable clinical practice guidelines, *J Biomed Inform*., 37(3), 147-61.

Brennan, T. A., Hebert, L. E., Laird, N. M., Lawthers, A., Thorpe, K. E., Leape, L. L., et al. (1991) Hospital characteristics associated with adverse events and substandard care, *J. of the American Med. Association*, 265(2)4, 3265–9.

Brézillon, P. (2011) Context-based Management of practices, Int'l Workshop on Modeling and Reasoning in Context, Karlsruhe, Germany, Springer Verlag, LNCS, Sept 26-30.

Brézillon, P. (2007) Context Modeling: Task Model and Practice Model, CONTEXT'07, 122-135.

Brézillon, J. and Brézillon, P. (2007) Context Modeling: Context as a Dressing of a Focus, CONTEXT 2007, 136-149.

Brézillon, P. and Araujo, R. (2005) Reinforcing shared context to improve collaboration, *Revue d'Intelligence Artificielle*, 19.

Brézillon, P., Borges, M. R. S., Pino, J. A. and Pomerol, J. (2004) Context-Based Awareness in Group Work, In FLAIRS, Florida, AAA Press, 575-580.

Brézillon, P. and Brézillon, J. (2008) Context-sensitive decision support systems in road safety. *Inf. Syst. E-Business Management*, 6(3), 279-293.

Bricon-Souf, N. and Newman, C. R. (2007) Context-awareness in health care: A review, *Int'l Journal of Medical Informatics*, 76, 2-12.

Brown, J. and Duguid, P. (1991) Organisational Learning and Communities of Practice: Towards a Unified View of Learning, Working and Innovation, *Organisation Science*, 2(1), 40–56.

Brown, J. S. and Duguid, P. (2000) The Social Life of Information, Cambridge, MA: Harvard Business School Press.

Bryman, A. (1984) The debate about quantitative and qualitative research: a question of method or epistemology, *The British Journal of Sociology*, 35(1), 76-92.

Bucur, O., Beaune, P. and Boissier, O. (2006) Steps Towards Making Contextualized Decisions: How to Do What You Can, with What You Have, Where You Are, In T. R. Roth-Berghofer, S. Schulz and D. B. Leake (eds.) MRC '05, LNAI 3946, Springer-Verlag, 62-85.

Burstein, F. V., Smith, H. G. and Fung, S. M. (1998) Experimental Evaluation of the Efficiency of a Case-based Organisational Memory Information System Used as a Decision Aid, HICSS, 209-217.

Burstein, F. and Holsapple, C. W. (eds.) (2008) Decision Support Systems in Context, Inf Syst E-Bus Manage., Springer-Verlag, 221-223.

Burstein, F., Brézillon, P. and Zaslavsky, A. (eds.) (2010) Supporting Real Time Decision-Making, *Annals of Information Systems,* 13, Springer.

Büscher, M., Gill, S., Mogensen, P. and Shapiro, D. (2001) Landscapes of Practice: Bricolage as a Method for Situated Design, *CSCW*, 10, 1-28.

Button, G. and Harper, R. (1996) The relevance of 'work-practice' for design, *CSCW*, 4(4), 263–280.

Button, G. and Dourish, P. (1996) Technomethodology: Paradoxes and Possibilities, ACM Conf on Human Factors in Computing Systems CHI'96, Vancouver, ACM Press, 19-26.

Cabana, M. D., Rand, C. S., Powe, N. R., Wu, A. W., Wilson, M. H., Abboud, P. A. and Rubin, H. R. (1999) Why don't physicians follow clinical practice guidelines? A framework for improvement, *JAMA*, 282, 1458-65.

Cain, C. and Haque, S. (2008) Organizational Workflow and Its Impact on Work Quality, In: Hughes, R. G. (ed.), Patient Safety and Quality: An Evidence-Based Handbook for Nurses, Rockville, MD: AHRQ, 217-244.

Card, S. K., Moran, T. P. and Newell, A. (1983) The psychology of human-computer interaction, Hillsdale, NJ: Lawrenece Erlbaum Associates.

Cairns, P. and Cox, A. eds. (2008) Research Methods for Human-Computer Interaction, Cambridge, UK: Cambridge University Press.

Cairns, P. (2007) HCI... not as it should be: inferential statistics in HCI research, British Computer Society Conf. on HCI, vol. 1, 195-201.

Carlile, P. (2002) A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development, Organization Science, vol. 13, no. 4, 442-455.

Carlile, P. R. (2004) Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries, *Organization Science*, 15(5), 555-568.

Carroll, J. M. (1997) Human-Computer Interaction: Psychology as a Science of Design, *Annu. Rev. Psychol*., 48, 61–83.

Carroll, J. M., Rosson, M. B., Chin, G. and Koenemann (1998) Requirements Development in Scenario-Based Design, *IEEE Transactions on Software Engineering*, 24(12), 1156-1170.

Carroll, J. M. (2011) Human Computer Interaction (HCI). In: Soegaard, Mads and Dam, Rikke Friis (eds.). Encyclopedia of Human-Computer Interaction, [online]. Available from http://www.interaction-design.org/encyclopedia/human_computer_interaction_hci.html. [Accessed on: 02 Nov 2011].

Casini, G. and Hosni, H. (2009) A Note on Cumulative Stereotypical Reasoning, European Conf. on Symbolic and Quantitative Approaches to Reasoning with Uncertainty, LNAI, Springer-Verlag, 590-601.

Cassens, J. (2008) Explanation Awareness and Ambient Intelligence as Social Technologies, Thesis for the degree doctor scientiarum, Norwegian University of Science and Technology, Trondheim, Norway.

Cater-Steel, A. and Al-Hakim, L. (eds.) (2009) Information Systems Research Methods, Epistemology, and Applications, Information Science Reference, NY: IGI Global Publishers.

Catwell, L. and Sheikh, A. (2009) Evaluating eHealth Interventions: The Need for Continuous Systemic Evaluation, *PLoS Medicine*, 6(8), e1000126.

Chaiklin, S. (2011) The role of practice in cultural-historical science, In Kontopodis, M. et al. (eds.) Children, Development and Education: Cultural, Historical, Anthropological Perspectives, Dordrecht: Springer, 227-246.

Chaiklin, S. and Lave, J. (1996) Understanding Practice: Perspectives on Activity and Context, Cambridge: Cambridge University Press.

Chaiklin, S. (2007) Modular or Integrated? - An Activity Perspective for Designing and Evaluating Computer-Based Systems, *Human-Computer Interaction,* 22(1-2), 173-190.

Chalmers, D. (2002) Awareness, Representation and Interpretation, *CSCW*, 11, 389-409.

Chandler, J. S. (1982) A Multiple Criteria Approach for Evaluating Information Systems, *MIS Quarterly*, 6(1), 61-74.

Chandrasekaran, B. (1990) Design Problem Solving: A Task Analysis, *AI Magazine*, 11(4), 59-71.

Charmaz, K. (2002) Qualitative interviewing and grounded theory analysis, In J. F. Gubrium and J. A. Holstein (eds.), Handbook of interview research: Context and Method, Thousand Oaks, CA: Sage, 675-693.

Checkland, P. (1981) Systems Thinking, Systems Practice, Wiley.

Chen, C. and Rada, R. (1996) Modelling Situated Actions in Collaborative Hypertext Databases, Journal of Computer-Mediated Comm., vol. 2, no. 3, [online], available <http://jcmc.indiana.edu/vol2/issue3/>, [accessed on: 28 Nov 2011].

Chen, W. and Akay, M. (2011) Developing EMRs in Developing Countries, *IEEE Transactions on Information Technology in Biomedicine*, 15(1), 1-4.

Cheng, C. H., Goldstein, M., Geller, E. and Levitt, R. (2003) The effects of CPOE on ICU workflow: An observational study, AMIA Annu Symp, 150-154.

Chi, E. H., Kittur, A., Mytkowicz, T., Pendleton, B. A. and Suh, B. (2007) Augmented social cognition: understanding social foraging and social sensemaking, HCIC Workshop, Feb 1-4, Frasier; CO.

Christensen, H. and Bardram, J. (2002) Supporting human activities – exploring activity-centered computing, Int'l Conf. on Ubiquitous Computing, 107–116.

Clancey, W. J., Sachs, P., Sierhuis, M. and van Hoof, R. (1998) Brahms: simulating practice for work systems design, *Int. J. Human-Computer Studies*, 49, 831-865.

Clancey, W. (2002) Simulating activities: relating motive, deliberation, and attentive coordination, In T. Ziemke (ed.), *Cognitive Systems Research*, Elsevier, 3, 471–499.

Clancey, W. J. (2006) Observation of Work Practices in Natural Settings, In A. Ericsson, N. Charness, P. Feltovich and R. Hoffman (eds.), Cambridge Handbook on Expertise and Expert Performance, NY: Cambridge University Press, 127-145.

Cheverst, K., Dix, A., Fitton, D., Graham, C. and Rouncefield, M. (2009) Situatedness of Awareness Information: Impact on the Design and Usage of Awareness Systems, In Markopoulos, P. and Mackay, W. (eds.) Awareness Systems: Advances in Theory, Methodology and Design, London: Springer-Verlag, 397-422.

Cole, M., Engestrom, Y. and Vasquez, O. eds. (1997) Mind, Culture, and Activity: Seminal Papers from the Laboratory of Comparative Human Cognition, NY: Cambridge University Press.

Cook, D. (1998) Evidence-based critical care medicine: a potential tool for change, *New Horiz.*, 6(1), 20–5.

Cook, S. D. N. and Brown, J. S. (1999) Bridging Epistemologies: The Generative Dance Between Organizational Knowledge and Organizational Knowing, *Organization Science*, 10(4), 381-400.

Crandall, B., Klein, G. and Hoffman, R. (2006) Working minds: A practitioner's guide to cognitive task analysis, MIT Press.

Crawford, D. (1995) Editorial Pointers, *Communications of the ACM*, 38(9), 5.

Creswell, J. W. and Plano Clark, V. L. (2007) Designing and Conducting Mixed Methods Research, Sage Publications, Inc.

Creswell, J. W., Fetters, M.D. and Ivankova, N. (2004) Designing a Mixed Methods Study in Primary Care, *Annals of Family Medicine*, 2(1), 7-12.

Crowley, J. L. (2006) Situation Models for Observing Human Activity, ACM Queue Magazine, May, Available from http://www-prima.inrialpes.fr/jlc/papers/Queue-Crowley.pdf. [Accessed on 15 Feb 2012].

Csikszentmihalyi, M. (1990) Flow: The Psychology of Optimal Experience, NY: HarperPerennial.

Cudré-Mauroux, P. (2012) Loose ontological coupling and the Social Semantic Web, *J Ambient Intell Human Comput*, DOI: 10.1007/s12652-012-0108-0

Cunningham, P. (2009) A Taxonomy of Similarity Mechanisms for Case-Based Reasoning, *IEEE Transactions on Knowledge and Data Engineering*, 21(11), 1532-1543.

Daniels, H., Edwards, A., Engeström, Y., Gallagher, T. and Ludvigsen, S. R. (2009) Activity Theory in Practice: Promoting learning across boundaries and agencies, Routledge.

Dasmahapatra, S. and O'Hara, K. (2006) Interpretations of Ontologies for Breast Cancer, *tripleC*, 4(2), 293-303.

Davenport, T. H. and Prusak, L. (1998) Working Knowledge: How Organizations Manage What They Know, Boston: Harvard Business School Press.

Davis, F. D. (1989) Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology, *MIS Quarterly*, 13(3), 319-340.

Dayton, D. (2000) Activity Theory: A Versatile Framework for Workplace Research, Ann. Conf. of the Society for Technical Communication, 47, 298–304.

de Camargo, K. R. and Coeli, C. M. (2006) Theory in Practice: Why "Good Medicine" and "Scientific Medicine" Are Not Necessarily the Same Thing, *Advances in Health Sciences Education*, 11(1), 77-89.

Della, M. V. (2001) What is e-Health (2): The death of telemedicine?, *Journal of Medical Internet Research*, 3(2), e22.

Denscombe, M. (2008) Communities of practice: A research paradigm for the mixed methods approach, *Journal of Mixed Methods Research*, 2, 270-283.

Denoeux, T. (1999) Reasoning with imprecise belief structures, *Int. J. Approx. Reasoning*, 20(1), 79-111.

Devlin, K. (2006) Situation theory and situation semantics, In Handbook of the history of logic, Elsevier, 601-664. Available from http://profkeithdevlin.com/Papers/HHL_SituationTheory.pdf. [Accessed on 03 April 2012].

Dey, A. K. (2001) Understanding and Using Context, *Personal and Ubiquitous Computing*, 5, 4-7.

Dey, A., Kortuem, G., Morse, D. and Schmidt, A. (eds.) (2001) Situated Interaction and Context-Aware Computing, *Journal of Personal and Ubiquitous Computing*, 5(1), 1-3.

Dix, A. (1997) Challenges for Cooperative Work on the Web: An analytical Approach, Computer-Supported Cooperative Work: *The Journal of Collaborative Computing*, 6, 135–156.

Doerry, E. (1995) Evaluating Distributed Environments Based on Communicative Efficacy, Conference Companion on Human Factors in Computing Systems, 47-48.

Dominguez, C. (1994) Can SA be defined? In M. Vidulich, C. Dominguez, E. Vogel, and G. McMillan (eds.), Situation Awareness: Papers and annotated bibliography, Ohio: Armstrong Laboratory, Human System Centre, 5-15.

Dourish, P. and Bellotti, V. (1992) Awareness and Coordination in Shared Workspaces, ACM conf. on CSCW, Toronto, Canada, pp.107-114.

Dourish, P. (2001) Where the Action Is: The Foundations of Embodied Interaction, Cambridge: MIT Press.

Dourish, P. (2001a) Seeking a Foundation for Context-Aware Computing, *Human-Computer Interaction*, 16(2-3).

Dourish, P. (2004) What We Talk About When We Talk About Context. *Personal and Ubiquitous Computing*, 8(1), 19-30.

Dourish, P. (2006) Implications for design, SIGCHI conf. on Human Factors in computing systems, 541-550.

Dourish, P. and Bly, S. (1992) Portholes: supporting awareness in a distributed work group, CHI '92, Monterey, California, 3-7 May, 541-547.

Doust, J. and Del Mar, C. (2004) Why do doctors use treatments that do not work? *BMJ*, 328(7438), 474-475.

Drucker, P. (1969) The Age of Discontinuity, NY: Harper and Row.

Duan, L., Street, W.N. and Xu, E. (2011) Healthcare information systems: data mining methods in the creation of a clinical recommender system, *Enterprise Information Systems*, 5(2), 169-181.

Dumas, J. S. and Reddish, J. C. (1999) Practical Guide to Usability Testing, Revised Edition, Exeter: Intellect.

Durso, F. T. and Sethumadhavan, A. (2008) Situation awareness: Understanding dynamic environments, *Human Factors*, 50, 442–448.

Edwards, A. (2011) Cultural Historical Activity Theory, British Educational Research Association, [online]. Available from http://www.bera.ac.uk/files/2011/06/cultural_historical_activity_theory.pdf. [Accessed on 03 November 2011].

Edwards, P. J., Jacko, J. A., Moloney, K. P. and Sainfort, F. (2006) HCI Challenges Case Study: Implementing an Electronic Medical Record, CHI Workshop, Montreal, Canada, April 22–27, 1-4.

Ekbia, H. R. and Maguitman, A. G. (2001) Context and relevance: A pragmatic approach, LNCS 2116, 156–169.

Elliott N. (2010) 'Mutual intacting': a grounded theory study of clinical judgement practice issues, *Journal of Adv Nurs*., 66(12), 2711-21.

Endsley, M. R. (1995) Toward a theory of situation awareness in dynamic systems, *Human Factors*, 37(1), 32–64.

Endsley, M. R. and Garland, D. J. (eds.) (2000) Situation Awareness Analysis and Measurement, Mshwah, NJ: Erlbaum Associates.

Endsley, M. R., Bolstad, C. A., Jones, D. G. and Riley, J. M. (2003) Situation Awareness Oriented Design: From User's Cognitive Requirements to Creating Effective Supporting Technologies, Presented at the Human Factors and Ergonomics 47th Annual Meeting, Denver, Colorado, October.

Engeström, Y. (1987) Learning by Expanding: An Activity-Theoretical Approach to Developmental Work Research, Helsinki: Orienta-konsultit.

Engeström, Y. (1990) When is a tool? Multiple meanings of artifacts in human activity, In Learning, Working and Imagining, Orienta-Konsultit, Helsinki, Finland, 171–195.

Engeström, Y. (1996) Developmental studies of work as a testbench of activity theory: The case of primary care medical practice, In S. Chaiklin, J. Lave (eds.) Understanding Practice: Perspectives on Activity and Context: Cambridge: Cambridge University Press, 64-103.

Engeström, Y. (2000) Activity Theory as a Framework for Analyzing and Redesigning Work, Ergonomics, 43(7), 960-974.

England, D. A., Taleb-Bendiab, A., Lisboa, P., Murphy, K. and Jarman, I. (2004) Decision Support for Post-Operative Breast Cancer Care, Coping with Complexity: Sharing New Approaches for the Design of Human-Computer Systems in Complex Settings, University of Bath.

Eraut, M. (1994) Developing Professional Knowledge and Competence, Brighton: Falmer Press.

Essex D. (2000) The Many Layers of Workflow Automation, Healthcare Informatics, 17(6), 121-2, 124-30.

EU (2010) European eHealth Interoperability Roadmap, Final European Progress Report, CALL for InterOPErability (CALLIOPE), December, [online]. Available from http://ec.europa.eu/information_society/newsroom/cf/itemdetail.cfm?item_id=7550. [Accessed on 15 December 2011].

Experts Group (2006) New Collaborative Working Environments 2020, European Commission Information Society and Media Directorate-General, Report on industry-led FP7 consultations and 3rd Report of the Experts Group on Collaboration@Work, Brussels, 28 February.

Eysenbach, G. (2001) What is e-health? *J Med Internet Res*, 3(2), e20.

Færgemann, L., Schilder-Knudsen, T. and Carstensen, P. H. (2005) The duality of articulation work in large heterogeneous settings - a study in health care, European Conference on CSCW, NY: Springer-Verlag, 163-183.

Fafchamps, D., Young, C. and Tang, P. (1991) Modelling Work Practices, In P. Clayton (ed.), Annu Symp Comput Appl Med Care, NY: McGraw-Hill, 788-792.

Fan, X., Brézillon, P., Zhang, R. and Li, L. (2011) A context-based framework for improving decision making in scientific workflow, Int'l Conf. on Computer Research and Development, IEEE, 2, Shanghai, China, 15-19.

Fassinger, R. E. (2005) Paradigms, Praxis, Problems, and Promise: Grounded Theory in Counseling Psychology Research, *Journal of Counseling Psychology*, 52(2), 156–166.

Favela, J., Tentori, M., Castro, L. A., Gonzalez, V. M., Moran, E. B. and Martínez-García, A. I. (2007) Activity recognition for context-aware hospital applications: issues and opportunities for the deployment of pervasive networks, *Journal Mobile Networks and Applications*, 12(2-3), 155–171.

Feng, Y., Teng, T. and Tan, A. (2009) Modelling Situation Awareness for Context-aware Decision Support, *Expert Systems with Applications*, 36(1), 455-463.

Fernando, T. (ed.) (2003) A Strategic Roadmap for Defining Distributed Engineering Workspaces of the Future, IST-2001-38346, Report on Future Workspaces Challenges, European Commission, Brussels.

Fioratou, E. Flin, R., Glavin, R. and Patey, R. (2010) Beyond monitoring: distributed situation awareness in anaesthesia, *British Journal of Anaesthesia*, 105(1), 83–90.

Fiscella, K., Franks, P., Gold, M. R. and Clancy, C. M. (2000) Inequality in quality: Addressing socioeconomic, racial, and ethnic disparities in health care, *JAMA*, 283, 2579–2584.

Fischer, L. (ed.) (2007) BPM and Workflow Handbook, Future Strategies Inc.

Fish, D. and Coles, C. (1998) Developing Professional Judgment in Health Care: Learning Through the Critical Appreciation of Practice, Oxford: Butterworth Heinemann.

Fitzpatrick, G. (1998) Locales Framework: Understanding and Designing for Cooperative Work, PhD Thesis, Department of Computer Science and Electrical Engineering, The University of Queensland.

Fjuk, A., Smørdal, O. and Nurminen, M. (1997) Taking Articulation Work Seriously – An Activity Theoretical Approach, TUCS Technical Report No 120, Turku Centre for Computer Science.

Foot, K. A. (2001) Cultural-Historical Activity Theory as Practical Theory: Illuminating the Development of a Conflict Monitoring Network, *Communication Theory*, 11(1), 56-83.

Forlizzi, J. (2007) Product Ecologies: Understanding the Context of Use Surrounding Products, Ph.D. Dissertation, Carnegie Mellon University.

Fox, M. S. (1986) Beyond the Knowledge Level, Expert Database Conf., 455-463.

Fox J., Alabassi A., Black E., Hurt C. and Rose T. (2004) Modelling clinical goals: a corpus of examples and a tentative ontology, *Stud Health Technol Inform*., 101, 31-45.

Fox, J. (2011) Formalizing knowledge and expertise: where have we been and where are we going? *Knowledge Eng. Review*, 26(1), 5-10.

French, H. T. and Hutchinson, A. (2002) Measurement of Situation Awareness in a C4ISR Experiment, Int'l command and Control Research and Technology Symposium, Quebec City, Canada.

Friedman, T. L. (2005) The World Is Flat: A Brief History of the Twenty-first Century, Farrar, Straus and Giroux.

Gabbay, J. and le May (2011) Practice-based Evidence for Healthcare: Clinical Mindlines, London: Routledge.

Gantt, M. and Nardi, B. A. (1992) Gardeners and gurus: patterns of cooperation among CAD users, SIGCHI conference on Human factors in computing systems, ACM Press, 107-117.

Garibaldi, J. M., Zhou, S., Wang, X., John, R. I. and Ellis, I. O. (2012) Incorporation of expert variability into breast cancer treatment recommendation in designing clinical protocol guided fuzzy rule system models, Journal of Medical Informatics, In press.

Garvin, J. H., Martin, K. S., Stassen, D. L. and Bowles, K. H. (2008) The Omaha System: Coded data that describe patient care. *Journal of the American Health Information Management Association*, 79(3), 44-49.

Garfinkel, H. (1967) Studies in Ethnomethodology, NJ: Prentice Hall Inc.

Gasson, S. (2005) Boundary-Spanning Knowledge-Sharing In E-Collaboration. HICSS'05.

Gasson, S. (2005a) The dynamics of sensemaking, knowledge, and expertise in collaborative, boundary-spanning design, *Journal of Computer-Mediated Communication*, 10(4), article 14.

Gautier, G., Bassanino, M., Fernando, T. and Kubaski, S. (2009) Solving the Human Problem: Investigation of a Collaboration Culture, IESA 2009, 261-267.

Gaver, B., Dunne, T. and Pacenti, E. (1999) Design: Cultural probes, *Interactions*, 6(1), 21-29.

Gawande, A. (2002) Complications: A Surgeon's Notes on an Imperfect Science, London: Profile Books.

Gay, G. and Hembrooke, H. (2004) Activity-centred design: an ecological approach to designing smart tools and usable systems, Cambridge, MA: MIT Press.

Geertz, C. (1983) Local knowledge: further essays in interpretive anthropology, NY: Basic Books.

Gerson, E. M. and Star, S. L. (1986) Analyzing Due Process in the Workplace, *ACM Transactions on Office Information Systems*, 4(3), 257-270.

Geyer, W., Muller, M. J., Moore, M. T., Wilcox, E., Cheng, L.-T., Brownholtz, B., Hill, C. and Millen, D. R. (2006) Activity Explorer: Activity-centric collaboration from research to product, *IBM Systems Journal*, 45(4), 713-738.

Gibbons, M. C. (2008) eHealth Solutions for Healthcare Disparities, Springer.

Gibson, J. J. (1986) The Ecological Approach to Visual Perception, Hillsdale, NJ: Lawrence Erlbaum.

Giddens, A. (1984) The Constitution of Society: Outline of the Theory of Structuration, Cambridge: Polity Press.

Giunchiglia, F., Maltese, V. and Dutta, B. (2012) Domains and context: First steps towards managing diversity in knowledge, *Journal of Web Semantics*, 12–13, 53–63.

Glaser, B.G. and Strauss, A. (1967) Discovery of Grounded Theory: Strategies for Qualitative Research, Sociology Press.

Glasgow, R. E. (2007) eHealth Evaluation and Dissemination Research, Am J Prev Med., 32(5 Suppl), S119-26.

Gómez-Pérez, A. and Benjamins, V. R. (1999) Overview of Knowledge Sharing and Reuse Components: Ontologies and Problem Solving Methods, IJCAI-99 Workshop on Ontologies and Problem-Solving Methods: Lessons Learned and Future Trends, CEUR Publications, 18, 1-15.

Gonzalez, C. and Wimisberg, J. (2007) Situation Awareness in Dynamic Decision Making: Effects of Practice and Working Memory, *Journal of Cognitive Engineering and Decision Making*, 1(1), 56-74.

Gil, Y. (2009) From data to knowledge to discoveries: Artificial intelligence and scientific workflows, *Scientific Programming*, 16(4), 231-246.

Goldkuhl, G. and Röstlinger, A. (2006) Context in Focus: Transaction and Infrastructure in Workpractices, Int'l Conf. on Action in Language, Organisations and Information Systems (ALOIS), Borås, 41-58.

Goud, R., van Engen-Verheul, M., de Keizer, N. F., Bal, R., Hasman, A., Hellemans, I. M. and Peek, N. (2010) The effect of computerized decision support on barriers to guideline implementation: a qualitative study in outpatient cardiac rehabilitation, *Int J Med Inform*., 79(6), 430-7.

Graham, C., Rouncefield, M., Gibbs, M., Vetere, F. and Cheverst, K. (2007) How Probes Work, Australasian conf. on Computer-Human Interaction: Entertaining User Interfaces, ACM, 29-37.

Green, B. (2009) Introduction: understanding and researching professional practice, In: B. Green (ed.), Understanding and researching professional practice, Rotterdam: Sense Publishers, 1-18.

Greenes, R. A. (ed.) (2007) Clinical Decision Support: The Road Ahead, Academic Press/Elsevier Science and Technology.

Grigsby, S., Burstein, F. and Parker, N. (2010) Context Modelling in Time-Critical Decision Support for Medical Triage, In. F. Burstein et al. (eds.), Supporting Real Time Decision-Making, Annals of Inf Syst, 13, Springer, 287-302.

Grimshaw, D., Mott, P. and Roberts, S. (1997) The role of context in decision making: Some implications for database design, *European Journal of Information Systems*, 6(2), 122–128.

Grinter, R. E. (2000) Workflow Systems: Occasions for Success and Failure, *CSCW*, 9, 189–214.

Grol, R. (1993) Development of guidelines for general practice care, *British J of Gen Practice*, 43, 146-51.

Gross, T., Stary, C. and Totter, A. (2005) User-centered awareness in computer-supported cooperative work-systems: Structured embedding of findings from social sciences, *Journal of Human-Computer Interaction*, 18(3), 323–360.

Gruber, T. (1993) A translation approach to portable ontologies, *Knowledge Acquisition*, 5(2), 199-220.

Grudin, J. (1990) The computer reaches out: the historical continuity of interface design, Conf on Human Factors in Computing Systems, ACM, 261-268.

Gutwin, C. (1997) Workspace Awareness in Real-Time Distributed Groupware, PhD Thesis, University of Calgary, Canada.

Guha, R. V. (1991) Contexts: a formalization and some applications, MCC Technical Report ACTCYC-423-91.

Haake, J., Hussein, T., Joop, B., Lukosch, S., Veiel, D. and Ziegler, J. (2009) Context Modeling for Adaptive Collaboration, Universität Duisburg Essen, Tech. Rep. 2, 1-49.

Haas, C. (1996) Writing Technology: Studies on the Materiality of Literacy, Mahwah, NJ: Lawrence Erlbaum Associates.

Halverson, C. (2002) Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories? *CSCW*, 11, 243–267.

Hannan, T. (1999) Variation in Health Care, The Roles of the Electronic Medical Record, *Int'l Journal of Medical Informatics*, 54(2), 127-136.

Harrison, M. I., Koppel, R. and Bar-Lev, S. (2007) Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis, *J Am Med Inform Assoc*., 14(5), pp. 542–549.

Harrison, M. B., Légaré, F., Graham, I. D. and Fervers, B. (2010) Adapting clinical practice guidelines to local context and assessing barriers to their use, *Canadian Medical Association Journal*, 182(2), E78–E84.

Hasan, H. (2009) A Taxonomy of modes of knowledge sharing between disparate groups, PACIS, Available at http://aisel.aisnet.org/pacis2009/48/. [Accessed on 12 Feb 2012].

Hayward, R. S. (2004) Clinical decision support tools: Do they support clinicians? Future Practice, 66-68.

Heath, C. C. and Luff, P. (1992) Collaboration and control: Crisis management and multimedia technology in London Underground Control Rooms, *CSCW*, 1(1-2), 69–94.

Heath, C., vom Lehn, D., Hindmarsh, J., Svensson, M., Sanchez, and Luff, P. (2002) Configuring Awareness, *CSCW*, 11(3-4), 317–347.

Hendriks-Jansen, H. (1996) Catching ourselves in the act – situated activity, interactive emergence, evolution, and human thought, Cambridge: MIT Press.

Hendrix, G, 1975. Expanding the utility of semantic networks through partitioning, IJCAI, 115-121.

Henriksen, K., Dayton, E., Keyes, M. A., Carayon, P. and Hughes, R. (2008) Understanding Adverse Events: A Human Factors Framework, In R. G. Hughes (ed.) Patient Safety and Quality: An Evidence-Based Handbook for Nurses, Rockville, MD: AHRQ Publishers.

Hernes, T. (2003) Enabling and constraining properties of organizational boundaries. In N. Paulsen and T. Hernes (eds.), Managing boundaries in organizations: Multiple perspectives, Houndmills: Palgrave McMillan, 35-54.

Higgs, J. and Jones, M. (2000) Clinical Reasoning in the Health Professions, 2nd Edition, Butterworth-Heinemann.

Hirschheim, R. and Klein, H. K. (1989) Four paradigms of information systems development, *Communications of the ACM*, 32(10), 1199-1216.

Hofstede, G. (2001) Culture's Consequences: Comparing Values, Behaviors, Institutions, and organizations across nations, California: Sage Publications.

Hoft, N. (1996) Developing a Cultural Model, In E. M. del Galdo & J. Nielsen (eds.), International User Interfaces, NY: John Wiley and Sons.

Hollingsworth, D. (1995) Workflow Management Coalition: The Workflow Reference Model, The WfMC Specification, TC00-1003, Issue 1.1, [online]. Available from http://www.wfmc.org/standards/docs/tc003v11.pdf. [Accessed on 20 Jan 2012].

Holmquist, J. P. and Goldberg, S. L. (2007) Dynamic Situations: The Soldier's Situation Awareness, University of Central Florida, Orlando, RTO-TR-HFM-

121-Part-II, [online], <available at: http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-HFM-121-PART-II///TR-HFM-121-Part-II-06.pdf>, [accessed on 02 Feb 2012].

Holzman, L. (2006) What Kind of Theory is Activity Theory? *Theory and Psychology*, 16(1), 5-11.

Hopwood, N. (2010) Dwelling in complexity: relational-ecological understandings of context, space, place, and the body in professional practice, Presented at the AARE Int'l Research in Education Conf., Melbourne, 28 Nov – 2 Dec.

Hoshi, K. (2011) Reframing Dichotomies: Human Experiential Design of Healthcare Technologies, In: M. Ziefle and C. Röcker (eds.), Human-Centered Design of E-Health Technologies: Concepts, Methods and Applications, Medical Information Science Reference, PA, US: IGI Global.

Househ, M., Kushniruk, A., Maclure, M., Carleton, B. and Cloutier-Fisher, D. (2009) A Case Study Examining the Impacts of Conferencing Technologies in Distributed Healthcare Groups, *ElectronicHealthcare*, 8(2), e10-e13.

Huang, Z., Chen, H., Guo, F., Xu, J. J., Wu, S. and Chen, W. (2006) Expertise Visualization: An Implementation and Study Based on Cognitive Fit Theory. *Decision Support Systems*, 42(3), 1539–1557.

Hughes, J., Randall, D. and Shapiro, D. (1993) From Ethnographic Record to System Design: Some experiences from the field, *CSCW*, 1(3), 123-141.

Humber, M., Butterworth, H., Fox, J. and Thomson, R. (2001) Medical decision support via the internet: PROforma and Solo, *Stud Health Technol Inform*, 10(1), 464-468.

Huser, V., Rasmussen, L. V., Oberg, R. and Starren, J. B. (2011) Implementation of workflow engine technology to deliver basic clinical decision support functionality, *BMC Medical Research Methodology*, 11(43), 1-19.

Hussain, S. and Abidi, S. S. (2009) Integrating Heterogeneous Healthcare Knowledge for Clinical Decision Support: A Semantic Web Based Approach for Healthcare Knowledge Morphing, AI in Medicine, Verona, Springer-Verlag, July 18-22.

Hutchins, E. (1995) Cognition in the Wild. Cambridge, MA: MIT Press.

Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B. B., Druin, A., Plaisant, C., Beaudouin-Lafon, M., Conversy, S., Evans, H., Hansen, H., Roussel, N., and Eiderbäck, B. (2003) Technology probes: inspiring design for and with families, Human Factors in Computing Systems, Florida, USA, April 05-10, pp.17-24.

Iakovidis, I., Wilson, P. and Healy, J.C. (eds.) (2004) E-Health: Current Situation and Examples of Implemented and Beneficial E-Health Applications, Amsterdam, NLD: IOS Press.

IANIS (2007) Guide to Regional Good Practice eHealth: Regional Challenges and Impact, Innovative Actions Network for the Information Society, Brussels [online]. Available from http://www.bth.se/fou/forskinfo.nsf/0/8feaa4dab175d317c12573c4004aea64/$FILE/IANISplus_GGP_eHealth.pdf . [Accessed on: 13 Dec 2011].

Igira, F. T. (2008) The situatedness of work practices and organisational culture: implications for information systems innovation uptake, *Journal of Information Technology*, 23(2), 79-88.

IOM (2001) Crossing the Quality Chasm: A New Health System for the 21st Century, Committee on Quality of Health Care in America, National Academy Press.

IOM (2000) To Err Is Human: Building a Safer Health System, Committee on Quality of Health Care in America, National Academy Press.

Isah, E. E. (2008) The information practices of physicians in clinical practice, Information Research, vol. 13, no. 1, [online]. Available from http://informationr.net/ir/13-4/wks02.html. [Accessed on 10 Dec 2011].

Jarrahi, M. H. and Sawyer, S. (2010) Social Networking Technologies and Informal Knowledge Sharing in Organizations, IFIP 8.2/Organizations and Society in Information Systems, Sprouts, 10(87), [online]. Available from http://sprouts.aisnet.org/10-87. [Accessed on 14 Dec 211].

Jarvenpaa, S. L. and Leidner, D. E. (1998) Communication and trust in global virtual teams, *Journal of Computer-Mediated Communication*, 3(4), 791-815.

Jehn, K. A. and Jonsen, K. (2010) A Multimethod Approach to the Study of Sensitive Organizational Issues, *Journal of Mixed Methods Research*, 4(4), 313-341.

Jennings, B. M. and Loan, L. A. (2001) Misconceptions among nurses about evidence-based practice, *J Nurs Scholarsh*, 33(2), 121–127.

Jensen, R. and Szulanski, G. (2004) Stickiness and the Adaptation of Organizational Practices in Cross-Border Knowledge Transfers, *Journal of International Business Studies*, 35(6), 508-523.

Jirotka, M., Gilbert, N. and Luff, P. (1992) On the social organisation of organisations, *CSCW*, 1, 95–118.

Johri, A., Pipek, V., Wulf, V. and Veith, M. (2007) Bridging artifacts and actors: supporting knowledge and expertise sharing work practices through technology, ACM Symposium on Computer Human Interaction for the Management of Information Technology (CHIMIT ‘07), 1–4.

Jovchelovitch, S. (2007) Knowledge in Context: Representations, Community and Culture, Routledge.

Judelman, G. B. (2004) Knowledge Visualization: Problems and Principles for Mapping the Knowledge Space, MSc Thesis, International School of New Media, University of Lübeck, Germany.

Jurisica, I. (1994) Context-based similarity applied to retrieval of relevant cases. Technical Report DKBS-TR-94-5, Department of Computer Science, University of Toronto, Toronto.

Kaenampornpan, M. and O’Neil, E. (2005) Integrating History and Activity Theory in Context Aware System Design, W8 ECHISE 2005 - 1st Int’l Workshop on Exploiting Context Histories in Smart Environments, Pervasive '05, Munich, Germany, 8-13 May.

Kajamaa, A. (2011) Boundary breaking in a hospital: Expansive learning between the worlds of evaluation and frontline work, *Learning Organization*, 18(5), 361-377.

Kammer, P., Bolcer, G. and Bergman, M. (1998) Requirements for Supporting Dynamic and Adaptive Workflow on the WWW, Workshop on Adaptive Workflow Systems, CSCW '98 Workshop, Seattle, WA.

Kaptelinin, V. (1996) Activity Theory: Implications for Human-Computer Interaction, In B. A. Nardi (ed.), Context and Consciousness: Activity Theory and Human-Computer Interaction, Cambridge, MA: MIT Press, 53-59.

Kaptelinin, V. and Nardi, B. (2006) Acting with Technology: Activity Theory and Interaction Design, Cambridge: MIT Press.

Karacapilidis, N. (2006) An Overview of Future Challenges of Decision Support Technologies, In: J. Gupta, G. Forgionne and M. Mora (eds.), Intelligent Decision-Making Support Systems: Foundations, Applications and Challenges, London, UK: Springer-Verlag, 385-399.

Karacapilidis, N. (2008) Technological and Social Issues of E-Collaboration Support Systems. In M. Khosrow-Pour (ed.), Encyclopedia of Information Science and Technology - Second Edition, IGI Global, Hershey, PA, 3674-3679.

Karasti, H. (2001) Increasing sensitivity towards everyday work practice in system design, PhD thesis, Department of Information Processing Science, University of Oulu.

Kaur, H. and Wasan, S. K. (2010) An Integrated Approach in Medical Decision-Making for Eliciting Knowledge, In: A. Lazakidou (ed.), Web-Based Applications in Healthcare and Biomedicine, Springer, 215-227.

Kay, J. (1994), Lies, damned lies and stereotypes: pragmatic approximations of users, In: A. Kobsa and D. Litman (eds.), Int'l Conf. on User Modeling (UM'1994), MA, USA, 175-184.

Kelle, U. (2005) "Emergence" vs. "Forcing" of Empirical Data? A Crucial Problem of "Grounded Theory" Reconsidered, Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 6(2), article 27, [online]. Available from http://nbn-resolving.de/urn:nbn:de:0114-fqs0502275. [Accessed on: 10 Jan 2012].

Kemmis, S. (2009) Understanding professional practice: a synoptic framework, In: B. Green (ed.), Understanding and researching professional practice, Rotterdam: Sense Publishers, 19-39.

Kerosuo, H. (2006) Boundaries in Action: An Activity-theoretical Study of Development, Learning and Change in Health Care for Patients with Multiple and Chronic Illnesses, Helsinki: Helsinki University Press.

Khazanchi, D. and Munkvold, B. E. (2000) Is information systems a science? An inquiry into the nature of the information systems discipline, *The Database for Advances in Information Systems*, 31(3), 26-44.

Kirlik, A. and Strauss, R. (2003) A Systems Perspective on Situation Awareness I: Conceptual Framework, Modeling, and Quantitative Measurement, Technical

Report AHFD-03-12/NTSC-03-2, Naval Training Systems Center, Orlando, FL.

Kirsch-Pinheiro, M., Gensel, J. and Martin, H. (2004) Representing Context for an Adaptative Awareness Mechanism, In: G.-J. de Vreede; L.A. Guerrero, G.M.Raventos (eds.), LNCS 3198 - CRIWG 2004, Costa Rica, Springer, 339-348.

Kirsh, D. (2001) The Context of Work, *Human computer Interaction*, 16(2-4), 305-322.

Klein, G. A. (1999) Applied decision making, In P.A. Hancock, (ed.), Handbook of Perception and Cognition: Human Performance and Ergonomics, NY: Academic Press, 87-108.

Kłopotek, M. A. and Wierzchoń, S. T. (2002) Empirical Models for the Dempster–Shafer Theory, In: Srivastava, R.P., Mock, T.J., (eds.), Belief Functions in Business Decisions. Series: Studies in Fuzziness and Soft Computing, Springer-Verlag, 88, 62–112.

Koch, M. (2008) CSCW and Enterprise 2.0 - towards an integrated perspective, 21st eConference on eCollaboration: Overcoming Boundaries through Multi-Channel Interaction, Slovenia, 18(12), 416-427.

Kock, N. and Nosek, J. (2005) Expanding the Boundaries of E-Collaboration, IEEE Transactions on Professional Communication, 48(1), 1-9.

Kock, N. ed. (2008) Encyclopedia of e-Collaboration, NY: IGI Global Publishers.

Kofod-Petersen, A. and Cassens, J. (2006) Using Activity Theory to Model Context Awareness, In Thomas R. Roth-Berghofer, Stefan Schulz, and David B. Leake, (eds.) Modeling and Retrieval of Context: MRC05, 3946, LNCS, 1-17.

Kofod-Petersen, A. and Aamodt, A. (2009) Case-based Reasoning for Situation-aware Ambient Intelligence: A Hospital Ward Evaluation Study, Int'l Conf. on Case-Based Reasoning ICCBR'09, Springer-Verlag, 450-464.

Kogan, S. L. and Muller, M. J. (2006) Ethnographic Study of Collaborative Knowledge Work, *IBM Systems Journal*, 45(4), 759-771.

Kohn, M. (2011) IBM Watson: Clinical Decision Support, Presentation to the New York Technology Council, 9 Dec, Available at: <http://www.slideshare.net/NYTechCouncil/ibm-watson-clinical-decision-support>, [accessed on 15 March 2012].

Kolodner, J. (1993) Case-Based Reasoning, Morgan Kaufmann Publishers Inc.

Kozminsky, L., Nathan, N. and Kozminsky, E. (2008) Using concept mapping to construct new knowledge while analysing research data: the case of the grounded theory method, In A. J. Cañas, P. Reiska, M. Åhlberg and J. D. Novak (eds.), Int. Conf. on Concept Mapping: Connecting Educators, Finland, Available: http://cmc.ihmc.us/cmc2008papers/cmc2008-p231.pdf. [Accessed on 03 Mar 2012].

Kraut, R., Fish, R., Root, R. and Chalfonte, B. (1990) Informal communication in organizations: form, function and technology, In I. S. Oskamp and S. Spacapan (eds.), Human Reactions to Technology: The Claremont Symposium on Applies Social Psychology, Beverly Hills, CA: Sage Publications, 145-199.

Kreifelts, T., Hinrichs, E., Klein, K., Seuffert, P. and Woetzel, G. (1991) Experiences with the DOMINO office procedure system, European conf. on CSCW, 117–130.

Kurtz, C. F. and Snowden, D. J. (2003) The new dynamics of strategy: Sense-making in a complex and complicated world, *IBM Systems Journal*, 42(3), 462-483.

Kuutti, K., Nissen, H. E., Klein, H. K., and Hirschheim, R. (1991) Activity Theory and its applications to information systems research and development, In Information Systems Research Contemporary Approaches and Emergent Traditions, Amsterdam: Elsevier, 529-549.

Kuutti, K. (1996) Activity theory as a potential framework for human-computer interaction research, In B. A. Nardi (ed.) Context and Consciousness: Activity Theory and Human-Computer Interaction, Cambridge: MIT Press, 17–44.

Kuziemsky, C. E. and Varpio, L. (2010) Describing the Clinical Communication Space through a Model of Common Ground - You Dont Know What You Dont Know, AMIA Annu Symp., 407-11.

Kuziemsky, C. E. and Varpio, L. (2011) A model of awareness to enhance our understanding of interprofessional collaborative care delivery and health information system design to support it, *Int. J. Med Inform*, 80(8), 150-160.

Lacson, R. C. (2000) Knowledge Representation of situation-specific clinical practice guidelines, MS Thesis, Cambridge, MA: MIT.

Lagerstrom, K. and Andersson, M. (2003) Creating and sharing knowledge within a transnational team—the development of a global business system, *Journal of World Business*, 38, 84–95.

Lantolf, J. (2006) Sociocultural theory and L2 development: State of the art. *Studies in Second Language Acquisition*, 28(1), pp. 67-109.

Latifi, R. (ed.) (2008) Current principles and practices of telemedicine and e-health, Amsterdam: IOS Press.

Lave, J. and Wenger, E. (1991) Situated Learning: Legitimate Peripheral Participation, NY: Cambridge University Press.

Lawrence, P. (ed.) (1997) Workflow Handbook 1997, Workflow Management Coalition, NY: John Wiley.

lé May, A. (ed.) (2009) Communities of Practice in Health and Social Care, Hoboken, NJ, USA: Wiley-Blackwell.

lé May, A. and Gabbay, J. (2010) Evidence-based practice: more than research needed?, In G. Lewith, J. Cousins and H. Walach (eds.) Clinical research in complementary therapies, Edinburgh: Elsevier.

Lee, J., Kim, J., Cho, I. and Kim, Y. (2010) Integration of Workflow and Rule Engines for Clinical Decision Support Services, *Studies In Health Technology And Informatics*, 160(2), 811-5.

Leech, N. L. and Onwuegbuzie, A. J. (2009) A typology of mixed methods research designs, Quality and Quantity *Int'l Journal of Methodology*, 43(2), 265-275.

Lehmann, D. J. (1998) Stereotypical Reasoning: Logical Properties, Logic *Journal of the IGPL*, 6(1), 49-58

Leidner, D., Alavi, M. and Kayworth, T. (2006) The Role of Culture in Knowledge Management: A Case Study of Two Global Firms, *Int'l Journal of e-Collaboration*, 2(1), 17-40.

Leont'ev, A. N. (1978) Activity, Consciousness and Personality, Englewood Cliffs: Prentice-Hall.

Lenat, D. (1995) Cyc: A Large-Scale Investment in Knowledge Infrastructure, *Communications of the ACM*, 38(11), 32-38.

Li, J. (2010) A Sociotechnical Approach to Evaluating the Impact of ICT on Clinical Care Environments, *Open Med Inform J.*, 4, 202–205.

Lindblom, J. and Ziemke, T. (2002) Social Situatedness: Vygotsky and Beyond, In: Prince, Demiris, Marom, Kozima and Balkenius (eds.), Int’l Workshop on Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems, Lund University Cognitive Studies, 94, 71-78.

Liu, L. and Pu, C. (1997) ActivityFlow: Towards incremental specification and flexible coordination of workflow activities, Int'l Conf. on Conceptual Modeling (ER’97), California, USA, Springer, 169–182.

Llewellyn, N. and Hindmarsh, J. (eds.) (2010) Organisation, Interaction and Practice: Studies in Ethnomethodology and Conversation Analysis, Cambridge: Cambridge University Press.

Loo, G. S. and Lee, P. C. H. (2001) A Soft Systems Methodology, Model for Clinical Decision Support Systems, *Medical Engineering & Physics*, 23, 217-225.

Lueg, C. (2002) Looking under the rug: On context-aware artifacts and socially adept technologies, Philosophy and Design of Socially Adept Technologies, ACM SIGCHI Conf. on Human Factors in Computing Systems, Canada NRC 44918.

Luff, P., Hindmarsh, J. and Heath, C. C. (eds.) (2000) Workplace Studies: Recovering Work Practice and Informing System Design, Cambridge: Cambridge University Press.

Luzon, M. J. (2008) Academic Weblogs as tools for E-Collaboration among Researchers, In Encyclopedia of e-Collaboration, Kock, N. (ed.), NY: IGI Global, 1-5.

Maguire, M. (2001) Context of Use within usability activities, *Int’l Journal of Human-Computer Studies*, 55(4), 453-483.

Mark, G., Poltrock, S. and Grudin, J. (2000) Virtually Collocated Teams in the Workplace, Workshop at CHI 2000, 1-6 April.

Malone, T. W., Crowston, K., Lee, J. and Pentland, B. (1999) Tools for inventing organizations: Toward a handbook of organizational processes, *Management Science*, 45(3), 425-443.

Mamykina, L., Mynatt, E. D. and Kaufman, D. R. (2006) Investigating health management practices of individuals with diabetes, CHI '06, NY: ACM Press, 927-936.

Markopoulos, P. and Mackay, W. (2009) Awareness Systems: Advances in Theory, Methodology and Design, London: Springer-Verlag.

Marouf, L. N. (2007) Social networks and knowledge sharing in organizations, *Journal of Knowledge Management*, 11(6), 110-125.

May, C. (2007) The Clinical Encounter and the Problem of Context, *Sociology*, 4(1), 29-45.

Mayrhofer, R. (2004) An Architecture for Context Prediction, PhD Thesis, Johannes Kepler University of Linz, Austria.

Martinez-Carreras, M. A., Munoz, A., Botia, J., Gomez-Skarmeta, A. F. (2011) Creating Context-Aware Collaborative Working Environments, *International Journal on Artificial Intelligence Tools*, 20(1), 195-207.

Martínez, A., Villarroel, V., Seoane, J. and del Pozo, F. (2005) Analysis of information and communication needs in rural primary health care in developing countries, *IEEE Transactions on Information Technology in Biomedicine*, 9(1), 66-72.

McCarthy, J. (1958) Programs with Common Sense, Symposium on Mechanization of Thought Processes, National Physical Laboratory, Teddington, England.

McCarthy, J. and Hayes, P. J. (1968) Some philosophical problems from the standpoint of artificial intelligence, In M. L. Ginsberg (ed.) Readings in nonmonotonic reasoning, Morgan Kaufmann, 26-45.

McCleverty, A. (1997) Ethnography, Partial Requirements for Computer Science 68I: Research Methodologies, University of Calgary, Canada.

McDermott, J. (1982) R1: A rule based configurer of computer systems, *Artificial Intelligence Journal*, 19, 39-88.

McGuiness, B. and Foy, L. (2000) A subjective measure of SA: The Crew Awareness Rating Scale (CARS), Human Performance, Situation Awareness and Automation Conf., Georgia, 15-19 Oct., SA Technologies, Inc.

McPherson, K., Wennberg, J. E., Hovind, O. B. and Clifford, P. (1982) Small-Area Variations in the Use of Common Surgical Procedures: An Int'l Comparison of New England, England, and Norway, *N Engl J Med*, 307(21), 1310-1314.

Mejia, D. A., Favela, J. and Morán, A. L. (2010) Understanding and supporting lightweight communication in hospital work, *IEEE Trans. on Information Technology in Biomedicine*, 14(1), 140-146.

Metzger, J. and MacDonald, K. (2002) Clinical Decision Support for the Independent Physician Practice, Oakland: California Healthcare Foundation.

Myers, B. A. (1998) A Brief History of Human Computer Interaction Technology, I*nteractions*, 5(2), 44-54.

Miksch, S., Shahar, Y. and Johnson, P. (1997) Asbru: A task-specific, intention-based, and time-oriented language for representing skeletal plans, Workshop on Knowledge Engineering: Methods & Languages (KEML-97), Open University, Milton Keynes.

Miller, M. and Drexler, K. (1988) Comparative Ecology: A Computational Perspective, In Huberman, B. A. (ed.), The Ecology of Computation, NY: Elsevier.

Miller, K. (2010) Clinical Decision Support: Providing Quality Healthcare with Help from a Computer, Biomedical Computation Review, 19-28.

Minichiello, V., Aroni, R., Timewell, E. and Alexander, L. (1995) In-depth Interviewing: Principles, Techniques, Analysis, Melbourne: Longman.

Minsky, M. A (1974) Framework for Representing Knowledge, MIT-AI Lab. Memo 306, Available from http://web.media.mit.edu/~minsky/papers/Frames/frames.html. [Accessed on 28 March 2012]

Montgomery, K. (2006) How doctors think: clinical judgment and the practice of medicine, Oxford: Oxford University Press.

Mora, M., Lopes, J., Viccari, R. and Coelho, H. (1999) BDI Models and Systems: Bridging the Gap, Workshop on Intelligent Agents V. Agent Theories Architectures and Languages, 1555, Springer-Verlag, 11-27.

Morán, T. and Dourish, P. (eds.) (2001) Introduction to this special issue on context-aware computing, *Journal of Human-Computer Interaction*, 16, 2-4.

Morán, A. L., Rodríguez-Covili, J., Mejia, D. A., Favela, J. and Ochoa, S. F. (2010) Supporting Informal Interaction in a Hospital through Impromptu Social Networking, CRIWG 2010, 305-320.

Muir Gray, J. A. (1997) Evidence-based Healthcare, London, UK: Churchill Livingston.

Muller, M.J.,Wharton, C.,McIver Jr.,W.J., Laux, L. (1997) Toward an HCI research and practice agenda based on human needs and social responsibility, SIGCHI Conference on Human Factors in Computing Systems, ACM Press, 155–161.

Muñoz, M., Gonzalez, V., Rodríguez, M. and Favela, J. (2003) Supporting Context-Aware Collaboration in a Hospital: An Ethnographic Informed Design, Workshop on Groupware (CRIWG 2003), LNAI, Springer Verlag, vol. 2806, 330–344.

Musen, M. A., Shahar, Y. and Shortliffe, E. H. (2000) Clinical decision-support systems, In: E. H. Shortliffe and L. E. Perreault, (eds.), G. Wiederhold and L.M. Fagan, (assoc. eds.), Medical Informatics: Computer Applications in Health Care and Biomedicine, NY: Springer-Verlag, 573-609.

Mursu, A., Luukkonen, I., Toivanen, M. and Korpela, M. (2007) Activity Theory in information systems research and practice: theoretical underpinnings for an information systems development model, Information Research, 12(3), paper 311. Available from http://InformationR.net/ir/12-3/paper311.html. [Accessed on 04 Mar 2012].

Mwanza, D. (2000) Mind the Gap: Activity Theory and Design, Technical Report KMITR-95, Knowledge Media Institute, The Open University, UK.

Nardi, B. (1996) Context and Consciousness: Activity Theory and Human-Computer Interaction, Cambridge, MA: MIT Press.

Nardi, B. and Engeström, Y. (eds.) (1998) A Web on the Wind: The Structure of Invisible Work, Special Issue of CSCW, 8(1-2).

Nardi, B. and Redmiles, D. eds. (2002) Activity Theory and the Practice of Design, Special Issue of CSCW, 11(1-2).

Nasirifard, P. (2007) Context-Aware Access Control for Collaborative Working Environments Based on Semantic Social Networks, Interdisciplinary Conf. on Modeling and Using Context (Context'07), Roskilde, Denmark.

NCI (2009) Adjuvant and Neoadjuvant Therapy for Breast Cancer, Available from http://www.cancer.gov/cancertopics/factsheet/Therapy/adjuvant-breast. [Accessed on 15 March 2012]

Neches, R., Fikes, R., Finin, T., Gruber, T., Patil, R., Senator, T. and Swartout, W. R. (1991) Enabling technology for knowledge sharing, *AI Magazine*, 12(3), 36-56.

Nerlich, M. and Schaechinger, U. (eds.) (2003), Integration of Health Telematics into Medical Practice, *Stud in Health Tech and Informatics*, 97, US: IOS Press.

Newell, A. (1981) The Knowledge Level, *AI Magazine*, Summer, 1-20, 33.

Nielsen, J. (1994) Usability Engineering, 2nd ed., California: Academic Press.

Nof, S. (2003) Design of Effective E-Work: Review of Models, Tools, and Emerging Challenges, *Production Planning and Control*, 14(8), 681-703.

Nonaka, I. and Takeuchi, H. (1995) The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation, Oxford: Oxford University Press.

Novak, J. (2007) Helping Knowledge Cross Boundaries: Using Knowledge Visualization to Support Cross-Community Sensemaking, HICSS, Waikoloa, HI, USA.

Nunes, V. T., Santoro, F. M. and Borges, M. R. S. (2009) A context-based model for Knowledge Management embodied in work processes, *Journal of Information Sciences*, 179, 2538-54.

Nutt, G. (1996) The Evolution Towards Flexible Workflow Systems, *Distributed Systems Engineering*, 3(4), 276-294.

Nwiabu, N. Allison, I., Holt. P. Lowit, P. and Oyeneyin, B. (2011) Situation awareness in context-aware case-based decision support, IEEE Conf. on Cognitive Methods in Situation Awareness and Decision Support, Feb, 9-16.

Oborn, E., Barrett, M. and Racko, G. (2010) Knowledge translation in healthcare: a review of the literature, Working Paper, Cambridge Judge Business School, University of Cambridge.

O'Cathain, A. (2009) Mixed Methods Research in the Health Sciences: A Quiet Revolution (editorial). *J of Mixed Methods Research*, 3(1), 3-6.

Oh, H., Rizo, C., Enkin, M. and Jadad, A. (2005) What is eHealth: a systematic review of published definitions. *J Med Internet Res*, 7(1).

Orlikowski, W. J. (2002) Knowing in Practice: Enacting a Collective Capability in Distributed Organizing, *Organization Science*, 13(3), 249–273.

Osheroff, J. A., Teich, J. M., Middleton, B., Steen, E. B., Wright, A. and Detmer, D. E. (2007) A roadmap for national action on clinical decision support, *Journal of the American Medical Informatics Association*, 14(2), 141–5.

Ozen, T., Garibaldi, J. M. and Musikasuwan, S. (2004) Modelling the Variation in Human Decision Making, North American Fuzzy Information Processing Society (NAFIPS2004), Banff, Canada.

Öztürk, P. and Aamodt, A. (1998) A context model for knowledge-intensive case-based reasoning. *Int'l Journal of Human-Computer Studies*, 48(3), 331-355.

Pace, T., Bardzell, S. and Fox, G. (2010) Practice-Centered e-Science: A Practice Turn Perspective on Cyberinfrastructure Design, ACM Int’l Conference on Supporting Group Work, ACM Press, 293-302.

Pace, S. (2004) A grounded theory of the flow experiences of web users, *Int'l Journal of Human-Computer Studies*, 60(3), 327-363.

Pallant, J. (2010) SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS program, (4th edition), Open University Press.

Panzarasa, S., Madde, S., Quaglini, S., Pistarini, C. and Stefanelli, M. (2002) Evidence-based careflow management systems: the case of post-stroke rehabilitation, *J Biomed Inform*, 35(2), 123-39.

Patel, V. L., Arocha, J. F. and Zhang, J. (2004) Thinking and reasoning in medicine, In: Keith Holyoak (ed.), Cambridge Handbook of Thinking and Reasoning, Cambridge, UK: Cambridge University Press.

Patkar,V., Acosta, D., Davidson, T., Jones, A., Fox, J. and Keshtgar, M. (2011) Cancer Multidisciplinary Team Meetings: Evidence, Challenges, and the Role of Clinical Decision Support Technology, *Int'l Journal of Breast Cancer*, 2011(831605).

Pedersen, K. V. (2004) Context Based Support for Clinical Reasoning, I-KNOW'04, Graz, Austria,30 Jun - 2 Jul.

Peek.N. (2011) Guideline-Based Decision Support Systems for Prevention and Management of Chronic Diseases, In: Jao, C. (ed.) Efficient Decision Support Systems - Practice and Challenges in Biomedical Related Domain, InTech Publishers.

Perednia, D. A. and Allen, A. (1995) Telemedicine Technology and Clinical Applications, *JAMA*, 273(6), 483-488.

Perin, C. (1991) Electronic social fields in bureaucracies, *Communications of the ACM*, 34(12), 74–82.

Petersen, M. G., Madsen, K. H. Kjær, A. (2002) The usability of everyday technology: emerging and fading opportunities, *ACM Transactions on Computer-Human Interaction*, 9(2), 74-105.

Pipek, V., Wulf, V. and Johri, A. (2011) Bridging Artifacts and Actors: Expertise Sharing in Organizational Ecosystems, *Journal of CSCW*, Springer, Online First, 26 July.

Plano Clark, V. L. (2010) The Adoption and Practice of Mixed Methods: U.S. Trends in Federally Funded Health-Related Research, *Qualitative Inquiry*, 16(6), 428-440.

Plowman, L., Rogers, Y. and Ramage, M. (1995) What are workplace studies for? In: ECSCW ’95, Stockholm, Dordrecht: Kluwer Academic.

Pomerol, J. and Brézillon, P. (2001) About Some Relationships between Knowledge and Context, Interdisciplinary Conf on Modeling and Using Context, Springer, 461-464.

Portoraro, F. (2011) Automated Reasoning, In E. N. Zalta (ed.), The Stanford Encyclopaedia of Philosophy, [online]. Available from http://plato.stanford.edu/archives/sum2011/entries/reasoning-automated/. [Accessed on: 24 May 2012].

Porzel, R. (2011) Contextual Computing: Models and Applications (Cognitive Technologies), Berlin/Heidelberg: Springer-Verlag.

Postill, J. (2010) Introduction: Theorising media and practice, In B. Bräuchler and J. Postill (eds.) Theorising Media and Practice, Oxford: Berghahn.

Pott, C., Johnson, A. and Cnossen, F. (2005) Improving Situation Awareness in Anaesthesiology, Annual Conf. on European Association of Cognitive Ergonomics, 255-263.

Priss, U. (2006) Formal Concept Analysis in Information Science, In: Cronin, Blaise (ed.), *Annual Review of Information Science and Technology*, 40, 521-543.

Quaresma, P. and Lopes, J. G. (1995) Unified Logic Programming Approach to the Abduction of Plans and Intentions in Information-Seeking Dialogues, *Journal of Logic Programming*, 24(1–2), 103–119.

Raeithel, A. (1992) Activity theory as a foundation for design, In: Floyd C. Züllighoven, H., Budde, R. and Keil-Slawik, R. (eds.) Software Development and Reality Construction. Berlin: Springer, 391-415.

Randall, D., Harper, R. and Rouncefield, M. (2007) Fieldwork for Design: Theory and Practice, Springer.

Rasmussen, J., Pejtersen, A. M. and Schmidt, K. (1990) Taxonomy for Cognitive Work Analysis, Report Risø-M-2871, Risø National Laboratory.

Rattenbury, T. L. (2008) An Activity Based Approach to Context-Aware Computing, PhD Thesis, University of California, Berkeley.

Razavi, M. N. and Iverson, L. (2006) A Grounded Theory of Information Sharing Behavior in a Personal Learning Space, ACM 2006 Conf.on CSCW, Banff, Alberta, Canada.

Reckwitz, A. (2002) Towards a theory of social practices: A development in culturalist theorizing, *European Journal of Social Theory*, 5(2), 243–263.

Reddy, M., Pratt, W., Dourish, P., and Shabot, M. (2003) Sociotechnical Requirements Analysis for Clinical Systems, Methods of Information in Medicine, 42, 437-444.

Reichert, M., Rinderle, S., Kreher, U. and Dadam, P. (2005) Adaptive process management with ADEPT2, Int'l Conf. on Data Engineering (ICDE'05), Tokyo, Japan, April, IEEE Computer Society, Press, 1113–4.

Resmini, A. and Rosati, L. (2011) Pervasive Information Architecture: Designing Cross-Channel User Experiences, Morgan Kaufmann.

Respício, A., Adam, F., Phillips-Wren, G., Teixeira, C. and Telhada, J. (2010) Bridging the Socio-technical Gap in Decision Support Systems: Challenges for the Next Decade, Frontiers in Artificial Intelligence and Applications, vol. 212, IOS Press.

Rich, E. (1979) User Modelling via Stereotypes, *Cognitive Science*, 3, 329-354.

Riemer, K. and Haines, R. (2008) Pools and Streams: A Theory of Dynamic, Practice-Based Awareness Creation in Mediated-Communication, JAIS Theory Development Workshop, Sprouts: Working Papers on Information Systems, 8(12), [online]. Available from http://sprouts.aisnet.org/8-12. [Accessed on: 15 Nov 2011].

Riemer, K., Klein, S. and Frößler, F. (2007) Towards a practice understanding of the creation of awareness in distributed work, 28th Int'l Conference on Information Systems (ICIS), Montreal, Dec 8-12.

Riesbeck, C. and Schank, R. (1989) Inside Case-based Reasoning. Northvale, NJ: Erlbaum.

Richter, M. (2008) Similarity, Studies in Computational Intelligence, 73, Springer, 25–90.

Robbins, D. (2006) What is Vygotskian Cultural-Historical Theory? Presented at the 2006 Int'l Vygotsky Conference, Moscow, Russia, Unpublished paper, 16th Nov.

Robbins, D. (2007) Critical Review of Sociocultural Theory: Redefining Vygotsky's Non-Classical Psychology, *International Pragmatics*, 4(1), pp. 85-97.

Robinson, M. and Bannon, L. (1991) Questioning Representations, European Conf. on CSCW, Amsterdam, 25-27 Sept.

Robinson, M. (1993) Design for unanticipated use..., European Conf. on Computer-Supported Cooperative Work, 187-202.

Robinson, M. (1997) As Real as It Gets . . . : Taming Models and Reconstructing Procedures, In Geoffrey Bowker, S. L. Star, W. Turner, and L. Gasser (eds.), Social Science, Technical Systems and Cooperative work: Beyond the Great Divide, Hillsdale, NJ: Erlbaum, 257–274.

Röcker, C. (2009) Perceived Usefulness and Perceived Ease-of-Use of Ambient Intelligence Applications in Office Environments, In: M. Kuroso (ed.), Human-Centered Design, HCII 2009, LNCS 5619, Springer, Germany, 1052-1061.

Rodden, T. and Schmidt, K. (1992) Putting it all together: Requirements for a CSCW platform, Technical Report CSCW/9/1992, Lancaster University Computing Department.

Roddick, J. F., Hornsby, K. and de Vries, D. (2003) A Unifying Semantic Distance Model for Determining the Similarity of Attribute Values, Conferences in

Research and Practice in Information Technology, 16, Australian Computer Society.

Rogers, Y. (2004) New theoretical approaches for human-computer interaction, *Ann. review of information science and technology*, 38(1), 87–143.

Rogers, Y. (2011) Interaction design gone wild: striving for wild theory, *Interactions*, 18(4), 58-62.

Röll, M. (2004) Distributed KM - Improving Knowledge Workers' Productivity and Organisational Knowledge Sharing with Weblog-based Personal Publishing, Presented at the European Conference on Weblogs, BlogTalk 2.0, Vienna.

Rossman, G. B. and Wilson, B. L. (1985) Numbers and words: Combining quantitative and qualitative methods in a single large-scale evaluation study, *Evaluation Review*, 9(5), 627-643.

Rosson, M. B. and Carroll, J. M. (2002) Usability engineering: Scenario-Based Development of Human-Computer Interaction, San Francisco: Morgan-Kaufmann.

Sacks, H. and Garfinkel, H. (1986) On formal structures of practical action, in H. Garfinkel (ed.), Ethnomethodological Studies of Work, Routledge, 160-193.

Sackett, D. L., Rosenberg, W. M., Gray, J. A., Haynes, R. B. and Richardson, W. S. (1996) Evidence based medicine: what it is and what it isn't, *BMJ*, 312(7023), 71-2.

Sandom, C. and Macredie, R. D. (2003) Analysing situated interaction hazards: an activity-based awareness approach, *Cognition, Technology and Work*, 5(3), 218-228.

Sari, B., Schaffers, H., Kristensen, K., Loh, H. and Slagter, R. (2008) Collaborative Knowledge Workers: Web Tools and Workplace Paradigms Enabling Enterprise Collaboration 2.0, In ECOSPACE IP - eProfessional Collaborative Workspace, Dienstag.

Saltmarsh, S. (2009) Researching context as a 'practiced place', In: B. Green (ed.), Understanding and researching professional practice, Rotterdam: Sense Publishers, 153-163.

Sellen, A. J., Murphy, R. and Shaw, K. (2002) How knowledge workers use the Web, CHI'2002, 4(1), ACM Press, 227-234.

Seyfang, A., Kaiser, K. and Miksch, S. (2009) Modelling Clinical Guidelines and Protocols for the Prevention of Risks Against Patient Safety, Stud Health Technol Inform., 150, 633–637.

Schaffers, H., Brodt, T., Pallot, M. and Prinz, W. (eds.) 2006, The Future Workspace: Perspectives on Mobile and Collaborative Working, The MOSAIC Consortium, The Netherlands, Telematica Instituut.

Schatzki, T. R. (1996) Social practices: a Wittgensteinian approach to human activity and the social, NY: Cambridge University Press.

Schatzki, T. R., Knorr-Cetina, K. and Savigny, E. (2001) Practice Turn in Contemporary Theory, Florence, KY, USA: Routledge.

Schatzki, T. R. (2010) The timespace of human activity: on performance, society, and history as indeterminate teleological events, Lanham, MD: Lexington.

Schein, E. H. (2004) Organizational culture and leadership, NY: John Wiley & Sons.

Schilit, B. N., Trevor, J., Hilbert, D. M. and Koh, T. K. (2002) Web Interaction Using Very Small Internet Devices, *Journal of Computer*, 35(10), 37-45.

Schmidt, K. and Bannon, L. (1992) Taking CSCW Seriously: Supporting Articulation Work, *Journal of CSCW*, 1, 7–41.

Schmidt, K. and Simone, C. (1996) Coordination Mechanisms: Towards a Conceptual Foundation of CSCW Systems Design, *Journal of Collaborative Computing*, 5, 155-200.

Schmidt, K. (2000) The critical role of workplace studies in CSCW, In: Health et al., (eds.) Workplace Studies: Recovering Work Practice and Informing System Design, 141-149.

Schmidt, K. (2002) The Problem with 'Awareness': Introductory Remarks on 'Awareness in CSCW', *Journal of CSCW*, 11(3-4), 285–298.

Schmidt, K., Wagner, I. and Tolar, M. (2007) Permutations of cooperative work practices: a study of two oncology clinics, ACM conference on Supporting group work, ACM, 1–10.

Schön, D. A. (1983) The Reflective Practitioner: How Professionals Think in Action, NY: Basic Books.

Scholtz, J. (2006) Metrics for evaluating human information interaction systems, *Interacting with Computers*, 18(4), 507–527.

Schraefel, M. C. et al. (2009) Interacting with eHealth – Towards Grand Challenges for HCI, Int'l Conf. on Human Factors in Computing Systems, CHI 2009, ACM, 3309-3312.

Schultze, U. (2000) A Confessional Account of an Ethnography about Knowledge Work, *MIS Quarterly*, 24(1), 3-41.

Schwandt, T. A. (2005) On modeling our understanding of the practice fields, *Pedagogy, Culture and Society*, 13(3), 313-332.

Scriven, M. (1967) The methodology of evaluation, In R. Tyler, R. Gagne, and M. Scriven (eds.), Perspectives of curriculum evaluation, Chicago, IL: R and McNally, 39-83.

Shabani, K., Khatib, M. and Ebadi, S. (2010) Vygotsky's Zone of Proximal Development: Instructional Implications and Teachers' Professional Development, English Language Teaching, vol. 3, no. 4, 237–248.

Shafer, G. (1990) Perspectives on the theory and practice of belief functions, *Int'l Journal of Approximate Reasoning*, 3, 1-40.

Shahar, Y., Miksch, S., and Johnson, P. (1998) The Asgaard project: A task-specific framework for the application and critiquing of time-oriented clinical guidelines, *Artificial Intelligence in Medicine*, vol. 14, 29-51.

Shapiro, D. (1994) The limits of ethnography: Combining social sciences for CSCW, ACM Conf. on CSCW, Chapel Hill, NC, ACM Press, 417–439.

Sharp, H., Rogers, Y. and Preece, J. (2007) Interaction Design: Beyond Human-Computer Interaction, 2nd edition, John Wiley.

Shneiderman, B. (1997) Designing the User Interface, Reading, MA: Addison-Wesley.

Shortliffe, E. H., Axline, S. G., Buchanan, B. G., Merigan, T. C. and Cohen, S. N. (1973) An artificial intelligence program to advise physicians regarding antimicrobial therapy, *Comput. Biomed. Res*., 6, 544-560.

Shortliffe, E. H. (2006) Medical Thinking: What Should We Do? Paper presented at Conference on Medical Thinking, University College London, 23 June.

Sierhuis, M. and Clancey, W. J. (1997) Knowledge, Practice, Activities and People, In Gaines, B. (ed.) AAAI Spring Symposium on Artificial Intelligence in Knowledge Management, 142-148.

Sierhuis, M., Clancey, W. J. and van Hoof, R. (2009) Brahms: An Agent-Oriented Language for Work Practice Simulation and Multi-Agent Systems Development, In R. H. Bordini et al. (eds.), Multi-Agent Programming, Springer, 73-117.

Silber, D. (2004) The Case for eHealth, In Iakovidis, I., Wilson, P. and Healy, J.C. (eds.), E-Health: Current Situation and Examples of Implemented and Beneficial E-Health Applications, Amsterdam, NLD: IOS Press, 3-27.

Simon, H. (1991) Bounded Rationality and Organizational Learning, *Organization Science*, 2(1), 125–134.

Sittig, D. F., Wright, A., Osheroff, J. A., Middleton, B., Teich, J. M., Ash, J. S., Campbell, E. and Bates, D. W. (2008) Grand challenges in clinical decision support, *Journal of Biomedical Informatics*, 41, 387–392.

Smith, K. and Hancock, P. (1995) Situation awareness is adaptive, externally directed consciousness, *Human Factors*, 37(1), 137-148.

Sniehotta, F. F. (2009) An experimental test of the Theory of Planned Behavior, Applied Psychology: Health and Well-Being, vol. 1, 257–270.

Sommerville, I .and Sawyer, P. (1997) Requirements Engineering: A Good Practice Guide, John Wiley & Sons.

Sosnovsky, S. (2007) Ontological Technologies for User Modeling, PhD Thesis, School of Information Sciences, University of Pittsburgh.

Sowa, J. F. (2000) Knowledge Representation: Logical, Philosophical and Computational Foundations, Brooks/Cole Publishing.

Spinuzzi, C. (2003) Tracing Genres Through Organizations – a Sociocultural Approach to Information Design, Cambridge: MIT press.

Staab, S. and Studer, R. (2004) Handbook on Ontologies, Springer.

Stahl, G. (2006) Group cognition: Computer support for building collaborative knowledge, Cambridge, MA: MIT Press.

Stahl, A. and Roth-Berghofer, T. R. (2008) Rapid Prototyping of CBR Applications with the Open Source Tool myCBR, In R. Bergmann and K. D. Altho (eds.), Advances in Case-Based Reasoning, Springer-Verlag, 615-629.

Stanton, N. A., Chambers, P. R. G. and Piggott, J. (2001) Situational awareness and safety, *Safety Science*, 39, 189-204.

Star, S. L. and Griesemer, J. R. (1989) Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39, *Social Studies of Science*, 19(3), 387–420.

Star, S. L. (1995) The Politics of Formal Representations: Wizards, Gurus, and Organizational Complexity. In Susan Leigh Star (ed.): Ecologies of Knowledge: Work and Politics in Science and Technology, NY: SUNY, 88–118.

Star, S. L. and Strauss, A. (1999) Layers of Silence, Arenas of Voice: The Ecology of Visible and Invisible Work, *Journal of CSCW*, 8, 9–30.

Stefanelli, M. (2002) Careflow Management Systems, Briefing paper, Commissioned by OpenClinical, [online]. Available from <http://www.openclinical.org/briefingpaperStefanelli.html>, [accessed on: 21 Jan 2012].

Stein, M. (2006) The map of medicine - an innovative knowledge management tool, AMIA Annu Symp, 1196.

Stetsenko, A. and Arievitch, I. M. (2004) The Self in Cultural-Historical Activity Theory: Reclaiming the Unity of Social and Individual Dimensions of Human Development, Theory and Psychology, Sage, 14(4), 475–503.

Stewart, M. (2001) Towards a global definition of patient centred care, Editorial, *BMJ*, 322, 444-5.

Stewart, S. A. and Abidi, S. S. R. (2012) An Infobutton For Web 2.0 Clinical Discussions: The Knowledge Linkage Framework, *IEEE Transactions on Information Technology in Biomedicine*, 16(1), 129-135.

Storey, L. (2007) Doing interpretative phenomenological analysis, In E. Lyons and A. Coyle (ed.), Analysing qualitative data in Psychology, London: Sage, 51-64.

Strauss, A., Fagerhaugh, S., Suczek, B. and Wiener, C. (1985) Social Organization of Medical Work, Chicago: The University of Chicago Press.

Strauss, A. and Corbin, J. (1998) Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, 2nd edition, Sage Publications.

Suchman, L. (1987) Plans and situated actions: The Problem of Human-Machine Communication, NY: Cambridge University Press.

Suchman, L. (1995) Making Work Visible, *Communications of the ACM*, 38(9), 56-64.

Suchman, L., Blomberg, J., Orr, J. E. and Trigg, R. (1999) Reconstructing technologies as social practice, *American Behavioural Scientist*, 43(3), 392–408.

Suchman, L. (2002) Practice-based Design of Information Systems: Notes from the hyper-developed world, *Inf. Soc*., 18(2), 139-144.

Sumner, T., Domingue, J., Zdrahal, Z., Hatala, M., Millican, A., Murray, J., Hinkelmann, K., Bernardi, A., Wess, S. and Traphöner, R. (1998) Enriching Representations of Work to Support Organisational Learning, OM'1998.

Sutton, D. R., Taylor, P. and Earle, K. (2006) Evaluation of PROforma as a language for implementing medical guidelines in a practical context, *BMC Medical Informatics and Decision Making*, 6(20).

Swan, J. (2001) Knowledge Management in Action: Integrating Knowledge Across Communities, HICSS, Maui, Hawaii, 9.

Szulanski, G. (2000) The process of knowledge transfer: A diachronic analysis of stickiness, *Organizational Behaviour and Human Decision Processes*, 82, 9–27.

Szymanski, M. H. and Whalen, J. (eds.) (2011) Making work visible: ethnographically grounded case studies of work practice, Cambridge, UK: Cambridge University Press.

Tadda, G. P. and Salerno, J. S. (2010) Overview of Cyber Situation Awareness, In S. Jajodia et al. (eds.), Cyber Situational Awareness, Advances in Information Security, Springer, 15-35.

Tan, J. (2005) E-Health Care Information Systems: An Introduction for Students and Professionals, San-Francisco: Jossey-Bass.

Tan, W. C., Haas, P. J., Mak, R. L., Kieliszewski, C. A., Selinger, P. G., Maglio, P. P., Glissmann, S., Cefkin, M. and Li, Y. (2012) Splash: a platform for analysis and simulation of health, IHI, 543-552.

Tang, L. (2008) Informal interorganizational knowledge sharing: The case of the biotechnology industry, Presented at the 94th Ann. Conf. of the NCA, San Diego, [online]. Available from http://citation.allacademic.com/meta/p_mla_apa_research_citation/2/5/5/0/9/pages255092/p255092-1.php. [Accessed on 31 Dec 2011].

Tanner, M. C.,Keuneke, A. M. and Chandrasekaran, B. (1993) Explanation Using Task Structure and Domain Functional Models, In J. David, J. Krivine, and R. Simmons (eds.), Second Generation Expert Systems, Springer, 599-626.

Tashakkori, A. and Teddlie, C. B. (2003) Handbook of Mixed Methods in Social and Behavioral Research (2nd edition), Sage.

Tawfik, H., Anya, O. and Nagar, A. (2012) Understanding Clinical Work Practices for Cross-boundary Decision Support in e-Health, IEEE Trans on Inf. Technol. Biomed., 16(4), 530-41.

Teich, J. M. (1998) Clinical information systems for integrated healthcare networks, AMIA Symp., 19-28.

Titler, M. G. (2008) The Evidence for Evidence-Based Practice Implementation, In Hughes, R. G. (ed.), Patient Safety and Quality: An Evidence-Based Handbook for Nurses, Rockville, MD: Agency for Healthcare Research and Quality.

Torpy, J. M., Lynm, C. and Glass, R. M. (2006) Evidence-Based Medicine, *JAMA*, 296(9), Sept.

Tsiknakis, M., Kouroubali, A., Vourvahakis, D. and Orphanoudakis, S. C. (2005) Implementing a Regional Health Information Network: Impact on Health Care Performance and the Management of Change, In G. T. Savage et al., (eds.) International Health Care Management, 5, Emerald, 297-329.

Tullis, T. and Albert, B. (2008) Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics, Morgan Kaufmann.

Tuomela, R. (2002) Philosophy of Social Practices: A Collective Acceptance View, New York: Cambridge University Press.

Turner, T., Qvarfordt, P., Biehl, J. T., Golovchinsky, G. and Back, M. (2010) Exploring the workplace communication ecology. Int'l Conf. on Human Factors in Computing Systems, ACM, 841-850.

Turner, J. and Kraut, R. E. eds. (1992) Sharing Perspectives, Conference on CSCW, NY, ACM.

Turner, S. (1994) The social theory of practices: Tradition, tacit knowledge, and presuppositions, Cambridge: Polity Press.

Turner, R.M. (2006) Explicit Representation and Retrieval of Contextual Knowledge for Real-World Agents, In Modelling and Retrieval of Context, Technical Report WS-06-12, AAAI Press, 23-27.

Unertl, K. M., Weinger, M. B., Johnson, K. B. and Lorenzi, N. M. (2009) Describing and Modeling Workflow and Information Flow in Chronic Disease Care, *J Am Med Inform Assoc*, 16, 826-836.

van der Aalst, W. M. P. (1998) Modeling and analyzing inter-organisational workflows, Int'l Conf. on Application of Concurrency to System Design, Japan, IEEE Computer Society, 262-272.

van der Vegt, G., Van de Vliert, E. and Oosterhof, A. (2003) Informational dissimilarity and organizational citizenship behavior: the role of intra-team interdependence and team identification, *Academy of Management Journal*, 46(6), 715-727.

van Gemert-Pijnen, J. E., Nijland, N., van Limburg, M., Ossebaard, H. C., Kelders, S. M., Eysenbach, G., Seydel, E. R. (2011) A holistic framework to improve the uptake and impact of eHealth technologies, *J Med Internet Res*, 13(4), e111.

van Wijk, R., Jansen, J. J. P. and Lyles, M. A. (2008) Inter- and intra-organizational knowledge transfer: a meta-analytic review and assessment of its antecedents and consequences, *Journal of Management Studies*, 45(4), 830–853.

Vanoirbeek, C., Rekika, Y. A., Karacapilidisa, N., Aboukhaleda, O., Ebela, N. and Vader, J. P. (2000) A web-based information and decision support system for appropriateness in medicine, *Knowledge-Based Systems*, 13(1), 11-19.

Veresov, N. (2010) Introducing cultural-historical theory: main concepts and principles of genetic research methodology, *Cultural-historical psychology*, 4, p. 83-90.

Vicente, K. (1999) Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work, Mahwah, NJ: Lawrence Erlbaum.

Vieira, V., Tedesco, P., Salgado, A. and Brézillon, P. (2007) Investigating the Specifics of Contextual Elements Management: The CEManTIKA Approach, Modeling and Using Context, LNCS, Springer, 493-506.

Viitanen, J. (2011) Contextual Inquiry Method for User-Centred Clinical IT System Design, Studies in health technology and informatics, vol. 169, 965-9.

Voida, S., Mynatt, E. D. and MacIntyre, B. (2007) Supporting Activity in Desktop and Ubiquitous Computing, In Kaptelinin, V. and Czerwinski, M. (eds.), Beyond the desktop metaphor: Designing integrated digital work environments, Cambridge, Massachusetts: MIT Press, 195–222.

Votruba, P., Miksch, S., Seyfang, A., Kosara, R. (2004) Tracing the formalization steps of textual guidelines, *Stud Health Technol Inform*., 101, 172-6.

Vukovic, M. and Robinson, P. (2005) GoalMorph: Partial Goal Satisfaction for Flexible Service Composition, *Int'l Journal of Web Services Practices*, 1(1-2), 40-56.

Vyas, D. (2011) Designing for Awareness: An Experience-focused HCI Perspective, PhD Dissertation, University of Twente, The Netherlands.

Vygotsky, L.S. (1978) Mind in Society: The Development of Higher Psychological Processes, Cambridge, MA: Harvard University Press.

Walsham, G. (1995) Interpretive case studies in IS research: nature and method, *European Journal of Information Systems*, 4(2), 74-81.

Weick, K. E. (1995) Sensemaking in Organizations, Sage.

Weiser, M. (1991) The Computer for the Twenty-First Century, Scientific American, Sept., 94-10.

Wenger, E. (1998) Communities of Practice: Learning, Meaning and Identity, Cambridge: Cambridge University Press.

Wenger, E., White, N. and Smith, J. D. (2009) Digital Habitats; stewarding technology for communities, CPsquare.

Wilson, T.D. (2006) A re-examination of information seeking behaviour in the context of activity theory, Information Research, 11(4). [online]. Available at http://InformationR.net/ir/11-4/paper260.html. [Accessed on: 10 Mar 2012].

Winograd, T. and Flores, F. (1987) Understanding Computers and Cognition: A New Foundation for Design, Addison Wesley.

Winograd, T. (2006) Shifting viewpoints: Artificial intelligence and human–computer interaction, *AI*, 170, 1256–1258.

Whittaker, S., Frohlich, D. and Daly-Jones, O. (1994) Informal Workplace Communication: What is it like and how might we support it? Human Factors in Computing Systems, Boston, ACM Press, 131-137.

Wong, B.L. and Blandford, A. (2001) Situation awareness and its implications for human-systems interaction, Australian conf. on Computer-Human Interaction OzCHI, Perth, 181-186.

Woolf, S. H., Grol, R., Hutchinson, A., Eccles, M. and Grimshaw, J. (1999) Clinical guidelines: Potential benefits, limitations, and harms of clinical guidelines, *BMJ*, 318, 527-30.

Wright A., and Sittig, D. F. (2008) A four-phase model of the evolution of clinical decision support architectures, *Int J Med Inform*, 77(10), 641–9.

Xu, L. (2011) Enterprise systems: state-of-the-art and future trends, *IEEE Transactions on Industrial Informatics*, 7(4), pp.630-640.

You, Y. (2000) A Survey for the Study of Awareness in Co-operative Systems, Conf. on Information Systems Research in Scandinavia (IRIS'23), Uddevalla, Sweden.

Yusof, M. M., Kuljis, J., Papazafeiropoulou, A. and Stergioulas, L. K. (2008) An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit), *Int'l J. of Med. Informatics*, 77, 386-398.

Zdunczyk, K. (2006), Human boundary objects – fact or fiction?, OLKC Conf., University of Warwick, Coventry, UK, 20-22 March, [online]. Available from http://www2.warwick.ac.uk/fac/soc/wbs/conf/olkc/archive/olkc1/papers/275_zdunczyk.pdf. [Accessed on 05 October 2011].

Zhang, P. and Bai, G. (2004) An Activity System Theory Approach to Agent Technology, In 5th Int'l Symposium on Knowledge and Systems Sciences, Ishikawa, Japan.

Zimmermann, A. and Augustin, S. (2003) Context-Awareness in User Modelling: Requirements Analysis for a Case-Based Reasoning Application, Case-Based Reasoning Research and Development, 2689, Springer, 718-732.

Appendix A

A.1 Survey Questionnaire

Context-Aware Clinical Decision Support in Cross-Boundary E-Health

Dear Participant,

This research project aims to develop an e-health system to enable healthcare professionals working in different hospitals, countries and regions to collaborate, share knowledge and provide suggestions, at anytime and from anywhere, to assist one another in clinical decision making. The aim of this survey is to gather real-world requirements to inform the design of the proposed system for supporting cross-boundary decision making in e-health.

This online survey is anonymous, and all data collected will be held strictly confidential. Should you have any questions about this research, please contact Obinna Anya, Liverpool Hope University, UK on 08009472@hope.ac.uk

Survey Questions

1 In your current hospital, trust or health organisation, you work as (please tick only one option)

A hospital doctor (registrar) A GP A consultant
A nurse An administrator A healthcare assistant
A pharmacist Other

2 What is your gender?

Male Female

3 What is your age?

Less than 25 Between 25 and 40 Between 41 and 60
More than 60

4 What is your ethnic background?

White/Caucasian African American/Black Asian
Hispanic/Latino Other

5 Your current hospital, trust or health organisation is located in (please tick only one option)

UK/Ireland UAE Nigeria

6 What is your current medical practice specialty?

Internal Medicine Obstetrics/Gynaecology Orthopaedics
Paediatrics Surgery Anaesthesiology
Physical Medicine Oncology Urology
Psychiatry General Practice

7 How many years of medical experience have you got – post medical school? (please tick only one option)

Less than 4 Between 4 and 7 Between 8 and 10
More than 10

8 Have you ever worked in another hospital (please tick only one option)

Yes (for up to 3 years) Yes (for more than 3 years) No

9 Are any differences you have noticed in the way clinical decisions are made or in the issues that influence clinical decisions between that hospital and your present work place? (please tick only one option)

Significant Not significant Don't know

10 Do you think variability in clinical decision making often arise as a result of: **1 being "not significant" and 5 being "highly significant"?**

Source	***Please circle only one in each row***
Physician's attitude	1 2 3 4 5
Physician's knowledge and experience	1 2 3 4 5
Patient's circumstances	1 2 3 4 5
The demographic characteristics of a physician's area of work	1 2 3 4 5
The context or circumstances of a physician's workplace, e.g. the availability of a universal health scheme	1 2 3 4 5
The availability or lack of relevant drugs and/or clinical equipment	1 2 3 4 5

11 In your clinical decision making, how much do you normally allow your patient's personal circumstances, values and expectations to influence your clinical decisions about him/her? **1 being "rarely" and 5 being "very often".**

Rarely	1	2	3	4	5	Very often

12 Please rate the following in terms of how often you use them to seek information when you are faced with a challenging clinical problem. **1 being "rarely" and 5 being "very often".**

Source	***Circle only one in each row***
Colleagues in the same workplace	1 2 3 4 5
Colleagues and fellow professionals outside of your workplace	1 2 3 4 5

Clinical guidelines (paper-based)	1	2	3	4	5
Books, magazines and subscription services	1	2	3	4	5
Search engines and general web articles	1	2	3	4	5
Specific organisational databases, electronic journals and research websites	1	2	3	4	5
Online communities of practice	1	2	3	4	5

13 Please estimate how often you encounter clinical problems that require your seeking information from outside your workplace. **Please circle only one.**

Rarely	1	2	3	4	5	Very often

14 How do you mostly communicate when seeking information from colleagues outside of your place of work to support your decision making process?

Call them on phone   Send them email   Chat with them online
A mix of all of the above   Arrange to visit them

15 Would you like an IT system that enables you to share information with other professionals outside of your workplace boundaries in order to support your clinical decision making?

Yes   No   Not sure

16 When you obtain information from a professional outside of your workplace, do you find it necessary to modify the piece of information so as to adapt it to suit your prevailing clinical case context? **Please circle only one.**

Rarely	1	2	3	4	5	Very often

17 How important would you rate the following with regard to how they are considered when adapting information obtained from outside your workplace to suit another working environment? **1 being "not important" and 5 being "very important".**

	Circle only one in each row				
Differences in available work equipment tools	1	2	3	4	5
Differences in technology	1	2	3	4	5
Differences in organisational policies and work culture	1	2	3	4	5
Patient's level of awareness and perspectives.	1	2	3	4	5
Patient's religious affiliation	1	2	3	4	5
Differences in staff's background and training	1	2	3	4	5

18 If you need support **in adapting a piece of information** obtained from outside your workplace to suit your prevailing work setting, which of these describes what you mostly do in order of preference? **1 being "least preferred" and 5 being "most preferred".**

	Circle only one in each row				
Adhere to guidelines	1	2	3	4	5
Follow what has worked for you out of experience	1	2	3	4	5
Seek a third party opinion (eg a colleague)	1	2	3	4	5
Consult books	1	2	3	4	5
Search the Web	1	2	3	4	5
Seek the opinion of members of online communities of practice	1	2	3	4	5

19 How do you think technology would best enable you to share information with other professionals outside of your workplace to support your clinical decision making?

As a tool that offers information in response to user request
As a tool that anticipates a user's problem and offers information to assist him/her in advance
As a tool that facilitates online meeting between clinicians from organisations, regions and countries
A mix of all of the above

20 How easy (in terms of accessibility) is it for you to obtain information from outside of workplace to support your clinical decision?

Very hard	1	2	3	4	5	Very easy

21 Please what percentage of your total work time do you spend searching relevant information from outside your workplace to support your clinical decision?

0%	20	40	60	80	100	100%

22 Please rate the following methods of information gathering according to how they are often used in seeking information outside your workplace to support your decision. **1 being "rarely used" and 5 being "most often used"**

Method of communication	*Circle only one in each row*				
Email	1	2	3	4	5
Chat	1	2	3	4	5
Fax	1	2	3	4	5
Conventional mail	1	2	3	4	5
Telephone	1	2	3	4	5

Paper-based clinical guidelines	1	2	3	4	5
Video conferencing system	1	2	3	4	5
Web Search	1	2	3	4	5
Specific organisational databases	1	2	3	4	5
Online communities of practice/ social networks	1	2	3	4	5

23 Please rate the following sources of information according to how confident you are (in terms of their usefulness) in using information from them (in terms of usefulness) to support your clinical decision? **1 being "not confident" and 5 being "very confident"**

	Circle only one in each row				
Colleagues in the same work place	1	2	3	4	5
Colleagues and fellow professionals outside of your place of work	1	2	3	4	5
Clinical guidelines (paper-based)	1	2	3	4	5
Books, magazines and subscription services	1	2	3	4	5
Search engines and general web articles	1	2	3	4	5
Specific organisational databases, electronic journals and research websites	1	2	3	4	5
Online communities of practice	1	2	3	4	5

24 What do you think are the major problems/challenges in adapting information across boundaries of workplace to support problem solving and decision making? **1 being "minor source of problem" and 5 being major source of problem"**

	Circle only one in each row				
Trust	1	2	3	4	5
Poor formulation of the suggestion seeker's query	1	2	3	4	5
Poor description of the suggestion seeker's work context	1	2	3	4	5
The information provided	1	2	3	4	5
The process of modifying (i.e., adapting) the information provided to suit the suggestion seeker's work context	1	2	3	4	5

25 Do you think most problems in applying or adapting information from a certain workplace setting to a different workplace context occur as a result of the following? Please rate; **1 being strongly agree, 5 being strongly disagree.**

	Circle only one in each row				
Differences in knowledge, e.g. experiences	1	2	3	4	5

Differences in work environment or work culture	1	2	3	4	5
Differences in organisational or regional health policies					
Inability of the information seeker to understand the intended meaning in a information	1	2	3	4	5
Poor communication	1	2	3	4	5
Differences in available technologies, tools and treatment aids	1	2	3	4	5
Patients' perspectives, life style and level of awareness	1	2	3	4	5
Inappropriate use of information obtained	1	2	3	4	5

26 The following are problems that tend to hamper the process of obtaining and using information from outside one's workplace in supporting their specific clinical decision making process. How would you rate them? **1 being "not relatively a serious problem" and 5 being "very serious problem".**

	Circle only one in each row				
Not knowing who to contact for information	1	2	3	4	5
Not knowing where to look for information	1	2	3	4	5
Inability to verify the **accuracy** and **authenticity** of information sources	1	2	3	4	5
Too much information originating from too many sources on the Web (e.g. articles, communities of practice)	1	2	3	4	5
Unavailability of relevant past medical cases on the Web in a manner that aids decision support	1	2	3	4	5
Human experts being **too busy to respond** to requests for information	1	2	3	4	5
Human experts **unable to clearly understand** suggestion seeker's prevailing work context	1	2	3	4	5
Mismatch of resources, i.e. available tools and technologies	1	2	3	4	5

27 How do you communicate when seeking information from colleagues outside of your place of work to support your decision making process?

			A mix of both			
Mostly in real time	1	2	3	4	5	Mostly with considerable time lag

A.2 Interview Guide

Context-Aware Clinical Decision Support in Cross-Boundary E-Health

Hello,

Thank you for meeting me today. I will be conducting this interview today.

The aim of this interview is to gather real-world requirements to inform the design of an e-health system to enable healthcare professionals working in different hospitals, countries and regions to collaborate, share knowledge and provide suggestions, at anytime and from anywhere, to assist one another in clinical decision making.

Every information we share today during this interview will remain confidential, and will be used solely for the purpose of the research. You will not be named in anything I write about this research. Should I require quoting what you have said or making reference to it, your details will be completely annonymised.

The following are noted:

- Interview date and place
- Interviewee's current job position/role
- Name of hospital, trust or health organisation
- Country or location

The Notion of Context of Work in Clinical Practice

1 Could you tell me about the last case of breast cancer you saw or dealt with? What happened? What did you do? What knowledge did you have that helped you make that decision? What other factors were important in making your decision or dictating the way you acted? Do you think other people would have done the same as you? Why? Do you think the fact you work in your present hospital influences the way you dealt with the patient? Why? Would you have dealt with the patient differently if you were in another hospital (in a different regional or geographical location)?

2 Have you ever worked in another hospital? Could you tell me about the practice in this hospital using an example of the last case of breast cancer you saw or dealt with? Do you think the practice in your former hospital differs from the practice in your present hospital? Why? How do you think the two cases you described (in your present and former workplaces) relate to best practices? Why?

3 Can you describe for me a recent case (of breast cancer) where you used guidelines to make decisions about care? And another example where you decided not to follow the guidelines? Can you tell me more about that? Why was the deviation necessary? What do you think are the good points, and the limitations of guidelines?

4 To what extent do you think we should articulate "the tacit forms of clinical work practices and decision making patterns", with their dependence on local settings, in clinical guidelines?

Understanding Expertise

5 Can you describe for me an experience you have had of working in a Multi-Disciplinary Team (MDT) meeting? (Or imagine you are part of an MDT meeting.) And the MDT includes a Consultant, an experienced nurse, a junior doctor (who have dealt with a related case in the past) and a lay representative in the room making a difficult decision about the care of a patient. What do you think each person would bring to the discussion? Whose opinion is of most value? Why? Who should make the decision in the end?

6 Imagine that you have been asked to help write the job specification for a new post in your hospital aimed to recruit a doctor in the oncology unit. What would you want to include in the specification, as additional requirements besides the mandatory college qualification, and why?

E-Collaboration, E-Work, Knowledge Management in E-Health

7 Can you describe for me a situation when you sought the opinion or advice of another specialist in your hospital, in an informal manner, to help you deal successfully with a challenging case? (Or vice versa, i.e., somebody sought your opinion or advice.) Do you think such informal face-to-face means of sharing opinions among clinicians within the same hospital can be as effective if used with technology support by clinicians in different hospitals to share opinions? Why?

8 Imagine that a junior doctor in a different hospital seeks your expert opinion in providing the best care for his breast cancer patient, who was developing post-operative complications, what is the minimal information you would require from this doctor in order to offer him or her an effective suggestion? Why? Do you think it would have been easier if the doctor was in the same hospital as you? Why?

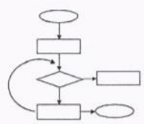
Decision Making for Cross-Boundary E-Health

9 Can you describe an example of a (breast cancer) patient that you have recently seen or made decision on? Can you describe the processes you used, or questions you asked, to make your decision? Did you have to get advice or more information from anywhere? How did you weigh the different pieces of advice or information you got in order to make your decision? Why?

System Implementation

10 Imagine that you have an IT system, which enables you to connect to the Web to obtain specific information to help you in dealing with challenging clinical problems and to collaborate with, and seek opinion and advice of, specialists outside of your hospital? How useful do you think such a system would be to you? Why? What problems do you envisage in using such a system in your daily clinical work?

A.3 Practice Probe Guide



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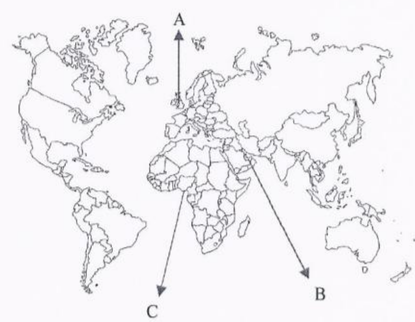


1 Can you describe how you derive the capabilities and knowledge you use in your encounters with patients and in making clinical decisions?

2 Can you describe this capability in terms 1) what you have gained through studies and professional training as a medical doctor, 2) the guidelines, policies, etc., that have been provided to you by virtue of the hospital and locality you work in, and 3) common-sense knowledge and serendipity generated on the spur of the moment?

3 How can you characterise your relationship with your 1) patients, and 2) colleagues?

4 Describe your best time working in this place?

5 Describe your worst time working in this place?

6 Do you think they affect your decision making? How?

7 What things do you think should be improved in your workplace?

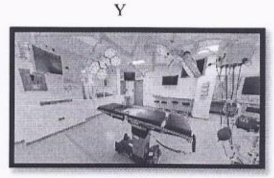
8 How does resource availability affect your clinical work and decision making?

9 We have provided three pictures below: how would working in X and Y affect your performance? If you are in Y, how would build an understanding of the X? If you are in X, how would adapt a suggestion provided by a person in Y to work for you?

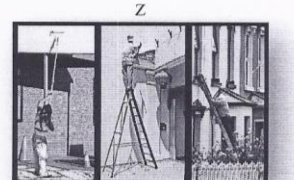
10 What can say about the three scenarios in Z in relation to job performance?

X

Y

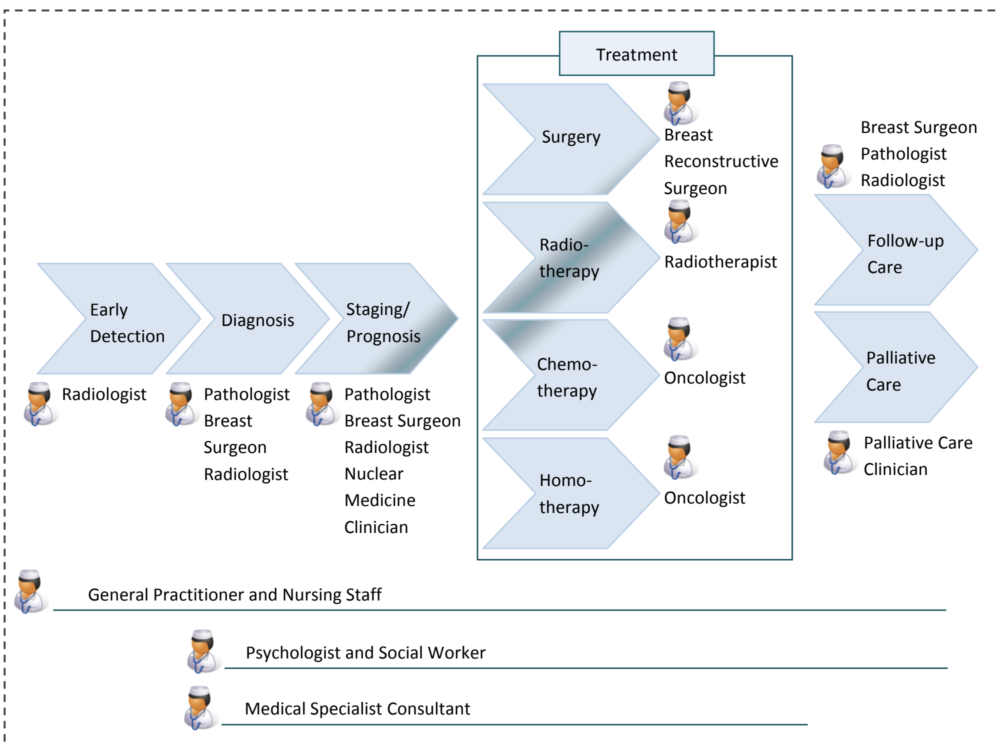


Z



A.4


CAUTION !!

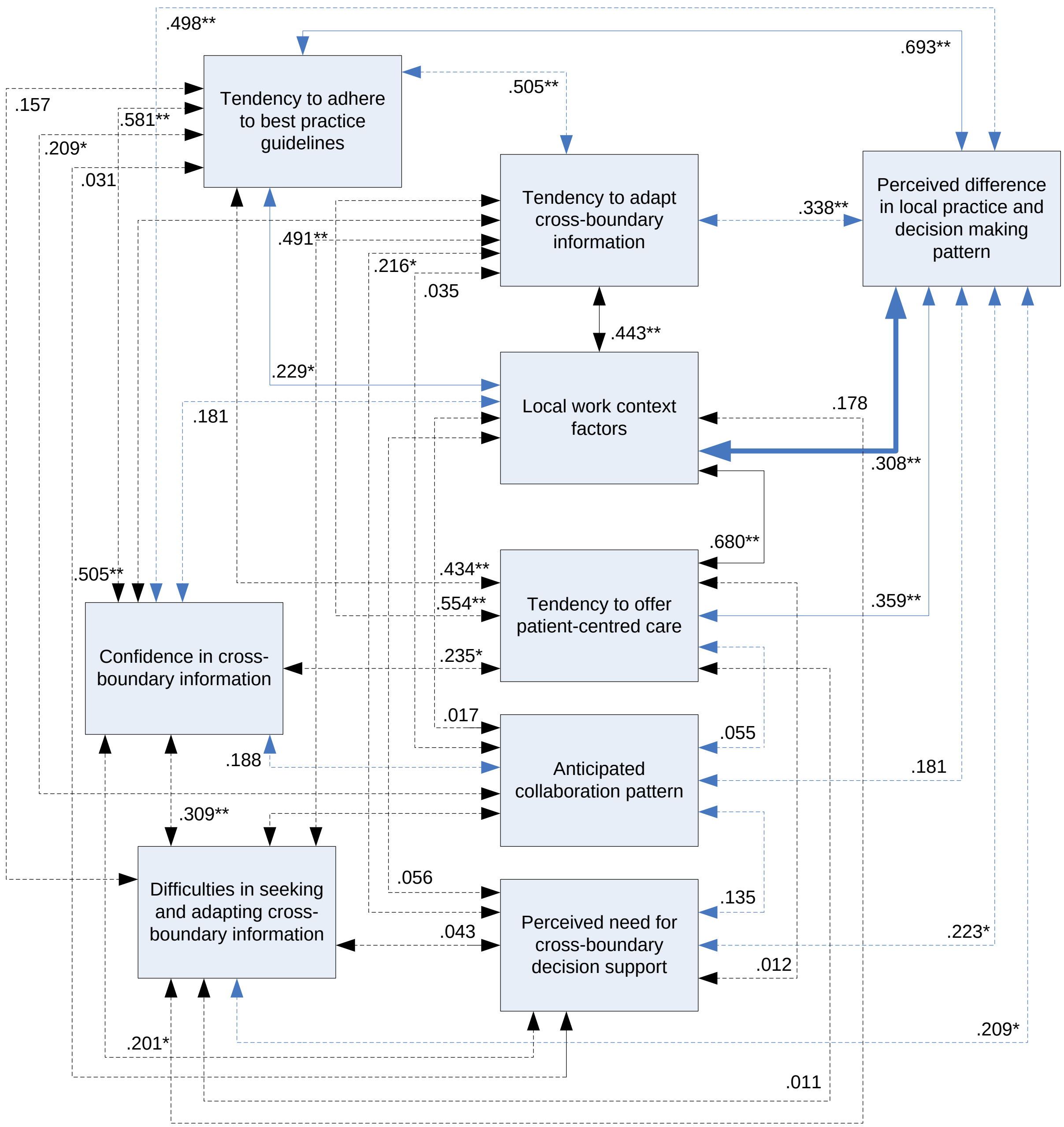


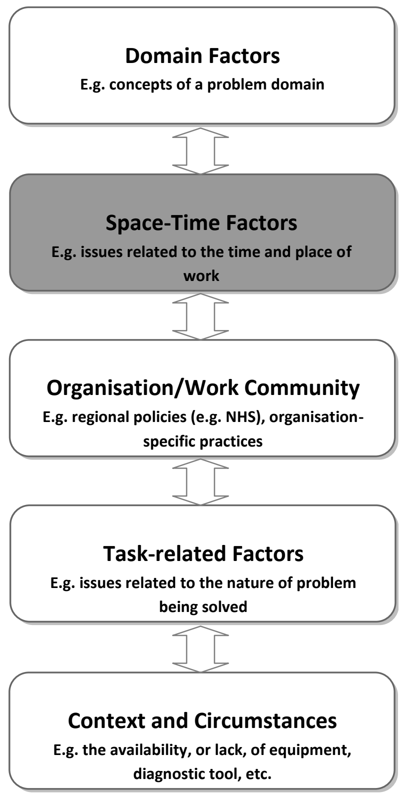
Treatment
Early Detection
Radiologist
Diagnosis
Pathologist
Breast Surgeon
Radiologist
Staging/ Prognosis
Pathologist
Breast Surgeon
Radiologist
Nuclear Medicine Clinician
Surgery
Breast Reconstructive Surgeon
Radio-therapy
Radiotherapist
Chemo-therapy
Oncologist
Homo-therapy
Oncologist
Breast Surgeon
Pathologist
Radiologist
Follow-up Care
Palliative Care
Palliative Care Clinician
General Practitioner and Nursing Staff
Psychologist and Social Worker
Medical Specialist Consultant

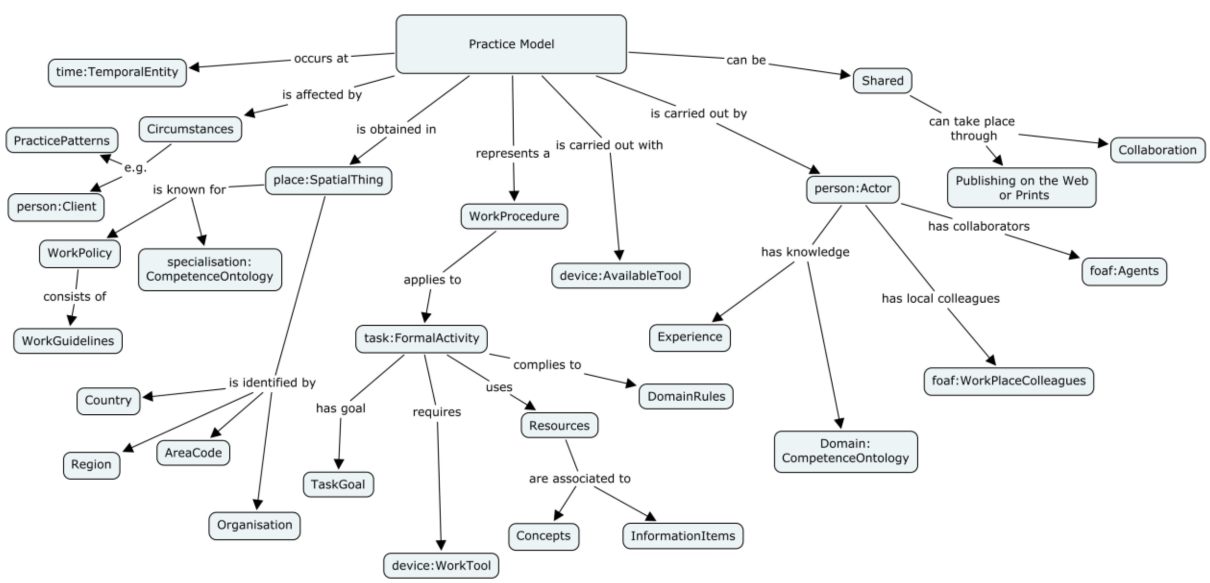
A.5 Data Analysis Worksheets

	Variables	Mean	SD	N	1	2	3	4	5	6	7	8
1	Perceived differences in local practice and decision making patterns	51.37	7.11	101								
2	Anticipated collaboration pattern	13.23	2.55	101	0.181							
3	Perceived need for cross-boundary decision support	14.59	2.35	101	0.223*	0.135						
4	Local work context factors	23.43	3.24	101	0.308**	0.017	0.056					
5	Confidence in cross- boundary information	24.04	4.50	101	0.498**	0.188	0.201*	0.181				
6	Tendency to adapt cross- boundary information	81.70	9.86	101	0.338**	0.035	0.216*	0.443**	0.505**			
7	Difficulties in seeking and adapting cross-boundary information	28.14	4.06	101	0.209*	-0.095	0.043	0.178	0.309**	0.491**		
8	Tendency to adhere to best practice guidelines	18.19	3.27	101	0.693**	0.209*	0.031	0.229*	0.581**	0.505**	0.157	
9	Tendency to offer patient-centred care	11.35	2.46	101	0.359**	0.055	0.012	0.680**	0.235*	0.554**	0.011	0.434**

** – Correlation is significant at the 0.01 level (2-tailed)
* – Correlation is significant at the 0.05 level (2-tailed)


Tendency to adhere to best practice guidelines
Tendency to adapt cross-boundary information
Perceived difference in local practice and decision making pattern
Local work context factors
Tendency to offer patient-centred care
Confidence in cross-boundary information
Anticipated collaboration pattern
Difficulties in seeking and adapting cross-boundary information
Perceived need for cross-boundary decision support
.498**
.693**
.505**
.157
.581**
.209*
.031
.338**
.491**
.216*
.035
.443**
.229*
.181
.178
.308**
.680**
.505**
.434**
.554**
.359**
.235*
.017
.055
.188
.181
.309**
.056
.135
.043
.223*
.012
.201*
.209*
.011


Domain Factors
E.g. concepts of a problem domain
Space-Time Factors
E.g. issues related to the time and place of work
Organisation/Work Community
E.g. regional policies (e.g. NHS), organisation-specific practices
Task-related Factors
E.g. issues related to the nature of problem being solved
Context and Circumstances
E.g. the availability, or lack, of equipment, diagnostic tool, etc.


Practice Model
occurs at
time:TemporalEntity
can be
Shared
is affected by
Circumstances
PracticePatterns
e.g.
person:Client
is obtained in
place:SpatialThing
is known for
WorkPolicy
specialisation: CompetenceOntology
consists of
WorkGuidelines
represents a
WorkProcedure
is carried out with
device:AvailableTool
is carried out by
person:Actor
can take place through
Collaboration
Publishing on the Web or Prints
has collaborators
foaf:Agents
has knowledge
Experience
Domain: CompetenceOntology
has local colleagues
foaf:WorkPlaceColleagues
applies to
task:FormalActivity
complies to
DomainRules
uses
Resources
are associated to
Concepts
InformationItems
has goal
TaskGoal
requires
device:WorkTool
is identified by
Country
Region
AreaCode
Organisation

A.6

NHS

National Research Ethics Service

Northwest 11 Research Ethics Committee - Preston
Barlow House
4 Minshull Street
Manchester
M1 3DZ

Telephone: 0161 625 7815

1 February 2011

Obinna Anya

Dear Obinna

Full title of project: Context Aware Decision Support in Cross-Boundary E Health

Thank you for seeking the Committee's advice about the above project.

You provided the following documents for consideration:

- Email outlining project and telephone conversation with Chair

These documents have been considered by the Chair.

I enclose a copy of our leaflet, "Defining Research", which explains how we differentiate research from other activities. The Chair has advised that the project is not considered to be research according to this guidance. Therefore it does not require ethical review by a NHS Research Ethics Committee.

You may wish to check whether the project should be reviewed by the ethics committee within your own institution.

This letter should not be interpreted as giving a form of ethical approval or any endorsement of the project, but it may be provided to a journal or other body as evidence that ethical approval is not required under NHS research governance arrangements.

However, if you, your sponsor/funder or any NHS organisation feels that the project should be managed as research and/or that ethical review by a NHS REC is essential, please write setting out your reasons and we will be pleased to consider further.

Where NHS organisations have clarified that a project is not to be managed as research, the Research Governance Framework states that it should not be presented as research within the NHS.

Yours sincerely

Mrs Carol Ebenerzer
Co-ordinator

Email: carol.ebenezer@northwest.nhs.uk

Enclosure: *NRES leaflet – "Defining Research"*

A.7 Coding in SPSS

Qns	Variable	SPSS Variable Name	Coding Instructions
1	Job role	role	1 = a hospital doctor; 2 = a GP; 3 = a consultant; 4 = a nurse; 5 = an administrator; 6 = a healthcare assistant; 7 = a pharmacist; 8 = any other role
2	Gender	gender	1 = male; 2 = female
3	Age	age	1 = less than 25; 2 = between 25 and 40; 3 = between 41 and 60; 4 more than 60
4	Ethnic background	background	1 = white/Caucasian; 2 = black African; 3 = white African; 4 = black American; 5 = Asian; 6 = Hispanic/Latino; 7 = any other group
5	Hospital location	location	1 = UK; 2 = UAE; 3 = Nigeria
6	Medical specialty	specialty	1 = internal medicine; 2 = obstetrics/gynaecology; 3 = orthopaedics; 4 = paediatrics; 5 = surgery; 6 = anaesthesiology; 7 = physical medicine/rehabilitation; 8 = oncology; 9 = urology; 10 = psychiatry; 11 = general practice
7	Years of experience	experience	1 = less than 4; 2 = between 4 and 7; 3 = between 8 and 10; 4 = more than 10
8	Had experience in another hospital	anotherexp	1 = yes (up to 3); 2 = yes (more than 3); no Recoded: 1 = no; 2 = yes(up to 3); 3 = yes(more than 3)
9	Noticed any significant difference	sigdiff	1 = not significant; 5 = highly significant Recoded: 1 = not significant; 2 = fairly significant; 3 = neutral; 4 = significant; 5 = highly significant
10	Major source of variation in clinical decision making	contextfactor1to contextfactor6	1 = not significant; 5 = highly significant
11	Accommodating patients' views and needs	pcentredcare	1 = rarely; 5 = very often
12	Means of information search	searchmeans1 to searchmeans7	1 = rarely; 5 = very often

Qns	Variable	SPSS Variable Name	Coding Instructions
1	Job role	role	1 = a hospital doctor; 2 = a GP; 3 = a consultant; 4 = a nurse; 5 = an administrator; 6 = a healthcare assistant; 7 = a pharmacist; 8 = any other role
2	Gender	gender	1 = male; 2 = female
3	Age	age	1 = less than 25; 2 = between 25 and 40; 3 = between 41 and 60; 4 more than 60
4	Ethnic background	background	1 = white/Caucasian; 2 = black African; 3 = white African; 4 = black American; 5 = Asian; 6 = Hispanic/Latino; 7 = any other group
5	Hospital location	location	1 = UK; 2 = UAE; 3 = Nigeria
6	Medical specialty	specialty	1 = internal medicine; 2 = obstetrics/gynaecology; 3 = orthopaedics; 4 = paediatrics; 5 = surgery; 6 = anaesthesiology; 7 = physical medicine/rehabilitation; 8 = oncology; 9 = urology; 10 = psychiatry; 11 = general practice
7	Years of experience	experience	1 = less than 4; 2 = between 4 and 7; 3 = between 8 and 10; 4 = more than 10
8	Had experience in another hospital	anotherexp	1 = yes (up to 3); 2 = yes (more than 3); no Recoded: 1 = no; 2 = yes(up to 3); 3 = yes(more than 3)
9	Noticed any significant difference	sigdiff	1 = not significant; 5 = highly significant Recoded: 1 = not significant; 2 = fairly significant; 3 = neutral; 4 = significant; 5 = highly significant
10	Major source of variation in clinical decision making	contextfactor1to contextfactor6	1 = not significant; 5 = highly significant
11	Accommodating patients' views and needs	pcentredcare	1 = rarely; 5 = very often
12	Means of information search	searchmeans1 to searchmeans7	1 = rarely; 5 = very often

13	Need for cross-border information	crossborderinfo1	1 = rarely; 5 = very often 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always
14	Communication pattern	collabpattern1	1 = visit; 2 = phone; 3 = a mix of phone, email and chat
15	Anticipated collaboration pattern	collabpattern2	1 = yes; 2 = no; 3 = not sure Recoded: 1 = no; 2 = not sure; 3 = yes
16	Need to adapt cross-border information	needtoadapt	1 = rarely; 5 = very often 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always
17	Factors considered when adapting cross-border information	adaptationfactors1 to adaptatiofactors6	1 = not important; 5 = very important
18	Useful process in adapting cross-border information	adaptationprocess1 to adaptationprocess6	1 = not useful; 5 = very useful
19	Ways of technology support for collaboration patterns	collabpattern3	1 = reactive/collaborative; 2 = proactive; 3 = a mix of reactive/collaborative/proactive
20	Obtaining cross-border information	crossborderinfo2	1 = not easy at all; 5 = very easy
21	Time spent searching information to support work	crossborderinfo3	1 = 0-20%; 2 = 21-40%; 3 = 41-60%; 4 = 61-80%; 5 = 81-100%
22	Tools for information search	searchtools1 to searchtools10	1 = rarely used; 5 = most often used
23	Confidence in cross-border information	confidence1to confidence7	1 = not confident; 5 = very confident
24	Challenges in adapting cross-border information	adaptchallenges1 to adaptchallenges5	1 = minor; 5 = major
25	Causes of challenges in adapting cross-border information	adaptcauses1 to adaptcauses6	1 = strongly agree; 5 = strongly disagree Recoded: 1 = strongly disagree; 5 = strongly agree
26	Fears in seeking cross-border information	fears1 to fears7	1 = relatively not a serious fear; 5 = relatively very serious fear
27	Anticipated communication and search mode	collabpattern4	1 = mostly in real time; 2 = mostly with a considerable time lag; 3 = a mix of both Recoded: 1 = mostly with time lag; 2 = mostly in real time; 3 = a mix of both

Appendix B

B.1 CaDHealth Evaluation Questionnaire

Survey Questions

How would you rate the **perceived usefulness** of the system in terms of the following?

	Strongly Disagree	Somewhat Disagree	Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
Using CaDHealth in my clinical decision making would enable me to accomplish more tasks quickly							
Using CaDHealth would make it easier for me to do my job							
Using CaDHealth would enhance my effectiveness at work							
Using CaDHealth would lead to improvement in my clinical decision making							
Using CaDHealth would increase my productivity							
I would find CaDHealth useful in my clinical work							

How would you rate the perceived **ease of use** of the system in terms of the following?

	Strongly Disagree	Somewhat Disagree	Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
I find it easy using CaDHealth to set up a clinical case, visualise the clinical case and obtain "second opinion" from remote experts							
I find learning to use CaDHealth easy							

I find my interaction with CaDHealth is clear and understandable							
It would be easy for me to become skillful at using CaDHealth							
I find CaDHealth easy to use							

The example scenario presented is an appropriate example for demonstrating some of the context-related issues that, often, occur in my workplace

Strongly Disagree Somewhat Disagree Disagree Neutral
Somewhat Agree Agree Strongly Agree

I currently work as a (please tick only one option)

- A hospital doctor (registrar)
- A GP
- A consultant
- A nurse
- Other

My current hospital, trust or health organisation is located in (please tick only one option)

- UK/Ireland
- UAE
- Nigeria

My current medical practice specialty is

- Internal Medicine
- Anaesthesiology
- Physical Medicine/Rehabilitation
- Oncology
- Urology
- General Practice

My level of experience in using computer-based systems to support my clinical work is (please tick only one option)

None Low Average High Very High

B.2 CaDHealth Evaluation Interview

Guide

As you perform the task, what were you thinking?
Were you stuck at any point? Where?

How did you feel about the performance of the tasks overall?

At this point [during a freeze], how would describe your awareness of user B's work context and problem? What would you say is/are their key problem requirements?

What are the positive feature(s) of the system?

What are the weak feature(s) of the system? Could you provide any suggestions to improve the system?

Appendix C
Description of CaDHealth Methods

getPercept(): this method is used by CaDHealth perception level to sense the environment so as to update the system's beliefs about the state of a work setting, and detect changes in problem requirments that require further information.

sendQuery(): contains user query sent to CaDHealth

getOntologicalPractice(): used to construct the initial information set describing a work setting based on domain of work

getStereotype(): used to construct the initial information set describing a work setting based on the stereotypes of the place and time of work

getSituatedPractice():used to construct the initial information set describing a work setting based on perceived information obtained by getPercept()

generatePracticeInfo(): contains the work practice description information sent to a remote collaborating agent as practice display

sendSuggestion(): contains the remote agent's suggestion

getDegOfCertainty(): used to determine the degree of certainty or trust level of a suggestion

decontextualiseSugg(): removes source context information in a suggestion with respect to applying the suggestion in a work practice description

morphSugg(): transforms a suggestion to be applied in a work setting based on the work practice description

recontextualiseSugg(): adds necessary destination context information to a suggestion with respect to applying the suggestion in a work practice description

augmentSugg(): adds more information to a suggestion to enrich it for use in a work setting

returnAdaptedSugg(): returns the enriched suggestion for decision support