Context-Centered Design:

Bridging the Gap between Designing and Understanding

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The design of Electronic Medical Record (EMR) systems and other clinical information systems challenges traditional HCI design in the following two ways: (a) system interactions involve multiple clinician/non-clinician teams, various interactive medical devices and medical artifacts in highly mobilized contexts, and (b) it is extremely difficult for designers to understand the highly knowledge-intensive clinical medicine field and design a system to fit into the hospital environment. Past literature suggests that context of system use could potentially solve these EMR design challenges. To enhance system design quality and bridge designers’ expertise and end-users’ domain understanding, we developed an operational method called Context-Centered Framework and carried out an empirical study to test the effectiveness of it. The empirical study examined the impact of the framework on a mobilized nursing task using scenario-based design and claims analysis approaches. The results indicated that designers improved their understanding towards the clinicians’ working environment and incorporated more usability concerns in their design product through the use of the Context-Centered Framework. This suggests that focusing on the context of system use could improve the quality of design for the systems situated in the highly complex, mobile and ubiquitous environment and could benefit clinicians’ practice.
CHAPTER 1: INTRODUCTION

The main objectives of the study were to develop a design method to inform the design of interactive systems in ubiquitous, complex and context-aware environments and to explore the importance of contextual information in the interactive system design process. We situated this study in the domain of medical informatics because medical systems often need to fit into the complex hospital environment where multiple clinical teams deploy various interactive systems in changing environments. The complexity of the context affects the systems usages. In such cases, understanding this context is crucial for Human-Computer Interaction (HCI) design. In this chapter, we describe the motivation for doing this work, challenges of current research and we introduce research questions of the study.

1.1 Motivation

This study is motivated by unsuccessful Electronic Medical Record (EMR) system implementation cases and also the challenges of the complex hospital environment enforced on the general system design process. In this section, we reviewed previous studies on deigning healthcare IT systems and summarized why it is so difficult to design medical information systems. This brought our attention to the context of system use.

What are EMR Systems?

An EMR system is a digitized version of paper-based patient record. EMR systems are created and maintained by healthcare providers regarding patient clinical information such as admission and progress notes, operation notes, anesthesia notes,
discharge summaries, and nurses’ records (Park, Shin, Choi, Ahn, & Hwang, 2005). An
EMR system is one of the major clinical information systems applied in the hospital
environment and its user groups consist of all types of clinicians. Though many clinical
information systems such as a computerized physician order entry system (CPOE) also fit
into the scope of this study; however, for the sake of the discussion, we simply use EMR
systems as an example to represent these electronic medical systems. Table 1
summarizes the major information system used in the medical domain.

Table 1: Summary of Various Information Systems Applied in Medical Domain

(Bates, Ebell, Gotlieb, Zapp, & Mullins, 2003; Iakovidis, 1998; Medical informatics:
computer applications in health care, 1990; Sittig & Stead, 1994)

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Name</th>
<th>Information Stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMR</td>
<td>Electronic Medical</td>
<td>Computerized patient medical records maintained by the healthcare organization</td>
</tr>
<tr>
<td></td>
<td>Record</td>
<td></td>
</tr>
<tr>
<td>CPOE</td>
<td>Computerized Physician Order</td>
<td>Medical order entry such as an order for a medication, clinical laboratory or radiology test, or procedure entered by either physicians or nurses within a healthcare organization</td>
</tr>
<tr>
<td>HIS</td>
<td>Hospital Information System</td>
<td>Patient, Clinical, administrative and financial information within the healthcare provider</td>
</tr>
<tr>
<td>EHR</td>
<td>Electronic Health Record</td>
<td>Longitudinal collections of health information about an individual or a larger scope of population by healthcare organizations</td>
</tr>
<tr>
<td>PHR</td>
<td>Personal Health Record</td>
<td>Personal health records maintained by individual</td>
</tr>
</tbody>
</table>

An EMR system not only serves as an information system for enhancing
accessibility and information sharing in hospitals, but it is also intended to bring
fundamental changes to the healthcare domain (Chan, 2002; Koppel et al., 2005; Sittig & Stead, 1994). Some proposed benefits of EMR systems include

- Enhancing accessibility and information sharing at the point of care
- Reducing medical errors since it is free of handwriting and easy to recognize
- Providing clinical decision support such as avoid adverse drug events and provide medication support
- Improving efficiency such as on nursing documentation efficiency and saving diagnostic time
- Reducing the cost of care
- Increased completeness and standardization of patient documentation
- Improved communication among various departments/clinicians (Bates et al., 2001; Bates et al., 1999; Kohn, Corrigan, Donaldson, & 2000; Raschke et al., 1998; Rind et al., 1994; Sittig & Stead, 1994; Tange, Schouten, Kester, & Hasman, 1998; Teich et al., 2000).

**Design Failures**

The intended benefits of an EMR system connect the system to the quality of the healthcare delivery and to patient safety. But surprisingly, some literature (Ash, Berg, & Coiera, 2004; Han et al., 2005; Koppel et al., 2005) suggests that in many cases, the implementation of EMR systems in hospitals introduced more problematic issues and medical errors than the proposed benefits to the clinical care process. Koppel et al. published a benchmark paper entitled “The Role of Computerized Physician Order Entry System in Facilitating Medical errors”, where he identified 22 types of errors and believed that “human-machine interface flaws” is one of the two major causes of the
errors. Nielson (2005) claimed that even the factors not classified as “human-machine interface flaws” in the paper are mostly usability problems led by poor HCI design.

### Table 2: Medical Errors Incurred by the CPOE Displays, adapted from (Nielson, 2005)

<table>
<thead>
<tr>
<th>Error Types</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misleading Default Values</td>
<td>Wrong default values led to insufficient medication dosage</td>
</tr>
<tr>
<td>New Commands Not Checked Against Previous Ones.</td>
<td>Info could be entered to the wrong patient record because the system didn’t log out the previous user.</td>
</tr>
<tr>
<td>Poor Readability</td>
<td>Small font, close display made clinician easier to pick up wrong patient</td>
</tr>
<tr>
<td>Memory Overload</td>
<td>Medications are displayed over multiple screens and this led to errors in choosing medicines</td>
</tr>
<tr>
<td>Date Description Errors</td>
<td>The wrong date on the system could delay the medication for up to 24 hours</td>
</tr>
<tr>
<td>Overly Complicated Workflow</td>
<td>The workflow in the system didn’t follow the routine workflow clinicians prefer to use</td>
</tr>
</tbody>
</table>

Aside from these direct impacts on healthcare delivery, indirectly, HCI design issues also account for other types of system failures. Many EMR implementations were not successful because of the lack of acceptance among clinicians (Edwards, 2006; Sittig, Krall, Dykstra, Russell, & Chin, 2006). User acceptance is a critical step to ensure successful system adoption. Instead of blaming users (Forsythe, 1992), many other factors, such as social and legal factors affect the adoption process. Gosbee & Ritchie (1997) came up with a three-level hierarchical model for medical system adoption: (a) policy and government support; (b) culture and management issues, and (c) HCI design issues. This model supports the role of HCI design in system adoption and also suggested to us
that compared to other rigid influential factors such as policy and culture, a better HCI
design probably is the easiest approach to increase the acceptance rate among clinicians
and to benefit the whole adoption process.

1.2. Design Challenges

Previous literature (Bates et al., 2001; Chan, 2002; Gosbee & Ritchie, 1997)
suggests that system usability can be largely improved by giving more attention to HCI
design. HCI is concerned with “how interactive systems are designed, evaluated and
implemented. It is a process which heed is paid to the views of potential users or the
nature of the real-world settings in which they work” (ACM SIGCHI Curricula for
Human-Computer Interaction). Ash et al. (2004) argues that the problem with the
interface design lies in the misfit of the system with the highly collaborative, interruptive
hospital environment. Along this line, we identified two EMR design difficulties, which
challenged the existing HCI design approach.

Complex Hospital Context

The complex hospital environment brings our focus to the fuzzy context where
the system is situated. As shown in the figure 1, an intensive care unit (ICU) environment
is filled with multiple clinicians, patients, patients’ charts, patients’ beds, chairs,
tremendous amounts of monitors and medical devices. All of this information interacts
with the applied information system and a system design has to be adaptive and
respondent to the situated environment. Past literature (J. G. Anderson & Aydin, 2005;
Chan, 2002; Cheng, Goldstein, Geller, & Levitt, 2003; Gosbee & Ritchie, 1997)
suggested that to a system has to be designed for such an environment.
Team Collaborations: Clinical work always needs to communicate and collaborate with others, which includes clinicians in both inpatient and outpatient settings. The collaboration is not merely on the individual level; most of the time, collaborations are among various departments. In this case, collaborations are among various clinical teams. These teams range from the non-clinical to the clinical side (J. G. Anderson & Aydin, 2005). Non-clinical teams focus on the business and other non-clinical aspects of the organizations, such as patient billing and patient admissions and discharge. In contrast, clinical or patient care teams are responsible for making patient care decisions. The clinical teams consist of a wide range of workers – physicians, nurses, pharmacists, physical therapists and others – who provide patient care (J. G. Anderson & Aydin, 2005).

Complex Task: The tasks to be solved through the systems are often extremely complex. A single patient case may involve multiple clinical and non-clinical teams, include a large amount of information and objects such as patient charts, various lab results, and all kinds of medical devices, and often times the task solving process is
conducted over multiple places since patients are constantly changing locations in hospitals (Gosbee & Ritchie, 1997).

Interruption: Interruptions occur frequently in the middle of clinical tasks. Interruptions may come from beepers, alarms or other co-workers (Coiera, Jayasuriya, Hardy, Bannan, & Thorpe, 2002; Hilda, lu, & Ina, 2001). Clinical cares are often conducted simultaneously and longitudinally. This may mean that one patient case may not be taken care of in a blocked time period. This situation becomes more severe for nursing tasks (Juliana et al., 2007) where mobility contributes to the existing interruption and makes it harder to manage the clinical workflow, thus leading to more medical errors. The widespread usage of information systems in hospitals may bring more interruptions to the clinical work.

Symmetry of ignorance

Clinical medicine is a highly knowledge-intensive field, where a good system design requires not only HCI design knowledge but also sufficient understanding towards the medical field (Gosbee & Ritchie, 1997). This phenomenon is known as “Symmetry of Ignorance” (Rittel, 1984) in the system design field and the importance of this phenomenon is associated with the ‘wicked’ nature of the design process (Rittle & Webber, 1973).

Rittel & Webber (1973) claimed that system design is a “wicked problem” since it differs from “problems in the natural sciences, which are definable and separable and may have solutions that are findable (p.160)”. A wicked problem can never be defined and solved at once. The solution is not fixed, but is discovered in the process of solving and understanding the problem. The problem is only understood as solutions are
developed. When it comes to design a system to fit into the complex environment, the
design process is intertwined with the process of understanding the environment,
according to the nature of the wicked problem. This emphasizes the importance of
understanding the problem domain for the system design.

Understanding the problem well enough to inform the design process in such a
complex environment is never an easy task. Rittel (1984) believed that the knowledge
needed in solving a complex task is often processed by people with different domain
expertise, in this case, designers and end-users. He said:

Symmetry of ignorance asserts there is nobody among all these carriers of
knowledge who has a guarantee that his knowledge is superior to any
other person’s knowledge with regard to the problem at hand (Rittel, 1984,
p 320).

The complexity of the clinical environment, along with the knowledge-intensive
medical domain makes the symmetry of ignorance phenomena become even more severe,
where designers and end-users can barely communicate and understand each other.
Designers who have system design expertise but no medical domain knowledge may
have difficulty capturing the design requirements; whereas, the clinicians who have
intensive medical knowledge lack the design expertise needed to understand the system.
In this case, a communication breakthrough is need to bridge the gap between designers’
expertise and the end-users’ domain understanding.
1.3 Research Questions

The EMR design challenges require the designers to design a system that fits into the hospital working environment. This could potentially reduce design flaws, decrease medical errors, improve the usability of the system and eventually contribute to better healthcare delivery. We intended to develop a design method to help designers emphasize the design focus on the context of the system use. To do so, two research questions were deployed in this study.

RQ1: How to represent context and incorporate contextual information in the system design process?

In order to design a system that fits into the situated environment, the system needs to be adaptive and responsive to the surrounding context. This requires the designers to put the focus of the design on the context of use and to consider and incorporate contextual information during the design process. A well-known challenge for doing so lies in the complexity of representing and capturing contextual data (Pascoe, 1997). Without good representations, applications developers will need to develop limited schemes for storing and manipulating this essential information.

A good representation of context also needs to be applied into the design process and transferred into the design product. This process often follows some design methods or tools. Each design method has its own individual strength and emphasis. The EMR design challenges require us to have a design method focusing on the context of system use. Designers could consider and incorporate the contextual information during their
design. By doing so, it would be possible to make the design better fit into the
environment and enhance the system quality. To make sure the method is easy to use, it is
necessary that the method is operationalized and applicable to the actual system design
process. Designers could base their design on this method and it would help integrate
contextual consideration into the design to let the system to be truly adaptive to the
environment.

RQ2: How does contextual information benefit interactive system design?

Previous literature (Ash et al., 2004; Gosbee & Ritchie, 1997; Koppel et al., 2005)
suggested that emphasizing design on the context of use could reduce some usability
problems and help designers gain an improved understanding towards the problem
domain (Fitzpatrick, Kaplan, & Mansfield, 1998). The second research question is to
verify whether providing contextual information into the design process does benefit the
design in these two ways. We designed and carried out an empirical study to evaluate the
design method we proposed for the first research question and discussed the effectiveness
of it.
CHAPTER 2: LITERATURE REVIEW

In the introduction, we identified the importance of the context to EMR system design and proposed the research questions of the study. The main purposes of the study are to develop a method to represent context and to incorporate contextual information in the interactive system design process, as well as to provide empirical evidence of how contextual information benefits interactive system design. In this chapter, we will review the current context studies, related design methods, as well as the current EMR systems design approaches.

2.1. Three Waves of HCI Design

HCI is about how people use systems to conduct tasks in some context. Traditional HCI research focuses on a single user or multiple users interacting with a computer system to complete their tasks. Though the impact and importance of context has long been recognized in the HCI field, it is not easy to involve context in the design process because of its broad meaning and abundant nature. Due to these issues, context is a relatively less studied area compared with user, system and task. In the 1980s the Scandinavian school of HCI research, Greenbaum & Kyng (1991) discussed the importance of involving end users in the design process and, in doing so, brought attention to the context in which work takes place. With the technology development, HCI studies evolved from a single user or a small group of users consciously engaging in a single device, to multiple users interacting with various interactive devices, performing multiple tasks simultaneously in changing contexts. This evolution has been referred to as the three waves in the HCI field.
The first wave HCI study is representative of the era of a single user interacting with a PC. This trend of HCI research initially started in the 1940s and it got widely recognized during 1970s. First wave HCI studies focuses on the user’s perception and ease of use of a single user interface. The attention was invested mainly on what happens between the user and the system, and what was situated outside the user-system interaction was not considered during design. By doing this, context of system use was often left out the design considerations.

With the technology development, information systems became networked and distributed and task-solving often needed team collaborations. The second wave HCI study concerns mainly synchronous or asynchronous collaborations across a small group of users, where interaction is not only among users and the system, but also among the users themselves. The focus of the second wave HCI design was on how to design an interactive system to support collaboration, coordination, and enhance awareness among team members.

The recent ubiquitous, context-aware and mobile applications initiatives require interactive systems to be able to seamlessly interact with heterogeneous devices and resources co-located in the working environment. This has been treated as a new HCI research frontier: the third wave HCI studies. Compared to the first wave of single users interacting with an interactive system and the second wave research of groupware systems, system usage in third wave research has became more pervasive. A system often needs to interact with multiple interactive devices and deal with frequently changed environments along with the users and tasks. Bødker (2006) argued that context is central to third wave HCI research. It is believed that contextual information is critical for
designing interactive systems which are implemented in complex, ubiquitous and mobilized environments.

**Figure 2: Three Generations of HCI studies, adapted from (Bødker, 2006)**

A brief overview of each initiative in third wave HCI studies is provided here to illustrate why context is central to determine the effectiveness of these applications.

*Ubiquitous computing*

In Ubiquitous computing (U bicomp) or Pervasive computing, information usages and applications are embedded into everyday objects and activities (Greenfield, 2006). Ubiquitous computing is about an interactive system interacting with users and many computational devices in the environment simultaneously. A ubiquitous environment is not the usual environment, but is an environment full of computing and communication
devices. Ubicomp applications need to adapt the way they work based on information sensed from the physical and computational environment (Abowd & Mynatt, 2000). A good ubicomp design should be able to gracefully integrate into the situated environment so the system becomes less intrusive to users and the environment. In order to create computing technology that has minimal intrusion to the original context, it is necessary to consider the possible interactions of the system with those interactive devices and users; thus, the system can be responsive and adaptive to the artifacts that are already located in the environment.

*Context-aware Computing*

Context-aware computing is considered to be one line in ubiquitous computing research. Context-awareness means that the system is able to sense the context information and adapt its behavior according to the surrounding environment. “A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task (Abowd et al., 1999, p.6)”\footnote{Abowd et al., 1999, p.6}. This definition indicates the importance of understanding context and what it means to the system design.

*Mobile Computing*

Mobile Computing stands for the systems that are moveable to various locations such as PDAs and Tablet PCs. Mobile systems deal with large amounts of changing resources since environments of interaction, execution, and usage often change frequently. From this sense, system design should be able to sense and consider the possible interaction executed from the changing locations.
The uses of the above three research threads are actually intertwined and the boundaries among them are rather blurry. The commonalities among them are that all three applications need to be responsive to the situated context and designing such systems needs to consider the interactions occurred within interactive devices, multiple users, and changing locations. For example, clinical work conducted in hospital environments requires system applications to be ubiquitous so that they can seamlessly work with various interactive devices, to be context-aware so that it can be adapted to the surrounding context and to be mobilized since almost half of hospital work is mobilized in nature (Morán EB, 2007).

2.2 Current Context Studies

The importance of context for system design has long been recognized in the HCI field. From many introductory HCI courses to the practical design process to the research communities, various levels of the HCI works are all aware of the importance of context for designing interactive systems. However, it is not easy to realize the goal of designing for context of system use in the design process. This is partially due to the difficulty in understanding the rather broad and vague context issue, and partially because of a lack of methods to utilize contextual information in the design process. In this section, we review current approaches to the context issue in HCI design areas and compare the strengths and shortcomings of these studies.

Context of system use was first introduced to system design through the Scandinavian school of HCI initiatives (Greenbaum & Kyng, 1991). The concept of participatory design (Greenbaum & Kyng, 1991) concerns involving end users in the design process and, in doing so, brings attention to the context in which work takes place.
Later, researchers realized that real users alone cannot provide enough contextual information to reveal the issues and concerns incurred and influenced by environments. It is believed that the best way to study context is to be in that environment and conduct field study there. The most commonly adopted field study approach is ethnography study. Ethnographic study is intended to identify routine practices, problems, and possibilities by observing users’ behavior and working habits in the real environment as they do their work activities using the technology and tools available to them (R. J. Anderson, 1994). The primary reason to choose ethnographic observation is because people’s needs, desires and work preferences are embedded into their work routines. The understandings are so habitual to people in the context that they can’t explicitly address them outside of it. Yet these understandings are hard to understand by an outside designer as well.

Ethnographic observation takes at least a couple of months or even several years to finish and since it is usually intended to uncover the inexpressible working habits of users, there is no clear goal of what it wants to find before the study. It is considered much too costly and time-consuming in real design and it may slow down the whole system development process. To overcome the inconveniences of conducting ethnographic studies and to speed up the process, Beyer and Holtzblatt (1997; Holtzblatt & Beyer, 1996) introduced a contextual design method to accommodate the field study in the real project development. Contextual design begins by recognizing that any system embodies a way of working. Users must accept a particular strategy, language and workflow. Successful systems offer a way of working that customers want to adopt. This method helps a cross-functional team agree on what their customers need and how to design a system for them.
The core element of contextual design is an interview methodology called contextual inquiry where designers interview and observe users to gain understanding of what they do in the real world. Usually the design team conducts individual interviews with representatives of users in their workplace to discover what matters in the work. Through discussion, the interviewer and user develop an interpretation of the work; insights and problems identified could be used to inform system design serve for this particular user group in the working environment. Designers who conduct contextual inquiry have rough ideas of what their intended system is. They could narrow their observations to the representatives of stakeholders and certain types of work routines instead of aimlessly observing all the people and activities in the working context. This strategy could keep designers focused only on their projects and reduce the time/energy spent on the field study process.

Field studies, no matter the traditional ethnographic observation or the adapted contextual inquiry, study the context through staying inside the particular environment and discovering the issues that affect system usage. However, even putting context as central to the research, field studies are usually only valid to the particular settings and there is no generalized understanding regarding what exactly is context and how to use it in the design. Several studies addressed these issues through their own interpretation as well as on top of the existing understanding derived from previous field studies.

2.3. Defining for Context of System Use

Context of the system use, while it has drawn more and more attention recently, has no any widely accepted definition for studying it. The term “context” itself has very
broad implications ranging from purely physical to virtual and social meanings. Context is defined as “the set of facts or circumstances that surround a situation or event” in Webster dictionary. Context could be completely physical artifacts such as a room alone with the artifacts inside the room, or a virtual environment such as an online community, which serves as a place for users to communicate and share information. It might even, in some cases, apply to social context, which regulates people’s behavior and beliefs and organizational context, which consists of rules, regulations, and politics.

Organizational and social contexts influence system design and users’ perception, but the impact is not direct. As Gosbee and Ritchie (1997) argued, the organizational and social context is rather rigid and difficult to address in the interactive system design stage. Because of that, as an assumption for this study, we were only concerned with the contextual information that directly impacts the system usage and we were not able to cover the social, organization and cultural context in the review and discussion in this study.

How to represent context is one of the biggest challenges for third wave HCI studies and the representation is also a basic foundation for utilizing the contextual information in the design process. Our review found that context, when used in information system design, has generally been viewed from two perspectives: non-interactive and interactive. In this study, we are interested in how to define context when it is used as an interactive property.
Non-Interactive View of Context

Context is treated as purely static physical artifacts in much context-aware research. It is notable that using contextual information to inform system design is not done merely in the HCI field; system design could also be designing from a software engineering or system architecture perspective. In the static point of view of context, context-awareness is the ability to sense different locations and be aware of the artifacts in those locations. This could also be referred to as a location-based system, which often treats the context of system use as a fixed physical location with the artifacts located inside it. The contextual information used to inform design mostly likely have been locations of the places, people and artifacts situated in the environment and sometimes also the time (Dey et al., 2001; Schilit & Theimer, 1994). Below are some commonly used definitions:

- “Location and the identity of nearby people and objects” (Schilit & Theimer, 1994)
- “Location, identity, environment and time” (Ryan, Pascoe, & Morse, 1997)
- “Location, artifacts, people’s role and time” (Tentori & Favela, 2007)

The reason we call this viewpoints non-interactive is because in these definitions, context is not connected to human-system interaction. Designers who design the system using these interpretations of context can hardly benefit from user interface design. Context as defined in the non-interactive viewpoints, does not interact with the systems situated within it and also doesn’t affect system usages. It can be depicted according to the physical representation of the locations where the system is implemented. In other words, contextual information is isolated with the system applications and the user
interaction. Derived from this viewpoint, context-aware systems are often described as a system that can be seamlessly transferred from one location to another (Schilit & Theimer, 1994; Want, Hopper, Falc, & Gibbons, 1992) and can be utilized in multiple locations. Mobility and the ability to sense the surrounding environment is the major contextual information needed in these cases.

*Interactive view of context*

Interactive view of the context, by contrast, treats context as a property that interacts with systems and affects the system usages. Contextual information, from this perspective, is not everything located in the environment but only those related interactions that affect system applications. Dey, Abowd, & Salber (2001) claim that the notion of context has not been well-defined yet when it is viewed as an interactive property. The three dominant views of studying context as an interactive property are from Abowd & Mynatt (2000), Dey et al. (2001) and Dourish (2004).

Abowd and Mynatt (2000) believe that context is not only simply location and people’s identify. Knowledge about time and history, people (non-users), as well as many other pieces of information often co-located in the environment and this information are part of context as well. Context is defined as the “five W’s”: who, what, where, when, and why (Abowd & Mynatt, 2000). These five elements represent people, location, activities, time and the rationale of why things are happening. This definition differs from non-interactive views of context by comprising activities and the reasoning into context. In doing so, context of system use does not simply represent the fixed artifacts,
but also the information related to what is happening/ has happened and why these
activities occur in certain locations, at certain times, and by certain people.

Dey and Abowd (2000) defines context as:

Any information that can be used to characterize the situation of an entity. An
entity is a person, place, or object that is considered relevant to the interaction
between a user and an application, including the user and application themselves.
(p. 3)

This definition identifies human-system interactions as the central element in identifying
contextual information and this definition complies with the overall HCI principle. From
Dey’s interpretation, physical location no longer serves as a boundary to identify context
in this case; whether people or artifacts are considered as context is determined only by
the relevance to the interaction. This approach points out that contextual information
could be too rich to depict, and what should be included as contextual information is
determined by the interaction. In other words, an artifact located in the current location
may not be contextual information if it is not involved in a users-applications interaction;
whereas, an artifact that is located in distance, as long as it affects the interaction, is part
of the context. Derived from this understanding, especially in a ubiquitous environment
saturated with rich information and communication, can never be a pure physical
representation of the fixed facts, but rather a combination of the physical and virtual
representation of the context (Dey et al., 2001; Vioda, Mynatt, MacIntyre & Corso, 2002).

Contextual information in Dey’s definition can be anything involved in the
interaction between user and the computing system, distributed across time and location.
Contextual information in this sense ranges from people and their roles, location and time to social relations, resources nearby and the availability of them, activities people carried out and schedules. This approach complies with our understanding of routine hospital work, such as the example of diagnosing a patient who is in an ICU room; however, information inside the room could be too rich to depict as contextual information. In this sense, context does not consist of everything in the room but only those who are relevant to the diagnostic process. Also, context may include information extended out beyond the current ICU room, such as lab results and past medical history/life patterns.

Dourish (2004) provided a more active view towards context. He identified two perspectives: representational (non-interactive) and interactional (interactive). He argued that the focus of context in interactive design should be on the interaction between objects and activities and context. In this case, it is defined as “a relational property that holds between objects and activities.” (p.21) Four main characteristics of context as an interactional property are:

1. Context is a relational property held between objects or activities. The contextual relevance is determined by the activity,
2. Context cannot be defined in advance since it is dynamic and keep changing depending on the activities carried out.
3. Context is not fixed information but particular to each occasion of activity.
4. Context is bounded, produced, maintained and enacted in the course of the activity. (Dourish, 2004, p. 21)
Greenberg (2001) also pointed out that context is not a fixed, descriptive element that can be pre-defined before the activities are carried out. It is a dynamic and an always-changing element that is associated with the activities.

The interactive viewpoints believed that context is relevant and influential to the system-environment interaction. This brought the system interaction to the definition of context and by linking it with user’s activities context has been connected with the other major factors of HCI design such as users, tasks (activities) and systems. This point of view broke the conventional view of presenting the physical as central to the context analysis, but rather believes it is a more dynamic relational property combining both physical and virtual contexts (Dey et al., 2001; Tentori & Favela, 2007).

2.4. Current Study about Designing for Hospital Environments

The fuzzy, interruptive and mobilized hospital environment brought attention from many recent EMR research. These studies may not have exclusively addressed the context of system use issue but the central focuses were all on how to better understand the working environment to inform the system design situated in hospitals. The majority of these studies still adopted the conventional field study approach. Reddy, Dourish, & Pratt (2006) observed medical work in a surgical intensive care unit to understand how clinicians seek and manage information. The field observation suggested that temporality is vital important for clinicians in integrating and coordinating their work. The patterns and insights found through observation can be transferred to inform system design in this environment. Similarly, an ethnographic study was carried out in a nursing trauma center to observe the nursing working routines, trying to uncover patterns of interruptions in the
nursing work and to examine how these various types of the interruptions attributed to the potential medical errors (Juliana et al., 2007). Upon understanding the rationale of how each type of interruption might lead to potential medical errors, designers could conceive some solution to reduce the chances of error prone property of their design.

As we pointed out earlier, there is no doubt of the power of field studies for understanding the real context of system use. But the effectiveness of these studies has been largely diminished by the extremely long time period, cost and the expenses invested. Both findings from the above studies took years of observation and data analysis and this timeframe is unlikely to be adopted in the real medical system design process. Bearing in mind that the system being designed is fairly complex and involves many types of clinical personals and expertise, it will be too costly to conduct field study over the whole hospital site.

Another approach to study the ubiquitous context and system design issue located in the healthcare domain is the Activity-Based Computing (ABC) model (Jakob & Henrik, 2007). The ABC model was also motivated by the nature of the highly complex hospital environment as well as the mobilized and highly interruptive property of clinical work. The core idea of the ABC approach was to look at system design from a unit of activity performed by the users. The decision to switch focus from the artifacts level, such as documents and forms, to the activity in the design process was driven by the fact that hospital work is highly collaborative and interruptive; it is often the case that different computer applications support different parts of an activity. These computing devices often are distributed over a long range of time and space; to better observe this issue, in the ABC model, the computing devices that are located ubiquitously in the shared
working environment are connected by the activity that users carry out, such as diagnosing or prescribing a medication to a patient. A few key principles of the ABC model are identified to direct ubiquitous system design such as “activity discovery”, “activity suspend-resume”, “activity roaming” and “activity sharing”.

It is believed in the ABC model that human activity is a key to coherent the relevant computing devices, the associated artifacts and data (Jakob & Henrik, 2007). These applications, artifacts and data are considered to be relevant contextual information. Thus, by using the activity as the central element, it is possible to identify the useful contextual information for the current user activity (Jakob & Henrik, 2007; Tentori & Favela, 2007). A system that could locate the possible contextual information to be associated with the current activity is considered an activity-aware application (Tentori & Favela, 2007). Jakob & Henrik (2007) also found in their study that users believed that the activity discovery process was useful, especially in the situations where they can associate the related contextual information with tasks such as nursing. Jakob & Henrik also claimed that it is possible to formulate some activity templates with associated information for the frequently occurring tasks in the hospital to reduce the difficulty in the design.

The ABC model provides us with the importance of activity that users carry out in identifying and studying the context of system use and the contextual information to system adaption. However there is no clear definition that tells us what information should be associated with the activity as contextual information and how to apply them into the design process. Voida et al. (2002) argued that contextual information should be a combination of both physical and virtual contexts and Tentori & Favela (2007) simply
deemed context information as the location, artifacts, role and time, such as the patient’s location; the patients under the recipients’ role is used to determine when the information must be sent and to whom it might be noteworthy. But they also noticed that that when and what kind of activities that clinicians will pursue is largely based on their own internal goals and mind activities (Tentori & Favela, 2007). This observation pointed out that people’s internal mind activities might also be related to the context of system use in this case.

2.5 Challenges for the Current Study

This study is motivated by the EMR design failures and it is believed that an improved understanding of the hospital environment and incorporating the contextual information in the design process can lead a better and more easy design (Ash et al., 2004). To do so, a method to interpret, represent and incorporate the contextual information in the design process is needed. The review of the literature found that studying context of system use has long been emphasized in HCI studies, but a few limitations exist in the current approaches, which prevents designers from applying contextual information during design.

Challenge in Representing Context

Even though the importance of context has long been recognized in the HCI design field, people interpret the concept of context as varying largely, depending on objectives of their research. There is no unified, well-recognized definition towards context in the interactive design area. Context-aware systems need to be adaptive and respondent to the surrounding context. But what exactly is the contextual information
pertinent to design? And what are the pieces of contextual information to be considered? A well-known challenge for context-aware systems is the complexity of representing and capturing contextual data (Pascoe, 1997). Good representation of context of system use is the first step to ensure the later understanding and designing work. As we reviewed, there are several approaches towards how to define context when it is viewed as an interactive property, but given the fact that context is dynamic and is a relational property, it can’t help designers to capture contextual information, and neither does it help to represent contextual information in the design.

Most of time, especially in the software engineering field, context is used similar to the way locations are used. Contextual information, from this point of view, could be geographical location with physical artifacts included in the locations (Ryan et al., 1997; Schilit & Theimer., 1994;). From this viewpoint, contextual information can be included into the system design process by outlining the locations where the system is intended to apply and the physical elements, which are located in the environment. For example, a context for a classroom system could be the classroom with the tables, chairs, podium and instructor. Even the static view of context can be difficult to utilize in some cases when a location contains tremendous amounts of artifacts such as an ICU room.

By contrast, the interactive viewpoints of context are treated as relational property, which affects system interaction. Context of system use no longer only consists of static physical representations within one location; contextual information is concerned with users, tasks and systems. Context is a relational property held between the user and the application where the contextuality is only determined by the activities carried out. In other words, not everything in the environment is relevant to the current tasks and only
those that affect system usages are considered contextual information. From this viewpoint, diagnosis of a patient who is located in an ICU room involves only the devices, personnel and artifacts that are connected to the particular diagnostic process. These artifacts or devices may even be located outside the ICU room, such as lab reports needed to be brought to the room for diagnosis proposes; additionally, certain people and devices inside this location may not be relevant to the current task. The interactive viewpoint broke the concept of the physical location and combined both virtual and physical environments together.

The interactive viewpoint is clearly more relevant to the HCI design principle since the interaction is the central concern here. However, these studies only addressed the properties of context in the interactive design process, such as dynamic or a relational property. These definitions and properties are not sufficient to inform the real system design. There lacks description about how to identify and represent context, and there is no description on how to utilize contextual information in the design process either. In other words, these definitions are not operational methods which designers can easily adopt and apply in the design process.

Challenging in Designing for Context

EMR system design needs to fit into the context of use in order to be adaptive and respondent to the hospital environment and to take full advantage of the context of the human-computer dialogue. To achieve this goal, it requires designers to design for the context of system use. To do so, simply recognizing contextual information is not enough; we need a method that helps to integrate this information in design and transfer it to
design considerations. Context has been involved into the design process mostly through ethnographic approaches, where inspectors observe people’s interaction with system applications in the real working environment to uncover users’ natural behavior. The observation notes and even audio/video types are analyzed through qualitative data analysis approach to provide some design suggestions. The whole process usually takes months, even years, to complete. Ethnographic observation is a powerful tool to provide insights to particular working environments and to discover the issues that are hardly to be noticed by other methods. Given the time, people and expenses involved in conducting field studies, it is usually not a cost-effective method for the real system design.

Real system design usually follows a strict timeline and the design process is directly by certain so-called inspection design methods. The term ‘system design’ in general stands for both design and evaluation activities. Design is supported by evaluation; whereas, evaluation is trying to discover the design flaw before it moves to the next stage. Especially in the early system design stage, evaluation could detect serious design flaws before major design efforts have been invested. Both design and evaluation activities are usually inseparable and driven by certain design and/or evaluation methods (Wania, Atwood, & McCain, 2006) and not every method can discover deficiencies regarding all aspects of the design. Each method has its own strengths. For instance, the cognitive walkthrough is to assess the ease of use, learning by exploratory property of an interactive system (Wharton, 1994); whereas, the mechanics of collaboration heuristics is focused on whether the system can support team collaboration (Baker, Greenberg, & Gutwin, 2001). Since we are interested in designing a system for the context of use, we
are curious whether there is an existing design and evaluation method that primary addresses this issue.

We reviewed the current inspection design & evaluation methods and found that there are a few inspection methods, either for design or evaluation, which implicitly covered some concerns about context of system use, but none of these methods put their primary emphasis on the context issue. This might be due to the broad meaning of context.

Most of the discount methods which cover context of system use apply scenarios in the design or evaluation process, trying to depict some working environment information to inform system design. The most commonly used is Scenario-based Design (SBD) (Carroll, 1995, 2000; Rosson & Carroll, 2001) and claim analysis approaches. (SBD) is a discount inspection method that covers the context of system concerns. SBD is an ideal way to measure the context implication in design (Pinelle & Gutwin, 2002). A scenario is “a narrative description of what people do and experience as they try to use of computer systems and applications (Carroll, 1995, p.3).” This description provides sufficient information to inform the design process.

Claims analysis is often applied to detect system deficiencies for the system described in the story (Carroll, 1995). Claims are the mechanism by which system designers or evaluators consider the trade-offs (positive and negative claims) of system support for a given scenario. Claim elicitation consists of having participants generate statements about what has happened or what one expects may happen as a result of engaging in a use scenario. Besides the above evaluation methods, task-centered
walkthrough and groupware walkthrough are both aware of the importance of context in system design and cover context considerations in the evaluation process through using scenarios as a tool to provide contextual information for early system evaluation (Lewis & Rieman, 1994; Pinelle & Gutwin, 2002).

2.6 Summary

In this chapter, we reviewed the current understandings of context in the HCI design field. Context has been treated as the center for third wave HCI studies and it is believed to be the key factor to ensure the design quality for the systems situated in the ubiquitous and mobile environment. Traditionally, the impact of context has been examined primarily through field study such as ethnographic studies. It is a rigid tool only when extensive time and budget is invested to study a small scale problem. With the recent context-aware computing initiatives, many studies have begun outlining the elements for context and trying to develop some low-cost approach to incorporating contextual information in the design process. Two mainstream viewpoints have been explored; the representative views are mainly applied in the software engineering design approach; whereas, the interactive context definitions consider context that affects system interaction. The interactive viewpoints comply with the requirement from HCI design, but they are not operational enough to be adopted by the practitioners.

In next chapter, we will introduce the conceptual framework, which we proposed for studying context of the system use. The conceptual framework has been developed by reviewing and summarizing the existing HCI theories in terms of how context has been represented and how it has been applied to the design process. The framework is intended
to be used as a basis for developing operational design and evaluation methods for practitioners later.
CHAPTER 3: CONCEPTUAL FRAMEWORK

This dissertation is motivated by the general EMR system design difficulties brought by the complex, ubiquitous hospital environment. To design a system to fit into this context, designers have to first understand the context of system use and secondly utilize the contextual information in the design process so that the system can be adaptive and responsive to the surrounding environment. However, the current studies in the interactive system design areas often approach the issue of context using ethnographic research. It is considered too costly in the real system building process. Some research explored the properties and described the context as an interactive component that affects the system design but they are not operationalized as a design method to be adopted by designers.

We set up two research questions for the current study to solve the difficulties brought by these challenges. We developed a conceptual framework called “Context-Centered Framework” to answer the first research question in this chapter. The second research question will be answered through the empirical study described in the Methodology, Results and Discussion chapters.

RQ1: How to represent context and incorporate contextual information in the system design process?

RQ2: How does contextual information benefit interactive system design?

The Context-Centered Framework is intended to identify contextual components and apply them in the interactive system design process. In our framework, we set the unit of analysis on an ‘activity’ level. This is because we believe that, from an
interactional perspective, contextual relevance is largely determined by user activities. Contextual relevance is not simply judged by artifacts located together but is determined by whether the information is relevant and interacts with the current task solving process. Four contextual aspects mediated by the same activity are: goals, settings, rules and awareness.

### 3.1 The Framework Development Process

From the interactive point of view (Dey et al., 2001; Dourish, 2004), context is a dynamic and interactive property that is relevant to the user and the application. This viewpoint concurs with the general HCI design principles since it associates the user-system interaction. Hence the context of system use, from this definition, matters with user interface design. Nevertheless, a few limitations prevent us from using them as operational methods in the actual system design process.

1. The current interactive context studies are only concerned with the properties of the context but there are no concrete descriptions about how to identify and use the contextual information. For a usually time-constrained system design project, these descriptions are unlikely to be adopted by the professional designers.

2. The goal of representing contextual information is eventually to benefit the real system design. Therefore, it is a necessity to have a design method for transferring the context representations into design considerations. The current studies are less concerned with how to apply the context understanding in the design process.

To overcome the barriers of utilizing context in the design process and to develop a low-cost design method that can be easily adopted in the design process, we built a
conceptual framework called “Context-Centered Framework” on top of seven HCI theories. The conceptual framework has been formulated through reviewing and summarizing previous theories. The main purpose of review is to find out how people interpret and use contexts in the HCI domain. In other words, how these theories represent and use context when it is considered an interactional property. The review process is guided by the following three questions, which were derived from the first research question.

1) How is context of system use defined in the theories?
2) What are the contextual components that consist of the context?
3) And how is contextual information to be utilized in the design process?

We chose to build the framework by reviewing existing HCI theories because the common approach of observation (ethnography) studies usually can only review insights in a certain environment. The complexity and uniqueness of context made it difficult to generalize the implications to every environment. The theories are built on top of many previous research findings and have been applied and modified through many studies afterwards. It is generalizable to a common situation. From this point of view, the summarization from many relevant theories makes the insights more reliable and can be applied to areas broader than one observation study.

Seven HCI theories have been selected for developing the conceptual framework since they already implicitly addressed the context of system use issue and they have been adapted as guidelines in studying the context issues in many studies. In other words, even though these theories didn’t explicitly address what context is, the usages and
considerations of context of system use have been embedded in the theories. Therefore, it is possible to extract the communities among these theories and contextual components. In the following sections, we will review each theory with regard to the three questions listed above and discuss the advantages and limitations. The theories reviewed include Activity Theory, Distribution Cognition, Situated Action, Locales Framework, GOMS, Awareness Theories and Pattern Languages. See Table 3.

**Table 3: Theories Applicable to the Using of Context in HCI**

<table>
<thead>
<tr>
<th>Theory</th>
<th>Basic Unit of Analysis</th>
<th>Components of context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity Theory</td>
<td>An activity – a form of doing directed to an object that transforms an object into an outcome</td>
<td>Subject, Tools, Object, Rules, Community, Division of labor</td>
</tr>
<tr>
<td>Distributed Cognition</td>
<td>A cognition system composed of individuals and the artifacts they use</td>
<td>Goals, Internal Representation, External Representation</td>
</tr>
<tr>
<td>Situated Action</td>
<td>The activity of persons-acting in setting</td>
<td>Person, Activity Setting, Relationship between person and setting</td>
</tr>
<tr>
<td>GOMS</td>
<td>GOMS-user’s cognitive structure</td>
<td>Goals, Operators, Methods for achieving the goals, Rules for choosing methods</td>
</tr>
<tr>
<td>Awareness</td>
<td>Awareness -knowledge about the state of some environment</td>
<td>People, Artifacts, Time Actions happened and happening</td>
</tr>
<tr>
<td>Locales Framework</td>
<td>Locales –the relationship between social world and its interactional needs, and the “site and means” its members use to meet those needs.</td>
<td>Locales foundation, Civic structures, Individual views, Interaction trajectory, Mutuality</td>
</tr>
<tr>
<td>Pattern Language</td>
<td>Patterns - solutions to recurring problems in interaction design</td>
<td>Name, What, Use when, Why, How</td>
</tr>
</tbody>
</table>
3.2 Activity Theory

Activity theory (AT) was originally developed in Soviet Psychology in the 1920s (Wertsch, 1985). AT was first proposed for understanding the relationship between consciousness and activity. It “incorporates strong notions of intentionality, history, mediation, collaboration and development in constructing consciousness” (Nardi, 1996, p.4). AT has recently been introduced to information systems/HCI design areas (Bødker, 1989; Nardi, 1996). In the 1990s, Nardi argued that AT was a descriptive tool that provides different perspectives on human activity. The activity structure is very similar to the concepts “context”, “situation” and “practice” that HCI research is trying to capture. AT has been used to provide context of use considerations in the course of developing collaborative and interactive systems (Fjeld et al., 2002; Zager, 2002).

AT takes actions and the situated context as a whole called “activity”. Activity is much different from human activities; it’s a combination of human actions with other contextual components. The structure of activity is always represented as a triangle shape as shown in Figure 3. Activity is the unit of analysis in AT and it contains various components: Subject, Objects, Tools, Rule and Division of labor (roles) etc. These artifacts together are considered a context that helps to understand actions and provide solutions to the problem. The elements in AT are not directed, but connected by mediation roles, like the relationship between subject and object is mediated by tools of using. Transforming objects into intended outcomes is motivated by the existence of an activity. In this structure, rules, community and division of labor all act as part of the environment that limits the current activity. The elements of activity in AT are not fixed but change as conditions change.
Activities can be defined as actions that are both singular and cooperative and the connection of such actions, related to each other by the same motive. Being part of an activity means purposely doing things that have clearly set goals. Unless there is a corresponding activity, these actions are not easily understood on their own. One may accomplish one activity using various actions depending on environment, etc.

Additionally, one action may be part of many different activities. If this is so, different reasons for performing various activities will give each action a different meaning for the one performing it. Actions are planned consciously and they are made up of many different operations, which are clearly defined practices that performers use to answer conditions as they perform the actions. It is not always clear where the line between action and activity lives; thus, it is possible that there would be movements in both directions.

Figure 3: The Structure of an Activity From (Nardi, 1996)
**Emphasis on Context**

The triangle structure activity is the unit of analysis in AT. Here, the term activity contains both the actions users carried out and the sitting where the actions occur. Kari Kuutti (1992) believes that AT is relevant to information systems because activity deals adequately with cooperation, tools mediated work activities in the correspondent context. Nardi (1996) also argues that activity theory puts forth a very specific idea of context: the triangle shape activity structure is the context of system use here. Context is formed during the process of performing an activity by deploying the relevant artifacts such as people and other resources. From this perspective, context is not merely the outer environment that surrounds people, but is determined and consciously generated by people's activities during their task-solving processes. It is dependent on internal states of involving specific objects and goals and externally involving artifacts, other people, and specific settings where the user activities are carried out. In AT, the external environment and the internal mind activities are combined together, serving as a context for achieving the final outcomes. The notion of context here embodies the relationship between people and artifacts, where people’s activities bound the contextuality of the artifacts.
AT can be adopted to analyze and represent the context of system use and it has the potential to direct attention to important contextual aspects of work. The central unit of analysis ‘Activity’ here contains multiple components, which could be used to extract the contextual information relevant to the current activity such as the contradictions and breakdowns in activity system that drives change. However, other than the fact that context of system use is not explicitly studied as the core objective in the activity theory, AT itself is less developed as an operational method that can be directly applied to impact design.

3.3 Distributed Cognition

Cognition science is concerned with the process of knowing. The traditional views of cognition are concerned only with cognitive events happening inside an individual’s brain. It assumes that the cognitive representations are exclusively within the human mind and the external objects serve only as outside assistance for the internal cognitive activities. As computation becomes pervasive and ubiquitous, the fuzzy environments that reside outside the human brain also influence and affect people’s internal mind activities. The traditional concern of the mind activities is not sufficient to study HCI issues of complex tasks and environments.

Hutchins (1995) did an extended cognitive ethnography of navigation on US Navy ships. He found that the outcomes that mattered to the ship were not determined by the cognitive properties of any single navigator, and were instead the result of the interactions of several navigators with each other and with a complex suite of tools. This viewpoint extended the traditional view of cognitive science to the artifacts and people
Distributed within the shared context. Distributed Cognition (DC) (Hutchins, 1995; Hollan, Hutchins, & Kirsh, 2000; Zhang & Norman, 1994) is a breakthrough from the traditional cognition theory that argues that cognitive activities are only located inside people’s brain. Cognitive activities are distributed through placing internal activates on the objects, individuals, and tools in the outside environment. DC brought the interaction and influence of physical environment into cognitive thinking process.

The unit of analysis in DC is called a “distribution cognition system”, which consists of internal mind activities processed in individuals and the artifacts located in the external environments. The internal and external representations are treated with equal importance in DC theory. The whole DC system solves problems through deploying both the internal and the external resources, internal activities include memory, attention, awareness, motivation and goals. And the outside resources contain people, artifacts surrounding us.

*Emphasize on Context*

The whole DC system is considered a unit of analysis of context of system use in DC theory. The distributed task-solving process is directed by goals and achieved by utilizing the resources in the distributed cognitive systems. DC doesn’t separate people and the outside environment. The distributed environment contains both the internal representation with the individual mind like knowledge, cognitive artifacts and the external representations as tools, and other artifacts and rules/constraints. Internal and external artifacts are treated equally in the DC theory. The most distinct property that DC brought into context interpretation is the emphasis on the internal cognitive activities.
This understanding largely differs with other theories we reviewed and by introducing internal mind activities as part of the context; the outer resources can be mediated by these activities.

DC theory is widely adopted in Computer Supported Collaborative Work (CSCW) studies where system design focuses more on designing for the collaborations across a group of people (Rogers & Ellis, 1994). The group tasks solved through the interactive systems are often distributed over time and distance. Unlike traditional studies approaching the distributed systems based only on location, DC integrates internal mind activities like goals, motivations of tasks, rules and limitations of utilizing the outsider resources into the context consideration.

DC combines the internal and external representations as a whole context for task solving. This complies with the interactive views of the context we reviewed. Context is not limited to one room or some physically located artifacts; it is composed of both events inside human minds and things surrounding people. It is not constrained to one location, but is distributed in various locations and places that are bound by the same groupware system. For instance, two middle school students are discussing a math problem at their home via the online discussion system. The online discussion system being used here is a normal distributed system that supports the discussion activities. Although, geographically, the two students are located far away from each other, they have been connected by the discussion board and the task goal of solving a math problem together. Students, and the artifacts that are related to the task solving process and are located in each of their current locations such as notebooks, references, previous solved math problems, are outsider contextual information in this case. The internal contextual
information would also include the goal they are trying to solve, the time limit of deploying the computer system and the artifacts and other cognitive activities related to this task.

DC contains methods of analyzing context from an interaction perspective (Nardi, 1996). It has been borrowed to design groupware systems and it has the possibility of being used more broadly in recent context-aware system. But most current research in context-awareness has overlooked the role of internal representations in the context identification process, which is an important step for analyzing context as an international construct.

Similar to AT, DC, though valid on its theoretical basis, is less well-developed as an operational method that provides professional designers with easy-to-follow instruction guiding the design process. The current description of DC theory is far easier to use in system design and analysis. Another issue that prevents designers from using a distributed cognition approach to frame their design is that although the distributed cognitive system has been proposed as context in the theory, there lacks concrete descriptions of what consists of internal representation and what the external artifacts are. Thus, it is less likely that designers could outline the information involved in a distributed cognitive system to inform the system design.

3.4 Situated Action

The Situated Action theory was first introduced in 1987 by Lucy Suchman (1987). Rather than decompose the circumstances and the actions being taken by a pre-outlined plan, In Situated Action, the actions are highly contextualized and highly
dynamic. The current situation determines what the next action should be pursuing.

Situated Action argues that even though people usually have plans of what and how to conduct tasks, the actual task-solving process often yields to changes due to the complex environments it encounters. Suchman believes that people construct their plan as they go along in the situation, creating and altering their next move based on what has just happened, rather than planning all actions in advance and simply carrying out that plan.

Situated Action theory emphasizes the emergent, contingent nature of human activity, which is bounded and influenced by a particular context. This viewpoint ties human actions and surrounded environments together and argues that actions are defined and determined by the situated context. The unit of analysis in Situated Action is “the activity of persons acting in setting”. The analytical focus, hence, is not on human actions, nor on the environment, but the relationship between the two. A setting in this sense is the relationship between people and their activities (Lave, 1988).

Situated Action highlights the importance of the responsiveness to the situated environment and improvisatory nature of human activity (Lave, 1988). It shows that for any given task in the context, there’s only a singular solution to a singular problem, which responds to a particular situation for that moment. Lave described a Weight Watchers example to illustrate the improvement property of the situated action. A participant in a well-known weight loss program was charged with preparing a serving of cottage cheese, which was to be .75 of the two-thirds cup of cottage cheese the program normally allowed. To find the correct amount, the participant, after trying to figure out the problem for a short while, filled a 1/3 measuring cup twice, dumped it out, patted it into a circle, marked an “X” on it, scooped away one quarter, and served the rest.
Emphasize on Context

Situated Action emphasizes the bounded relation of action and surrounded settings. It believes that context is a dynamic property associated with actions. Sitting is not fixed elements but rather a dynamic property. It is unique to each occasion of action and will, in turn, direct the following action. From the Situated Action point of view, an action plan is not pre-defined, but consists of many unpredicted actions that are determined by the specific context in which it is situated. Hence, it is not possible to generalize and predict people's behavior from one situation to the next; due to this, to understand users’ and organizations’ specific needs in designing software, it is necessary to carefully examine how they work and how situational and organizational factors fit into that process through ethnographic observations (Suchman, 1987).

Although Situated Action theory connects actions and sittings together, there are limitations of applying the Situated Action approach into the HCI field, especially into system design (Nardi, 1996). The main limitation is that the moment-by-moment level of analysis of Situated Action models is too low for comparative work. The analysis process is hardly to follow the detailed, one-time actions process, and may miss the higher-level descriptions which usually used to regular design work.

Besides the overly specific levels of analysis, in the Situated Action model, contextual information directs people’s actions and it can be used to explain why certain actions are happening. From this sense, the action-setting model is more from a perspective to derive users’ action changes through the existing contextual information, rather than capture contextual information to inform certain actions. The Situated Action
model is not sufficient to act as a model to capture and represent contextual information in the interactive system design process as the main objective of the study requires.

3.5 Locales Framework

Locales Framework (Fitzpatrick, Mansfield, & Kaplan, 1996) was proposed as a solution to help people understand the relationship of social activity and work, and how a ‘locale’ supports collaborative activities in the CSCW field. The motivations for proposing this theory were based on: (a) The lack of the insights into the effect of the virtual context to the development of CSCW system, and (b) as part of the HCI research, CSCW design is also a wicked problem where the design solutions are discovered in the process of understanding the problem domain. The distributed nature of CSCW design makes it difficult for designers to understand this multi-disciplinary field.

The unit of analysis of Locales Framework is the notion of “Locale”. Basically, a locale is a space together with the resources resides inside the current locale that has a particular relationship with the social world and interaction needs to meet people’s requirements. “Locale” represents “site and means” in Locales Framework. It could either be a physical or virtual site for people conducting their activities. Or it can be a means that regulates the way in which activities are being conducted. Locales Framework is developed upon the understanding of the implications of the social world and spaces where a system is situated. When this framework is applied in CSCW design, it emphasizes the abstraction and evolution of the space in terms of how to meet the interactional needs of a space.
Locale consists of five aspects according to Fitzpatrick. These aspects depict different perspectives of the Locale. The locales studied here, although intended to improve the virtual space, could be physical, computer-based or a mix of both physical and virtual features. The five locales aspects are cited from (Fitzpatrick, Mansfield, & Kaplan, 1996, p. 35)

1. Locale foundations define the basic locale structures that provide the affordances to support the work of social worlds.

2. Mutuality describes the way in which interactions between members of social worlds are supported through presence-awareness, and capability-choice mechanisms.
3. Individual views describe the way in which individuals construct personalized views of the multiple social worlds of which they are a member based on their current level of participation in those worlds.

4. Interaction trajectories describe the temporal dimensions of interactions.

5. Civic structures define the relationship of locales into public spheres of interaction.

Locales Framework, along with the five locale aspects, can be utilized as a communication role between the understanding and designing (Fitzpatrick et al., 1998). On one hand, it serves as a starting point to facilitate analysts and designers capture the key features of the collaborative working environment. Designers can formulate the field observation and interviews using the five locales aspects. On the other hand, by identifying the locales in the existing systems, system design can be accessed and improved through analyzing whether the design meets the general requirements of the locales. New locales can also be created to coalesce the distributed life of an existing group or to facilitate the emergence of a new social world.

Emphasis of Context

When computer systems become networked and distributed, the traditional view of context as one room, one building that is bound to the physical locations is not enough to understand the new themes brought by the new technologies. Spaces are more virtual and socialized, which is beyond the conventional view of physical locations. Locales Framework provides a different perspective to study context in respect to the social, virtual properties of the context. The ‘Locale’ concept breaks the boundary of the
physical or spatial spaces and leads the focus of context to a broader sense of virtual space where geographical separated places can be studied jointly.

Locales Framework can be adopted in the design process directly since the five locales aspects serve as a concrete guideline to direct the analytical process. Several HCI studies already built their design in order to use it to understand the domain and to capture essential contextual information in the early design process (Lee, 2003; McEwan, & Greenberg, 2005). Greensburg, Fitzpatrick, Gutwin, & Kaplan (1999) even built a heuristic evaluation method for assessing the collaborative property of the groupware systems. It is worth noting that Locales Framework is not only concerned with locale itself, but also how different locales interrelate with each other. For instance, individual view connects locales from the involver’s perspective and civic structure aspects connect the locales with the related locales. This would help build connections among various locales when designing a big system.

A remote consultation example has been described (Fitzpatrick et al., 1998; Fitzpatrick et al., 1996) to illustrate how the Locales Framework theory supports virtual views of the spaces and how to use the five locales properties to help better understand the problem situation. It is known that medical consultation deals with a complex environment saturated with patients, assorted machines, clinicians, patient record, clinician notes and lab results. When this consultation occurs in a face-to-face situation, it is easier for doctors to get access to and utilize the artifacts available to them. But when the required expertise is not available in the local hospital, a distant consultation may occur over some ICT system. This usually involves two or even more physically distant locations and two or more teams of participants. The current consultation locale is shown
in the Figure 6. This is more of a breakthrough than the traditional views of context in which contexts are studied inside a conference room or an ICU. In that case, the context is not complete enough to solve the current problem. Using Locales Framework, two separate locations are connected together as one unit analysis. In doing this, the same locale merges the two physically isolated places into one virtual place where the properties necessary to support the collaborative consultation work can be depicted through the five locals principles.

Figure 6: From (Fitzpatrick et al., 1998) showing the structure of remote consultation locale

Locales Framework introduces the concept of locale and depicts the five locales properties which could be used in both collaborative system design and the evaluation processes. However, given the fact that all the proposed design and assessment abilities of this framework are all based upon successfully identifying the locales in the problem domain, there has been no sufficient information on how to identify the boundaries of a
locale. Locale may be physical, virtual or a mix of these two; it might be crossing multiple physical locations or even over long period of time. It is not easy for a designer, who is an outsider to the domain, to be able to build the locales. When the problem is rather small, like the medical consultation described, it is very easy to depict the locale aspects and extract the relevant contextual information. However, for a big system of designing the whole EMR system, there is no rule available in the framework on how to identify a locale and build the locales relation maps there. This makes the framework slightly less difficult to adopt.

3.6 GOMS

GOMS is a collection of related techniques proposed by Card, Moran, and Newell (1983) for modeling and describing human task performances. GOMS is an acronym that stands for Goals, Operators, Methods, and Selection Rules. There are four types of GOMS today, all based on one GMOS concept and together they have been called the GOMS family.

- Goals: an outcome that user(s) is trying to accomplish, usually specified in a hierarchical order including high and low level.
- Operators are the set of actions which a user carried out in the process of achieving the goal.
- Methods represent series of operators for solving the goal users’ have. There might be multiple ways to achieve the goal.
- Selection Rules determine which method is choosing for a given goal.
GOMS can be used to predict people’s performance both quantitatively and qualitatively (John & Kieras, 1996a). Quantitatively, it gives good predictions on time and learning for designers to examine the tradeoffs of a system, compares certain functions, and decides what is relevant to one’s user-group or task situation. Qualitatively, GOMS provides a way to assess information needed to solve the certain goals. It can be used in design help systems. There is much flexibility in using GOMS to analyze system performance. It can be applied in the early system design stage even before the system has been built (John & Kieras, 1996a; John & Kieras, 1996b) to avoid fatal flaws in the design.

*Emphasis on Context*

GOMS provides an alternative view towards context. Context, instead of being a shared space, could also be a “mean”, which defines the way an activity is conducted and why it is happening. The contextual considerations in GOMS are represented by the selection rules. Rules determine what method to use for achieving a certain goal and the timing and process for choosing this method. Rules could either reside inside the human mind’s activities or can be external constraints for deploying resources. As a cognitive modeling technique, GOMS fully acknowledges the importance of goals in achieving certain actions. The tasks or activities that users carry out are all directly affected and led by their goals. Although the goal may change during the process of problem solving, it is the force that directs what and why the current action should be carried out. From this sense, goal-activity is closely associated and it decides what the methods and rules are.
Although GOMS provides an alternative interpretation of what is contextual information, it only partially covers the context consideration in the interactive design. The more common view of treating context as a space or site has been left out. As a cognitive modeling technique with fixed elements and procedures, the GOMS technique is less flexible in depicting and capturing users’ working habitats, their preferences and other influential factors in the working context.

Furthermore, GOMS is an analytical approach designed to be deployed only by the HCI experts. This limits the effective use of GOMS to only HCI specialists with profound expertise. When it comes to the “wicked” nature of system designing, profound expertise of HCI does not guarantee a profound understanding of the complex user working environment.

3.7 Awareness

The notion of awareness often includes knowledge and consciousness in two parts. In the HCI area, awareness is studied as it relates to system interaction. Dourish and Bellotti (1992) defined awareness as “an understanding of the activities of others, which provides a context for your own activities (p.107).” In this sense, awareness could simply mean ‘knowing what’s going on in the situated context’. Awareness has already arisen many interests among CSCW researchers and many related notions have been explored, such as concept awareness, social awareness and workspace awareness (Gutwin, Stark, & Greenberg, 1995) etc. All these theories emphasize different aspects of awareness. Gutwin & Greenberg (2002) states four characteristics of the awareness as:
1. Awareness is knowledge about the state of a situation bounded between time and space.

2. Environments change over time, so awareness is knowledge that must be maintained and kept up-to-date.

3. People interact with the environment, and the maintenance of awareness is accomplished through this interaction.

4. Awareness is almost always part of some other activity. That is, maintaining awareness is rarely the primary goal of the activity; the goal is to complete some task in the environments.

*Emphasis on Context*

Awareness could be simply mean ‘knowing what’s going on in the context’, which indicated that awareness is associated with the context under which the intended task is being processed. In reverse, from a system design perspective, knowing what’s going on definitely provides users with feedback of what is going on and what has happened, as well as with the sense of consciousness of being in the context. When the context of system use becomes the focus of the design, awareness is part of the context that defines and, in turn, affects the context of using.

Awareness is an almost unavoidable topic for any CSCW system design and research due to its importance for the collaborative work. In Locales Framework, the interaction trajectories and mutuality are actually represented in the awareness considerations, only it has been separated by the dimensions of activities and resources. Interaction trajectories concern what happened and what’s going on and mutuality is about whether people are aware of other people and artifacts co-located in the locale.
Different from Locales Framework, studies of awareness tend to emphasize only the people’s understanding and perception of the shared context, not on the real space and artifacts inside the environment in their scopes of studies.

Research in the awareness area is, in general, practically oriented and the concerns can be easily transformed to system design process. It is usually used as a guideline that contains specific items for designers to consider such as guideline proposed in the workspace awareness (Gutwin & Greenberg, 2002) and heuristics for synchronous collaborative systems (Drury, 2001). But awareness is considered partially context information since it only provides a sense of shared environment to the people. It is perceptions perceived by the people located in the context, but the other context elements, especially physical artifacts, are left outside the awareness research.

3.8 Pattern Language

The concept of pattern languages was first introduced by Christopher Alexander (1977, 1979) and was used to inform designs in the architectural domain. Alexander, as an architect, believes that a certain unnamed quality called ‘pattern’ existing in the design of buildings and towns made it so comfortable for people to live there. The design of the enjoyable buildings succeeded just in supporting the patterns of events that frequently occurs. A pattern in architecture is possible good solutions to a recurrent problem in a certain context. Patterns are not specific to a particular situation but have certain generality to solve recurring problems. For example, the "Entrance Transition" (Alexander, 1977) is a design pattern that describes that a home must have a doorway so that people feel as though they are coming into a private and safe space. The doorway is
presented in every decent design and this is the quality material that made the design so enjoyable but unexpressed by the one who actually lives there.

According to Alexander (1977, 1979), a pattern expresses a relation between a problem and a solution in a context. Here context represents a certain condition where problem and solution occurs and it determines what solution is applicable for the given problem.

The understanding of patterns is tacit knowledge that users process but is hard to explicitly express. Whereas, it is the quality of design architects try to capture in their design. Alexander’s patterns language (Alexander, 1977) is a shared language to facilitate the communication between architects and non-architects. The users of the environment are able to create a suitable environment for themselves since they live there. Though it is hard for users to explicitly name or describe what these patterns are and why they use them, they are inside their heads and they employ them into their everyday lives.

In recent years, the concept of patterns has been borrowed by the HCI design field (Borchers, 2001; Tidwell, 2005) since constructing an information system is very similar to the design of an architect. The patterns in HCI do not exclusively represent the unnamable qualities in the physical world but also involve the quality elements in the virtual environment. HCI patterns share the same structure with the architectural patterns of a problem and a solution in certain contexts. HCI patterns provide reliable solutions to ensure the quality of the interface design. Interactive patterns are extracted on the top of the existing HCI designs.
Emphasis on Context

Context is outlined as one of three essential elements for a pattern. It serves as a “means” to possible solutions to a certain problem where context is the determining factor in forming the problem and solution relationship. In doing so, pattern language has been viewed as a shared communication tool between end-users and system designers.

Context, in a pattern, is the conditions in which the problem and solutions are situated. Context is environment deciding what, why, and how the solution is to be applied. The context could either be a physical environment, as Alexander first advocated in the civil design, or a virtual setting such as the problem background information for an interactive pattern. A pattern is a recurring element that applies to several similar problems. But the pattern theory does not cover how to use the contextual information embedded in the patterns; in other words, when there is a problem and an intended solution, how could we capture and represent the context it might affect?

3.9 Understanding towards Context

The theories reviewed in this chapter provide a good snapshot of how context is defined and utilized in the HCI domain. As we mentioned earlier, these theories, although embedded the contextual considerations and can be borrowed for studying the context of system use, are not primary designed to study this issue. In this case, each theory we reviewed has its own strength and unique perspectives but none of them covered all aspects sufficient in studying context issues in the current ubiquitous environment. However, the synthesis of the theories provides a good basis for understanding the context issue in the design process.
The interactive viewpoints of context suggested that context is “a relational property holds between objects or activities. We cannot simply say that something is or is not context; rather, it may or may not be contextually relevant to some particular activity” (Dourish, 2004, p21). This viewpoint states that contextual information is dynamic and particular to each occasion of activity. This argument appears in most of the theories we reviewed. The review process suggested to us that context is either a setting or a method:

- Setting with artifacts inside to support activities (Activity theory, distributed cognition, situated action, locales framework, awareness).
- Methods of when, how and why to carry out the current activity (activity theory, locales framework pattern language, GOMS).

The review and analysis suggested that context is not a fixed, descriptive element. Instead, it is a dynamic and interactive element that arises from the activity and is particular to each occasion of activity. From the review of theories we identified the following properties for context when it is viewed as an interactive artifact.

- Context arises from the activity and is particular to each occasion of activity.
- Context is a dynamic and interactive property.
- Context is not purely external representation of surrounding artifacts; internal mind activities also define context and is part of context.
- Awareness which provides people the sense of context is also part of the context.
3.10 Contextual Elements Identified

From the above review, we conclude that context, although defined and used differently in these theories, does share some common elements. Some theories using different names for the same element, like mutuality in locales framework is actually part of the awareness. In this section, we grouped the major elements with the exact or similar meanings together in order to exclude bias. The contextual factors extracted from each theory are outlined (see Table 4).

**Table 4: Contextual Factors Extracted from HCI Theories.**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Explanations</th>
<th>Relevant Theories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>The reasons for a action</td>
<td>Activity Theory, GOMS</td>
</tr>
<tr>
<td>Goal</td>
<td>The intend outcome for the an action</td>
<td>Activity Theory, GOMS</td>
</tr>
<tr>
<td>Activity</td>
<td>Action</td>
<td>Activity Theory, Distributed, Cognition, Situated Actions, GOMS, Awareness, Locales Framework</td>
</tr>
<tr>
<td>Rules</td>
<td>Principles or regulations of a action</td>
<td>Activity Theory, Distributed Cognition, GOMS</td>
</tr>
<tr>
<td>Constraint</td>
<td>Limitation or restriction of a action</td>
<td>Activity Theory, Distributed Cognition</td>
</tr>
<tr>
<td>Awareness</td>
<td>Knowing what’s going on</td>
<td>Awareness, Locales Framework</td>
</tr>
<tr>
<td>Methods/tools</td>
<td>Different ways of conducting a action</td>
<td>Activity Theory, GOMS, Locales Framework</td>
</tr>
<tr>
<td>People</td>
<td>People involved in a action and their roles</td>
<td>Activity Theory, Distributed Cognition, Awareness, Locales Framework</td>
</tr>
<tr>
<td>Objects</td>
<td>Relevant artifacts</td>
<td>Activity Theory, Distributed Cognition, Awareness</td>
</tr>
<tr>
<td>Settings</td>
<td>Either physical or virtual space for a action</td>
<td>Distributed Cognition, Awareness, Locales Framework</td>
</tr>
</tbody>
</table>
In order to construct our context-centered framework, we used the contextual factors, which were extracted from the traditional HCI theories (Table 4). As shown in Figure 7, we grouped the factors that have similar meanings or that overlapped significantly. Five main groups of factors are as follows:

- Motivation, goal, intended outcomes etc
- Activity, action etc.
- Methods, tools, people, objects, artifacts all located in the shared settings
- Rules, constrains
- Awareness

- **Motivation and goals** define why user perform the current activity and the intend outcome.
- **Methods, tools, people, objects** alone with the situated setting is consist the environment where the activity is carried out.
- **Rules and constraints** either internally within people’s mind or externally located in the environments determine how, when, and why to perform the activity.
- **Awareness** provides a sense of what is going on.

**Figure 7: Major contextual components extracted from the HCI theories**
By observing these five groups of factors, we found that all other four are relevant to the activity and mediated by the activity. This concurred with our previous understanding of activity-bounded context. Thus, in this study, we captured and represented contextual information from each activity level. For each activity, there were four aspects to analyze. These four aspects were highly interdependent and overlapping. They have been connected by the same action undertaken. Together, these aspects could possibly be able to capture and represent major contextual characteristics in a working setting.

**Goal:** The first thing in understanding the context is to identify the object of the activity. It could determine what relevant context information is. Goals includes users’ motivation and intended outcome of performing this activity.

**Setting:** Setting is the place where participants perform the activity; it could have been either a virtual or physical environment. The relevant setting information included:

- People who conduct this activity and their roles;
- Characters of the setting where the activity performs;
- Available tools like other available methods and approaches;
- Artifacts involved in the setting like other devices and objects.

**Rules:** Rules of using the resources in the setting and constraints of allocating resources to perform the activity. E.g. Time preference is a rule for performing an action.

- Constraints of using the resources in the working settings
- Rules of allocating resources
Awareness: An understanding of the others (either objects or people), which provides feedbacks and consciousness of the context and the activities.

- The shared context:
  - Awareness of other people who are involved in the activity and their roles;
  - Awareness of the tools and artifacts in the current settings; Awareness of the rules/constraints for performing this activity

- Actions: Awareness of the actions has been taken; Awareness of the actions being carried out.

3.11 Context-Centered Framework

The Context-Centered Framework was developed in respect to the first research question of the study: how to represent context and how can we incorporate contextual information in the design process? By synthesizing and identifying the contextual factors from the HCI theories, the context could be represented by the factors. In this section, we intended to build a framework that facilitates designers in incorporating the five contextual factors into the design process. And by doing so, we believe it would serve as a communication tool between end users and helps designers enhance the design quality through an improved domain understanding.

Compared with Locales Framework, considering context as a static space, we adapted a dynamic view to studying the context issue from the activity perspective. This approach combined context with the task solving process. Hence, it was possible to identify context and represent contextual information from a task-solving perspective.
We took activity as a unit of Analysis in this framework and activity was treated as the central component, mediated by other contextual components.

*Activity as a Unit of Analysis*

The review showed that context is inseparable from activities; whether it is something that is considered to be context or not is determined by its relevance to a particular activity (Dey et al., 2001; Dourish, 2004). A close checking of the other contextual components identified also suggested to us that activities were the core elements that link and mediate other contextual elements. Therefore, in this study we set the unit of analysis to an Activity level. From the interaction point of view, contextual information is initiated from and bounded by the activities happened within it. According to Nardi’s (1996) hierarchical levels of activities, the outcomes of activities are achieved through a sequence of small steps of lower-level actions.

*Aspects of Context-centered Framework*

From the hierarchy of activity point of view (Nardi, 1996), the activity is the lower of the task that users are trying to accomplish, actions are steps of achieving it, and operations are the procedures under each step. Context differs in each step and also in the overall task. For each action, there are four aspects to analyze. These four aspects are highly interdependent and overlapping. They have been connected by the same action under taken. The four aspects together can help extract contextual information which is associated with the current activity.
Table 5: Aspects of the Context-centered framework

<table>
<thead>
<tr>
<th>Goal</th>
<th>Object determines what contextual information for the activity is.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>Setting is the place where participants perform activities. Includes the resources involved in the task solving process.</td>
</tr>
<tr>
<td>Rules</td>
<td>Rules and constraints of using the resources.</td>
</tr>
<tr>
<td>Awareness</td>
<td>An understanding and conscious of the setting and activity.</td>
</tr>
</tbody>
</table>

3.12 Summary

In this chapter, we developed a conceptual framework called ‘Context-Centered Framework’ to answer the first research question of the dissertation. The framework was built through synthesizing previous HCI theories in terms of how contextual considerations have been embedded and utilized in the interactive system design. Since the primary concerns of these theories are not set for studying context of system use, each theory only partially covers the problem. Because of that, we combined the contextual components embedded in the theories together and the combined contextual factors were proposed as the contextual representation for the conceptual framework. Since these contextual factors are all mediated and bounded by activities that users carried out in the tasking solving process, we set the unit of analysis of the framework on each activity level. By doing so, the contextual information could be outlined and applied to the design process through examining user activity.

Next, in the methodology section, we will introduce the empirical study designed to verify the effectiveness of the conceptual framework. The main objective of the framework was to answer the second research question: How does contextual information benefit interactive system design? The study was carried out on groups of participants...
with nursing or design expertise on a nursing handheld system task. Concrete
descriptions about the experiment design, materials and participants as well as
experiment procedures will be covered in the next chapter.
CHAPTER 4: METHODOLOGY

To evaluate the effectiveness of the Context-Centered Framework and to explore the importance of context in the interactive system design process, we designed a 2x2 controlled experiment using scenario-based design (SBD) and claims analysis (Carroll, 1995, 2000) methods to a nursing handheld system task. The two independent variables were: (a) participants’ expertise and (b) instructions. Participants with either nursing or design knowledge were recruited and randomly assigned to one of the following two groups: (a) a control group using regular Scenario-based Design instruction or (b) an experimental group using an adapted Context-Centered Scenario-based Design instruction. The study was carried out over five months from August 2007 to December 2007. 124 students participated in the study.

4.1. Objective

RQ1: How to represent context and incorporate contextual information in the system design process?

RQ2: How does contextual information benefit interactive system design?

Two main research questions have been raised and used to direct this dissertation. The first research question, “How to represent and use contextual information in the design process?” has been answered through building the Context-Centered Framework. Therefore, the main objective of this empirical study was to explore whether contextual information is beneficial to the interactive design, and how it affects the design quality. We used the Context-Centered Framework as our conceptual framework in the experiment.
In this study, subjects with nursing knowledge or design expertise were asked to write claims for four nursing handheld system features. Due to the property of the task scenario, we considered nursing students as domain experts or end-users and design students as designers. Our review suggested that contextual information could serve as a breakthrough to communicate design work and domain understanding. In this case, we hypothesized that nursing students who had working experience in the hospital and experience of using handheld system in the nursing domain will perform better than the designers. But designers could grasp the contextual information through using the context-centered framework and this would narrow down the gap of their understating towards problem domain with end-users.

H1a: End-users who have solid understandings of their working environment perform better than the system designers.

H1b: Designers could improve their understanding towards the problem domain through using the Context-Centered Framework.

As a basic HCI concept, context of system use is an important aspect of interactive system design and design focusing on context of use can eliminate possible usability flaws, but there is no empirical proof of how it benefits the system design process. In this empirical study, the task solving process, though it is only to outline claims for a scenario, can be considered as early stage system analysis and design. Thus, we hypothesized that the contextual information helps designer produce better design through incorporating contextual information into design process and reducing the usability problems of the product.
H2: Designers produce better design products through using Context-Centered Framework in the early system design stage.

4.2. Method

The experiment was carried out using scenario-based design and claims analysis methods (Carroll, 1995, 2000). Scenario-based Design is a commonly used, low-cost HCI design method mainly for early stage system analysis and design (Carroll, 1995, 2000). A scenario is a narrative story describing the tasks that users carried out using certain technologies in the designated context. It could inform system design by analyzing how these technologies are beneficial or harmful to users’ activities.

There is an evaluation process associated with scenario-based design called Claims Analysis (Carroll, 2000). A claim asserts the consequences of new technology brought to the users in certain situation. Consequences are judged on the basis of the claim schema and it is commonly classified as positive or negative (Carroll, 2000). Claim analysis provides flexibility to the evaluation process since the claims can be labeled across multiple dimensions in addition to the basic positive or negative classifications. Haynes, Purao, & Skattebo (2004) reported the use of claim analysis to assess collaborative systems by coding the claims using guideline for designing collaborative systems and extracting the concerns regarding the collaboration perspective of system use. Similarly, by adapting the claim schema to emphasize on the context of the system use, in our case, the four contextual factors in the Context-Centered Framework, we can measure whether the system design incorporates contextual considerations and whether it can fit into the situated environment or not. In this adapted
claims analysis process, the desirable consequences are those that highlight one or more contextual factors; undesirable consequences are the ones that hinder or restrict the contextual factors.

There are few stages of scenario usages in the design process (Carroll, 2000): (a) a problem scenario is to describe the current problem domain and user activities; (b) activity scenario describes the users’ needs and how new functionalities of the technologies could meet their needs; and (c) information design scenario contains concrete information about the technologies and the rational of using these technologies. Claims analysis can be applied in either problem scenario and activity scenario stages to help designers assess the current task and the proposed new functionalities (Carroll, 2000). The current experiment design proposed to use claims analysis method to analyze the tradeoff of new system features on the activity scenario level. The task scenario used in the study contains descriptions of the new system functionalities and the users’ activities in the working environment.

Scenario-based Design and claims analysis have several advantages for the design.

1). The story-like scenario contains rich contextual information that describes how, why and what happens in the task solving process. It provides information for inspectors to relate the task to the situated context. Scenarios are considered as ideal tools to assess context of use before the system is implemented into the real working environment (Pinelle & Gutwin, 2002). This simplified the study design.

2). System usage can be depicted before the actual system is built and its impacts become reality. By doing so, system designers could speculate how the system is used
and possibly detect system design deficiencies in the early system design stage and avoid major and serious system design flaws from happening.

3). No any evaluation can detect all aspects of the system deficiencies, but to find major problems, which the main propose of the evaluation is designed to inspect. The Claims Analysis method provides us with flexibility to judge the desirable and undesirable consequences by adapting the claim schema to emphasize the main evaluation goals. In this study, we embedded the Context-Centered Framework into the regular claim schema to emphasize the evaluation process on the aspects of contextual information.

4.3. Experimental Design

We designed a 2x2 between-subjects study. The two independent variables were participants’ expertise (nursing vs. design) and the instructions (regular control group vs. context-centered experimental group). In the following section, we will first provide an overview of the study, and then introduce the details of participants, instructions and the task scenario.

Table 6: Research Design

<table>
<thead>
<tr>
<th></th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants with Design Expertise</td>
<td>Context-Centered</td>
<td>Regular Design Group</td>
</tr>
<tr>
<td></td>
<td>Design group</td>
<td></td>
</tr>
<tr>
<td>Participants with Nursing Expertise</td>
<td>Context-Centered</td>
<td>Regular Nursing Group</td>
</tr>
<tr>
<td></td>
<td>Nursing Group</td>
<td></td>
</tr>
</tbody>
</table>
Experimental Procedure

It took participants four steps to complete the experiment. Participants with nursing domain knowledge or design expertise were randomly assigned to either a control group or experimental group. Experiments were conducted on an individual basis to avoid the possible interruption and distraction.

1. Pre-experiment questionnaire

Participants were asked to fill out a background questionnaire asking for their gender and age. They were also asked their major and which year they were in the program as well as their existing knowledge about either system design or nursing practice. The primary propose of this questionnaire was to capture participants’ demographic information and their backgrounds in system design or in the nursing field. Design knowledge was judged by numbers of HCI courses participants took before. Since the nursing program has a fixed course schedule for students, nursing knowledge was assessed through the year participants were in the program.

2. Training session

Participants were trained on how to write claims. Instruction was given to each participant based on the group assignment. Participants were asked to read the instruction and the two claim examples. To ensure that participants understood the instruction and could write claims following the instruction, we provided them a simple task scenario with one system feature to practice and get familiar with the instruction first.

3. Main Task
Participants then received a task scenario describing how a nurse uses a tablet PC to conduct routine work. Four system features were outlined for this scenario. Participants were asked to write pros and cons for each feature based on the instruction received. The nursing handheld system task was the major task of the study.

4. Post-experiment Questionnaire

The last step of the experiment was to fill out a post-study questionnaire regarding participants’ perception and opinions about the experiment, such as how well they understood the instructions and task scenario and how well they understood the nursing and design domain. They were also asked to evaluate what areas they thought could be improved to make the study run more smoothly.

The demographic and background information gathered through the pre-questionnaires was reported in the expertise factors section. The post-questionnaire was mainly applied to assess whether participants were able to understand the instruction and their opinions on improving the future studies. We list them in the appendix section.

*Expertise Factor*

The experiment was designed to be carried out on participants with various levels of expertise. To ensure that both sides of participants possessed a relatively equal level of expertise in this study, the subjects were all recruited from the undergraduate student population.
Design Expertise

The 62 participants in the two design groups (control group and Context-Centered group) consisted of undergraduate students from the Drexel University, College of Information Science and Technology (IST), majoring in either Information Systems or Software Engineering. Design participants were required to complete at least 1 Human-Computer course prior to the study. HCI courses offered in IST cover basic system design, evaluation and usability principles. Students were also required to work on a team project during the course. Some students also had few months’ internship experience in software companies. It was guaranteed that participants all understood basic HCI design principles and they were considered as novice designers. Fifty males (81%) and twelve females (19%) took part in the experiment. The designing students’ ages ranged from 18-36.

Nursing Expertise

For the nursing side, 62 undergraduate students majoring in Nursing were recruited from Drexel University, College of Nursing and Health Professionals (CNHP). The two prerequisites for nursing participants were: (a) students had taken the Nursing Informatics course, and (b) students had at least six months internship in hospitals. The Nursing Informatics course is a required course offering for sophomores in the 5-year regular co-op program and the second quarter for the ACE program for the Nursing major. The course covers basic informatics knowledge such as how to use PDA downloading and checking drug references, how to connect online and how to do basic documentation. The Nursing program also requires that students start their first 6-month internship in a hospital during their pre-junior year (third year of study.) These two prerequisites ensured
that participants were familiar with mobile system applications in the nursing domain, had real experience with patient care and had exposure to a hospital environment. Based on the prerequisites, we recruited participants from the following three levels of classes:

a. Pre-junior in the regular co-op program or the Second quarter of the ACE program

b. Junior in the regular co-op program or the Third quarter of the ACE program

c. Senior in the regular co-op program or the Fourth quarter of the ACE program

Six males (11%) and fifty-six females (89%) age 20 to 43 took part in the experiment. The designing students’ age range was from 20-43.

<table>
<thead>
<tr>
<th>Table 7: Participants’ Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Design Groups</td>
</tr>
<tr>
<td>Nursing Groups</td>
</tr>
</tbody>
</table>

The data showed very distinct gender difference among participants, where 89% of the nursing participants were females; by contrast, 81% of the designing subjects were males. This was unavoidable in our design since, in general, male students dominate technology-related majors and traditionally, nurses tend to be females.
Instructions

Two sets of instructions were used in this study: (a) the regular scenario-based design instruction and (b) the context-centered scenario-based design instruction. Both the control and experimental groups’ instruction sets contained three parts:

1. Scenario-based Design and Claims Analysis instruction
2. Two claims examples
3. A hands-on exercise

The major difference between the two sets of instructions lie in the claim schema. The control group’s claim schema was the regular one where participants asserted consequences of system features from only desirable and undesirable perspectives. The experimental groups’ instruction was adapted to include the concerns from the Context-Centered Framework. This adapted claim schema defined desirable consequences as any consequence that emphasizes the contextual components and undesirable ones are those which inhibit them. By doing so, the claims still processed positive and negative consequences in two parts, but focused on the contextual components proposed in the conceptual framework.

After reading the instruction, participants were asked to write a claim for the hands-on task. Participants were allowed to ask any question during this process and the inspector could correct them if they misunderstood the instruction or had confusion at this stage.
Instructions contained the definition of the Scenario-based Design and Claims Analysis, claim schema used in the study and the structure of the claim (Figure 8).

**Scenario-based design** (SBD) uses narrative stories to describe tasks users carried out in the real world to inform the system design. There is an evaluation process associated with SBD called *claim analysis*. A claim asserts that a given feature of an artifact in a situation of use can have various specific consequences for a user. Consequences may be either positive (*pros*) or negative (*cons*). Both positive and negative consequences are judged on the basis of the claim schema or the goal of the evaluation.

In general, a claim schema is looks like the following:

1. Positive consequences or *pros* would facilitate, enable or increase the current activity.
2. Negative consequences or *cons* would inhibit or decrease the activity.

A claim is in the following structure.

*Feature of use*

- **Cause** (positive consequences or *pros*)
- **But may also cause** (negative consequences or *cons*)

**Figure 8: Regular Group’s Instruction**

The instruction sets contained an example to show participants what a claim looks like and how to produce a claim from a giving scenario. We adapted this example from the online problem-solving scenario used in the previous study (Chin & Rosson, 1998). The example included a short scenario describing how students collaboratively worked on their group assignment and two claims. One claim was about using a video-conferencing system, discussing problems and the other was to leave notes on an electronic white board. Since the participants in the study were all college students and
used online education technologies previously, we speculated that the hands-on task was closely related to their daily life so that subjects could focus more on how to apply instruction there. We also included a one-sentence explanation for each consequence outlined in the example to make sure students understood the rationale behind each consequence.

Students were told that they may include all the consequences they felt were reasonable to the system’s features. There was no limitation on how many they could write and they could leave it blank if they had nothing to write.

Example

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Group members use video conferencing system to discuss problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pros</td>
<td>+ allows group members’ remote presence.</td>
</tr>
<tr>
<td></td>
<td>The feature supports communication when students are not co-located together.</td>
</tr>
<tr>
<td></td>
<td>+ allows a more vivid discussion experience.</td>
</tr>
<tr>
<td></td>
<td>The videomediated discussion helps students discuss problems by seeing and talking to each other.</td>
</tr>
<tr>
<td></td>
<td>+ enables students more engaged into the problem solving process.</td>
</tr>
<tr>
<td></td>
<td>The video mediated discussion helps students discuss problems by seeing and talking to each other.</td>
</tr>
<tr>
<td></td>
<td>+ creates a discussion environment which is natural to students.</td>
</tr>
<tr>
<td></td>
<td>By seeing others, students have a discussion environment similar to the classroom discussion before.</td>
</tr>
<tr>
<td>cons</td>
<td>- BUT the system may provide poor sound or video.</td>
</tr>
<tr>
<td></td>
<td>Students may be hard to talk if the audio or video is not clear.</td>
</tr>
<tr>
<td></td>
<td>- BUT students may feel frustrated when technical problems occur.</td>
</tr>
<tr>
<td></td>
<td>The technique problems may interrupt students’ discussion.</td>
</tr>
</tbody>
</table>

Figure 9: One Example showed in the Regular Group
Figure 9 shows an example in the regular group’s instruction. A short scenario was given for participants to understand this claim.

Three middle school students have elected to work together on an assignment. The three group members need to jointly interpret some data they collected previously. They will communicate through a video-conferencing system and use an electronic-white board to annotate their assignment.

**Hands-on exercise**

A Hands-on exercise was used to make sure that participants understood the instructions and could write claims follow the instructions. Both the control group and experimental group received the same practice task. The practice scenario was chosen from a task that closely associated with students’ school life so that they could pay more attention to how to deploy the instruction here.

Mike is a student in an online course which is organized by the “Virtual classroom system.” He is requested to make a presentation about his term project during tomorrow’s class through the presentation function in the system. During the presentation, he will use interactive sharing area to display his slides, images and other related materials to the rest of the class.

Participants were allowed to ask any question during this process and the practice claim was checked before the real task scenario was given to rule out a possible misunderstanding of the claims.

**Instruction Set: Experimental Groups**

We embedded the Context-Centered Framework into the regular Claims Analysis instruction for the experimental groups. In order to do so, it was necessary to match the unit of analysis of the framework and the claims analysis. Nardi (1996) mentioned the
hierarchy of the activity in the activity theory, which consists of activity, action and operation. But the actual boundary between activity and action is rather blurry in the real system design. In the current study, we simply treated each system feature as an individual activity, and then each system feature was considered as one unit of analysis in the Context-Centered Framework. Therefore, the claims analysis for each system feature could be emphasized on the contextual aspects outlined in the framework.

Scenario-based design (SBD) uses narrative stories to describe tasks users carried out in the real world to inform the system design. There is an evaluation process associated with SBD called claim analysis. A claim asserts that a given feature of an artifact in a situation of use can have various specific consequences for a user. Consequences may be either positive (pros) or negative (cons). Both positive and negative consequences are judged on the basis of the claim schema or the goal of the evaluation.

Here is the claim schema we will use in today’s study:

1. **Goal**: the motivation and intended outcome

2. **Setting**: Setting is a place where participants perform the activity: it could be either a virtually or physically located place
   a. **People** involved in and their **Roles** in solving the task
   b. The **Properties of the Context** which related to the task solving process.
   c. The available **Tools, Artifacts** and **Resources** for conducting this task.

3. **Rules and Constraints**: the rules or constraints for using these tools and resources. E.g. time preference or Jim has priority to use the system.

4. **Awareness**: an understanding of the actions, people, artifacts and time in the context of system use. The system should provide this understanding in order to keep people aware of what is going on and what has happened.

A claim is in the following structure.

(Feature of use)

    Cause (pros which emphasize the above four aspects)
    But may also cause (cons which inhibit the above four)

---

**Figure 10: Experimental Group’s Instruction**
As mentioned earlier, the desirable consequences in the experimental groups are those which facilitate the four contextual aspects; whereas, the undesirable consequences inhibit the contextual aspects. Figure 10 shows the instruction used in the real study. Similar to the control group’s instruction, it includes the definition of the Scenario-based Design and Claims Analysis, the claim schema and the structure of the claim.

It is notable that although there are four aspects on the claim schema, the claims still consist of only pros and cons in two parts. In order to ensure that participants followed instruction and considered all four of the contextual aspects during the study, they were asked to tag the consequences with the names of the contextual aspects.

The same task scenario was deployed to the experimental groups since the claim schema consisted of four big categories and participants were asked to consider these aspects during their task solving process. To guarantee they did take the time to consider these factors, we asked participants to tag each pro or con with a specific category name after it. The rationale for why each consequence belonged to a certain category was listed in the claims. The examples used in the experimental groups were the same as the regular group. But to be able to show the rational for each category listed in the claim schema, we included 1-2 more consequences in the context-centered groups’ examples.

Participants were told that there was no requirement for writing at least one pro/con for each category listed in the instruction, and they could leave it blank if they thought there were no pros or cons for a claim. It was fine to assign more than one tag to a consequence if they thought it was necessary. By doing so, we gave participants full
flexibility to write whatever occurred to them as relevant consequences and there was no limitation on the total number of consequences for each claim.

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Group members use video conferencing system to discuss problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pros</td>
<td>+ allows group members to collaborate remotely (goal).</td>
</tr>
<tr>
<td></td>
<td><em>The feature supports the goal of the activity which is to facilitate students’ discussion.</em></td>
</tr>
<tr>
<td></td>
<td>+ provides a shared environment for group members to meet (setting)</td>
</tr>
<tr>
<td></td>
<td><em>All the discussion activity is situated in the video conferencing system.</em></td>
</tr>
<tr>
<td></td>
<td>+ provides audio and video communication (setting-tool)</td>
</tr>
<tr>
<td></td>
<td><em>Video conferencing system provides tools for students to communicate.</em></td>
</tr>
<tr>
<td></td>
<td>+ allows synchronous communication (rule)</td>
</tr>
<tr>
<td></td>
<td><em>The properties of the video conferencing system support synchronous communication.</em></td>
</tr>
<tr>
<td></td>
<td>+ allows participants to be aware of the ongoing discussions (awareness)</td>
</tr>
<tr>
<td></td>
<td><em>Students participating in the discussion session know what others are doing right now.</em></td>
</tr>
<tr>
<td>cons</td>
<td>- BUT the system doesn’t assign the leader to the group (setting-people)</td>
</tr>
<tr>
<td></td>
<td><em>Without specifying people’s roles, especially the session leader, the discussion will go chaotic.</em></td>
</tr>
<tr>
<td></td>
<td>- BUT the system may provide poor sound or video (setting-tool)</td>
</tr>
<tr>
<td></td>
<td><em>Poor sound and video tools may affect students’ communication.</em></td>
</tr>
<tr>
<td></td>
<td>- BUT the system may not support asynchronous communication (rule)</td>
</tr>
<tr>
<td></td>
<td><em>This is a constraint of using audio and video communication.</em></td>
</tr>
<tr>
<td></td>
<td>- BUT students may lose track of what has happened (awareness)</td>
</tr>
<tr>
<td></td>
<td><em>Students cannot trace back to see what others said before in the video system.</em></td>
</tr>
</tbody>
</table>

**Figure 11: One Example showed in the Experimental Group**

**Task**

Each participant, no matter which groups they were in, received the same task scenario after the training session. The task scenario used in this study was adapted from
two previous studies regarding context-aware system applications in hospital settings (Dahl, Sorby, & Nytro, 2004; Muñoz, Rodríguez, Favela, Martinez-Garcia, & González, 2003). The task scenario described a nurse doing the regular bedside care using an innovative handheld hospital information system.

We situated this study into the Nursing Informatics research and more broadly, Medical Informatics research. The reasons we chose this task are: (a) Nurses are part of the clinician team and their routine work also relies more on technology, and (b) Nursing tasks are often mobilized, highly interruptive that all deal with changing context. Mobile systems such as PDAs or tablets systems are believed to facilitate nursing documentation and other patient care tasks (Shneyder, 2002). As a byproduct of the study, we were also interested in comparing the claims with the other designs. This helped us identify the usability problems in the other designs.

Since two groups of participants with very different backgrounds were involved in the study and they needed to comprehend the task individually, we chose to only include very basic nursing and design descriptions in the task scenario to make sure that understanding the scenario would not be a factor affecting the claim generation. To eliminate the possible gender bias enforced by the task scenario, one female role and one male role version scenarios were evenly distributed among the groups.
Mary is a nurse in a local hospital. This hospital has recently applied a hospital wide wireless-based hospital information system (HIS) system. Clinicians could have access to the HIS system through either a regular desktop or a tablet PC.

Mary was on duty in the morning shift today. She brought her tablet PC with her to the second floor where the patient rooms are located. While she was checking the patient’s condition in room 203, suddenly the alarm on her tablet PC went off. It showed that patient Tony needs help. Mary rushed into Tony’s room. Right after she entered the room, Tony’s record was automatically displayed on her tablet PC. Mary found that the patient was not responding well to the medication and was vomiting now. She sent out an alarm through her tablet PC to request a doctor to come over for a consultation and sent a message to the main doctor Davis asking about the patient’s dose of Warfarin. She indicated that she needs an immediate reply. She then requested the lab results to be transferred to her tablet PC and to the doctors who are responsible for this patient. She checked the vital signs of the patient and updated the record through her tablet. Mary left a note on the electronic white-board which is embedded in the HIS system and reminded nurses in the afternoon shift pay more attention to Tony.

**Figure 12: Nursing Handheld System Task Scenario**

After reading the task scenario, participants were asked to write claims for four pre-outlined system features. Originally in the claims analysis process, participants were supposed to come up with any claim they wanted. To compare the results of each participant and to better control the study, the four claims were pre-set for the participants in this study.
**Feature 1**: Clinician could send/receive calls, messages or alarms to others when they need help.

**Feature 2**: Clinicians can request lab test results and other information to be transferred and displayed on their tablet PC directly.

**Feature 3**: The system automatically displays patient information on the tablet PC when clinicians enter the patient’s room and updates patient’s record after each check-up.

**Feature 4**: Clinicians can leave important notes on the electronic message board for personnel on the next shift.

Participants were asked to fill in pros and cons in the data recording sheet (Figure 13), where each system feature covered a whole page and the pros/cons areas remained blank. Students’ background determined that some of them (mostly IST students) prefer typing on PC and others (nurses) like hand-writing. In this study, students chose to either type the claims on a PC or write it down on paper based on their preferences. The same page layout was shown on the PC screen. The hand-writing claims were proofread before participants left the study to guarantee correct transcription later.

Students completed the major task of the study after they finished writing claims for the nursing handheld system scenario. They were presented a short questionnaire regarding their perception of the study, and then the whole study session was complete.
### Feature 1
Clinician could send/receive calls, messages or alarms to others when they need help.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Figure 13: Task Recording Sheet

### 4.4. Summary

In this chapter we introduced the methodology deployed in the study. We designed a 2x2 between-subjects experiment among groups of nursing and design participants using Scenario-based Design and Claims Analysis methods. Participants were asking to write claims for a Nursing Handheld System scenario using either a regular scenario-based design instruction or an adapted context-centered scenario-based design instruction.

In the next chapter, we describe the data analysis process. The collected claims were rated by two raters using a three metrics evaluation guideline on the per subject
basis. The rating scores as well as the study time were analyzed through a two-way ANOVA analysis on the two independent variables: (a) expertise factor and (b) instruction factor. The results of the statistical analysis are reported in the next chapter.
CHAPTER 5: RESULTS

A 2x2 between-subjects experiment was carried out using Scenario-based Design and Claims Analysis methods on 124 participants. The independent variables were participants’ expertise (Design vs. Nursing) and the instructions used in the study (Control vs. Context-Centered). The main measurements of the study were three quality metrics graded by two raters. Claims were rated by the raters individually on a per-subject basis. The three evaluation metrics aimed to measure “domain understanding”, “usability concerns” and “quality of the claims” respectively. Other than the main measurements, the total study time, training time and the main task solving time (minute level) were also analyzed.

In this chapter, we first introduce the data rating process and the metrics used in the study, the statistical method for analyzing the data. Then, we present the main statistics results from the rating scores as well as the time spent on the study.

5.1 Data Rating Process

The study included 124 participants and each participant was asked to write four claims. To show the difference of the claims from control groups and experimental groups, here we present some data samples for the system feature 1: send and receive alarms/call/messages. These examples were randomly selected from the collected data and the quality of each sample does not represent the quality of the whole experiment group.

The following examples show the difference between groups. The two experimental groups’ data present as pros and cons following the contextual tags such as
goal, setting, tool and awareness showed in the claims. The control groups’ claims contain only pros and cons. Other than this, there is no obvious difference between two participants groups.

<table>
<thead>
<tr>
<th><strong>Pros:</strong></th>
<th><strong>Cons:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Allows clinician to send and receive calls, messages and alarms. (goal)</td>
<td>1. BUT system may not function depending on location (setting – tool)</td>
</tr>
<tr>
<td>2. Allows nurse to contact specific roles such as the doctor in charge, any doctor, or any nurse. (setting – people)</td>
<td>2. BUT system may not support sending and receiving of multiple calls (rule)</td>
</tr>
<tr>
<td>3. Provides patient records relative to location. (setting – tool)</td>
<td>3. BUT clinician may not be aware of priority of messages and calls (awareness)</td>
</tr>
<tr>
<td>4. Allows nurse to post to the electronic white-board. (setting – tool)</td>
<td>4. BUT clinicians may lose track of alarms and messages (awareness)</td>
</tr>
<tr>
<td>5. Allows clinicians to view updates to patient record and to electronic white board. (awareness)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 14: Claim Sample 1 - Context-Centered Design Group**

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unlimited access to medical staff</td>
<td>1. Sudden Alarms or buzzers on PC could startle patients</td>
</tr>
<tr>
<td>2. Can save time when needing to communicate short messages</td>
<td>2. With aging medical community, new technology could take a while to learn</td>
</tr>
<tr>
<td>3. Less reliance on using cell phones, which often do not get service in hospitals</td>
<td>3. Could be bulky/heavy to carry around</td>
</tr>
<tr>
<td></td>
<td>4. Would require more reliance on hospitals network to get internet in all areas of hospital. Including areas that have thick or lead walls.</td>
</tr>
</tbody>
</table>

**Figure 15: Claim Sample 2 - Regular Design Group**
### Pros

1. Clinicians would be in constant communication w/each other - awareness
2. Allows immediate updates regarding patients’ conditions - goal
3. Allows nurse to reorder priorities more quickly – setting: context

### Cons

1. Who has access? What determines the importance of an alarm? –setting: people
2. Are alarms sent to specific clinicians or are they unit-wide?-awareness

Figure 16: Claim Sample 3 - Context-Centered Nursing Group

### Pros

1. The messages will get to the person quickly
2. There is a faster response for the entire team to help with the patient
3. RN can stay with the patient until someone else arrives.
4. RN can reach different doctors quickly no matter where they are located

### Cons

1. The alarm may not work properly
2. The tablet PC may malfunction and no one get the message

Figure 17: Claim Sample 4 - Regular Nursing Group

---

**Data Preparation**

In total, 7 out 124 data sets were excluded from the data analysis stage due to the following reasons: (a) subject did not complete the task; (b), participants weren’t majoring in IST/Nursing or they had trainings on both sides of expertise; (c) participants did not follow the instructions; or (d), the study got interrupted in the middle. Table 8 shows the final numbers included in the data analysis for each group.
Table 8: Number of Participants in Each Condition

<table>
<thead>
<tr>
<th></th>
<th>Context-Centered SBD instruction</th>
<th>General SBD instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Groups</td>
<td>Context-Centered Design Group</td>
<td>Regular Design Group</td>
</tr>
<tr>
<td></td>
<td>31 included</td>
<td>29 included</td>
</tr>
<tr>
<td></td>
<td>1 excluded</td>
<td>1 excluded</td>
</tr>
<tr>
<td>Nursing Groups</td>
<td>Context-Centered Nursing Group</td>
<td>Regular Nursing Group</td>
</tr>
<tr>
<td></td>
<td>28 included</td>
<td>29 included</td>
</tr>
<tr>
<td></td>
<td>3 excluded</td>
<td>2 excluded</td>
</tr>
</tbody>
</table>

As we stated earlier, the only difference between groups are that the experimental groups’ claims contain the contextual tags. Raters would be able to tell if the participants were from control or experimental groups if the tags remained in the data. To eliminate the possible bias, we manually removed the contextual tags on the two experimental groups before the data was sent to raters for assessment. We also replaced the previous group number with a unique participant number for each data set. This was also to avoid the possibility of identifying groups’ information during the rating process.

**Pros:**

1. Allows clinician to send and receive calls, messages and alarms. (goal)
2. Allows nurse to contact specific roles such as the doctor in charge, any doctor, or any nurse. (setting – people)
3. Provides patient records relative to location. (setting – tool)
4. Allows nurse to post to the electronic white-board. (setting – tool)
5. Allows clinicians to view updates to patient record and to electronic white board. (awareness)

**Cons:**

6. BUT system may not function depending on location (setting – tool)
7. BUT system may not support sending and receiving of multiple calls (rule)
8. BUT clinician may not be aware of priority of messages and calls (awareness)
9. BUT clinicians may lose track of alarms and messages (awareness)

*Figure 18: Data Sample before Removing Tags*
**Pros:**
1. Allows clinician to send and receive calls, messages and alarms.
2. Allows nurse to contact specific roles such as the doctor in charge, any doctor, or any nurse.
3. Provides patient records relative to location.
4. Allows nurse to post to the electronic white-board.
5. Allows clinicians to view updates to patient record and to electronic white board.

**Cons:**
6. BUT system may not function depending on location
7. BUT system may not support sending and receiving of multiple calls
8. BUT clinician may not be aware of priority of messages and calls
9. BUT clinicians may lose track of alarms and messages

**Figure 19: Data Sample after Removing Tags**

**Raters**

Two HCI experts voluntarily rated the collected data based on the evaluation instruction provided. The two experts were senior faculty members in the HCI field who each had over 20 years of research and design experience in interactive design. Their expertise qualified them to examine the HCI concerns embedded in the collected claims. The two experts separately rated the whole data set.

**Evaluation Guideline**

A guideline containing three metrics was used in the data evaluation process. The quality measurements were designed to judge if the results support the two hypotheses of the study. The hypotheses were concerned with the understanding of the nursing domain, the understanding of the design field and the quality of the design.
1. Domain Understanding

The first metric ‘How well do the claims represent the system features?’ was intended to measure participants’ understanding of the problem domain. The better the participants understood the nursing domain and the environment in which the handheld system was situated, the easier it was for them to speculate about the possible benefits and the implications of using these features in the environment. The raters could judge how well a participant understood the nursing environment through how well they wrote their claim.

2. Usability Concerns

The second metric aimed to judge the quality of the system design. System quality can be very broad and extend to every aspect of the design. In this study, since we approached system design from a HCI perspective, we chose to use ‘ease of use’ as our main criterion to evaluate the system quality. Ease of use concerns are considered to be the core principle in HCI and it appears in almost every usability definition (ISO, 1998; Mayhew, 1999; Nielsen, 1993; Norman, 1998). Even though the writing documents are not the actual information system, certain consequences in the claims do reflect how usable the feature is and what the potential usability problems are. Applying these concerns into the design will lead to an easier to use system.

Using the claim displayed in the previous section as an example: the pro “Allows nurse to contact specific roles such as the doctor in charge, any doctor, or any nurse” indicates that the system should allow users to designate the personnel to contact instead of sending alarms to all the clinicians. By doing so, other personnel in the hospital may
get fewer alarms. This would make the alarms less distractive. In the meantime, the clinicians who are involved in the case get direct notices and the alarms would be responded to in a more efficient way. This concern would make the real system feature ease to use since nurses can get in touch with people with specific expertise in the hospital without interrupting others. The con of “but system may not support sending and receiving multiple calls” suggested that in the case of multiple calls coming in at the same time, the system should have a way to deal with it so that clinicians won’t miss any important messages. Another con of “but clinician may not be aware of priority of messages and calls” pointed out the importance of having a severity rating so that clinicians could make a quick decision about whether or not they should stop their current work for a more urgent patient case.

3. The Quality of the Claims

The 3rd evaluation metric: the quality of the claims was proposed to judge the quality of the claims themselves. This metric aimed to measure how good a HCI expert thought the claims were in designing systems. In other words, can the concerns expressed in claims be understood by the designers and transferred to design product? To the best of our knowledge, there are no studies on evaluating the writing claims; however, we borrowed some evaluation criteria from a scenario evaluation study (Cox & Phalp, 2000) to better help raters formulate their judgment.

1. Are the claims are relevant and meaningful to the particular system feature?
2. Can the claims be understood by the system designers? The claims should be written in a clear and concise way so that raters understand the meaning and no confusion.

3. Do the claims contain sufficient information to inform system design? A con such as “system may fail” certainly meets the first two concerns but it lacks the necessary details for system design.

---

**Claim Rating Instruction**

Please rate the claims using the following metrics. Note that the subjects are NOT required to explain the rationale for the pros/cons they wrote in this study. Participants may use various formats to write their pros/cons such as questions and phrases.

(In general, RN= Nurses, MD=Doctors, PT=Patient)

**Participant Number: _________________________________**

1. How well do the claims represent the system features in the nursing handheld system? This metric is to judge whether the claims represent the intend benefits that the system features represent? It focuses more on the pros side of the claims to see if the subjects outlined the benefits of using the features.

<table>
<thead>
<tr>
<th>Poor</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Excellent</th>
</tr>
</thead>
</table>

2. How well the claims contribute to design a useable system? Do the claims contain the USABILITY considerations which would lead to design a useable system? In other words, whether the system design based on these claims would satisfy the general USABILITY criteria?

<table>
<thead>
<tr>
<th>Not useful</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Very useful</th>
</tr>
</thead>
</table>

3. How useful were the pros/cons of the claims if they are used for the system design? This metric is to judge the usefulness of the claims themselves when apply them in the real design process. It may cover, but not limited to these few aspects: 1) whether the claims relate to system design or could be applied in the design process; 2) whether the claims are clear enough to use and be understood by a designer? 3) Whether the claims include sufficient information (completeness) to be used in the design process?

<table>
<thead>
<tr>
<th>Not useful</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Very useful</th>
</tr>
</thead>
</table>

*Figure 20: Data Evaluation Guideline*
The evaluation guideline was first tried out on the pilot data so that the raters understood the rating process. Then the experiment data were sent to each rater with a copy of the task scenario used in the study. Raters were asked to write the scores on the first page of each data. This is to ensure that the scores would not get misplaced afterwards. The rating score were inputted into SPSS for further analysis.

5.2. Time Spent on the Study

Other than the three rated measurements, three more dependent variables regarding time were also recorded and analyzed. We recorded the whole length of the time each participant spent during the experiments on minute level. We also recorded the training time & the main task solving time. Since the questionnaires used in the study were relatively simple and it only took participants less than a minute to finish, we did not separate them into different time slots for further analysis.

First part: From the time that participants came to the study until they finished the hands-on exercise. This time slot included filling out the consent form and the per-experiment questionnaire, reading the instruction and examples and writing a practice claim.

Second part: From the time that participants received the task scenario until they finished the whole experiment, including the time spent on reading the scenario, writing the four claims and filling out the post-experiment questionnaire.
5.3. Statistical Method

Two-way ANOVA analysis was chosen as the main statistical method for this study. Two-way ANOVA analysis is used on cross factorial design of two nominal variables with one measureable variable (Pallant, 2001). Two independent variables used across the whole study were: participants’ expertise (design vs. nursing) and instructions (control vs. experimental). Six dependent variables of the study were three evaluation metrics plus three time measures. To use ANOVA analysis, the collected data have to be normally distributed and equal variances (Pallant, 2001).

We assessed the homogeneity of variances using the Levene test (Pallant, 2001). To make sure that the variability of scores for each group is similar, the Levene test has to be non-significant. As shown in Table 9. None of the results were significant in our study (p>.05).

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>F (3, 113)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric 1: Domain Understanding</td>
<td>0.35</td>
<td>.79</td>
</tr>
<tr>
<td>Metric 2: Usability Concerns</td>
<td>2.53</td>
<td>.06</td>
</tr>
<tr>
<td>Metric 3: The Quality of the Claims</td>
<td>1.16</td>
<td>.33</td>
</tr>
<tr>
<td>Total Study Time</td>
<td>0.59</td>
<td>.63</td>
</tr>
<tr>
<td>Training time</td>
<td>1.50</td>
<td>.22</td>
</tr>
<tr>
<td>Main Task Solving Time</td>
<td>1.24</td>
<td>.30</td>
</tr>
</tbody>
</table>
We used the Kolmogorov-Smirnov statistic to check the normality of the distribution of scores (Pallant, 2001). A non-significant result (p > .05) indicates normality (Table 10). The results showed that more than half of the scores were significant, which indicated the violation of the assumption of normal distribution. But ANOVA analysis was still considered as robust when the normality was violated, especially when the sample size was big (more than 30) and each condition had similar numbers (Pallant, 2001). The normal q-q plot shows that the data line were relatively straight and close enough to the expected normal distribution line. Considering the big sample size (117 subjects in total) and equal number of participants in each group (the sample size in each group are 28, 29, 29 and 31), ANOVA was still a valid statistical tool for this study.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Context-Centered Groups</th>
<th>Regular Groups</th>
<th>Nursing Participants</th>
<th>Design Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric 1: Domain Understanding</td>
<td>.08</td>
<td>&lt;.00</td>
<td>&lt;.00</td>
<td>.06</td>
</tr>
<tr>
<td>Metric 2: Usability Concerns</td>
<td>.01</td>
<td>&lt;.00</td>
<td>&lt;.00</td>
<td>&lt;.00</td>
</tr>
<tr>
<td>Metric 3: The Quality of the Claims</td>
<td>.01</td>
<td>.01</td>
<td>.02</td>
<td>.03</td>
</tr>
<tr>
<td>Total Study Time</td>
<td>.17</td>
<td>.02</td>
<td>.03</td>
<td>.20</td>
</tr>
<tr>
<td>Training time</td>
<td>&lt;.00</td>
<td>.02</td>
<td>&lt;.00</td>
<td>&lt;.00</td>
</tr>
<tr>
<td>Main Task Solving Time</td>
<td>.01</td>
<td>.01</td>
<td>&lt;.00</td>
<td>.20</td>
</tr>
</tbody>
</table>
5.4. Results of Experts Rating

We calculated the inter-rater reliability using the Inter-class Correlation (ICC) method. ICC (Shrout & Fleiss, 1979) is the most commonly used statistical method for two or more raters with continual data sets. The inter-rater reliability for the whole data set is 0.81, which indicated a high level consensus between the raters.

We also calculated the inter-rater reliability for each evaluation metric separately. There was a high level of reliability for the first metric (ICC=0.83), and medium levels of reliability for the second (ICC=0.55) and the third metric (ICC=0.72). This shows that raters had high levels of agreement in judging the domain understanding and the quality of the claims, but more divergence on the usability concerns embedded in the writing claims.

<table>
<thead>
<tr>
<th>Reliability Measures</th>
<th>Intra-Class Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric 1: Domain Understanding</td>
<td>0.83</td>
</tr>
<tr>
<td>Metric 2: Usability concerns</td>
<td>0.55</td>
</tr>
<tr>
<td>Metric 3: The Quality of the Claims</td>
<td>0.72</td>
</tr>
<tr>
<td>Overall Reliability</td>
<td>0.81</td>
</tr>
</tbody>
</table>

It is notable that inter-rater reliability for Usability concerns was only considered as medium level (ICC=0.55) and the common acceptable minimum ICC should be above
0.70. It shows that the two raters didn’t reach high level consensus on the metrics 2. We discussed the possible reasons that account for it in Chapter 6.

We used the sum of the two raters’ scores to average the difference between them. In the following section, for all the three evaluation metrics, the means and the numbers of the statistical analyses were all the sum of the two raters’ scores.

**Metric 1: How well do the claims represent the system features in the giving scenario?**

Table 12 summarized the means and standardized deviations for the four groups. Both context-centered groups received higher rating scores than the correspondent regular groups.

### Table 12: The Sum of the Ratings for Metric 1: Domain Understanding by Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Metric 1</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>9.74</td>
<td>2.11</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>8.96</td>
<td>2.02</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>7.72</td>
<td>2.05</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>8.76</td>
<td>1.96</td>
<td>29</td>
</tr>
</tbody>
</table>

We analyzed backgrounds (nursing vs. design) and instruction (regular vs. context-centered) on each participant’s sum score for the evaluation metric 1. Two-way ANOVA analysis yielded that context-centered group’s scores (M=9.37, SD=2.09) were
significantly higher than the regular groups (M=8.24, SD=2.05) F (1, 115) =8.68, P<0.05. The main effect of participants was non-significant F (1,115) =0.12, P>0.05. However, the interaction effect of participants and interaction, F (1, 115) =5.76, P<0.05 indicating that the context centered instruction had a greater effect on the designing participants than the nursing participants.

Table 13: Statistical Results Domain Understanding

<table>
<thead>
<tr>
<th>Factors</th>
<th>F (1, 115)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>8.680</td>
<td>.004</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>0.116</td>
<td>.734</td>
</tr>
<tr>
<td>Interaction</td>
<td>5.765</td>
<td>.018</td>
</tr>
</tbody>
</table>

As show in Figure 21, the dotted line represents nursing participants and the solid line is for designing participants. On the left side is the regular scenario-based design groups (control groups) and on the right side are the context-centered groups (experimental groups). The numbers showed on the figure are the sum of the two raters rating scores.
Figure 21: Means Plot Domain Understanding

Metric 2: How well do the claims contribute to designing a useable system?

The descriptive statistics for evaluation metric 2 shows that both context-centered designing groups received higher scores than the correspondent regular groups. Design participants had a big improvement comparing experimental and control groups; whereas, the increase on nursing side was less effective.
Table 14: The Sum of the Ratings for Metric 2: Usability Concerns by Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>8.19</td>
<td>2.06</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>6.86</td>
<td>1.30</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>6.28</td>
<td>1.62</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>6.48</td>
<td>1.81</td>
<td>29</td>
</tr>
</tbody>
</table>

Two-way ANOVA analysis of the dependent variable: sum of the ratings for metric 2 on two independent variables: backgrounds and instructions suggested that there was a main effect on factor instruction $F(1, 115) = 12.86, P<0.001$; the average scores for designers ($M=7.27, SD=2.08$) were significantly higher than the nurses ($M=6.67, SD=1.57$), whereas there was no significant main effect on the variable participants $F(1, 115) = 3.23, P>0.05$. The interaction of independent variables participant and instruction $F(1, 115) = 5.83, P<0.05$ indicated that the context-centered instruction affected the designers more than the nurses.

Table 15: Statistical Results Usability Concerns

<table>
<thead>
<tr>
<th>Factors</th>
<th>$F(1, 115)$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>12.853</td>
<td>$&lt;.001$</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>3.121</td>
<td>.080</td>
</tr>
<tr>
<td>Interaction</td>
<td>5.827</td>
<td>.017</td>
</tr>
</tbody>
</table>
Similar with the above figure, here the dotted and solid lines represent the nursing and designing participants. The control groups are shown on left side of the figure and the experimental groups are on right side. The numbers analyzed are the sum of the two raters’ scores for each participant.

Figure 22: Means Plot Usability Concerns

Metric 3: How useful are the claims if they are used for system design?

Table 16 shows the means of SD for the evaluation metric 3. Both design groups received higher scores than the correspondent nursing groups; also, both context-centered groups performed better than the regular group on the same expertise condition.
Table 16: The Sum of the Ratings for Metric 3: The Quality of the Claims

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean of Metric 3</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>6.81</td>
<td>1.94</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>4.89</td>
<td>1.32</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>4.00</td>
<td>1.98</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>4.72</td>
<td>1.73</td>
<td>29</td>
</tr>
</tbody>
</table>

The result of metric 3 on the backgrounds (nursing vs. design) and instruction (regular vs. context-centered) showed that context-centered group’s scores (M=5.93, SD=2.15) were significantly higher than the regular groups (M=4.81, SD=1.53) F (1, 115) =9.112, P<0.05. The main effect of participants also showed strong significant F (1,115) =11.20, P=0.01, where designers’ scores (M=5.9, SD=1.92) were significantly higher than the nurses (M=4.86, SD=1.85). The interaction effect of participants and interaction was also significant this time, meaning that the instruction was more effective for the design groups than the nursing groups F (1, 115) =6.26, P<0.05.

Table 17: Statistical Results Quality of the Claims

<table>
<thead>
<tr>
<th>Factors</th>
<th>F (1, 115)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>9.112</td>
<td>.003</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>11.196</td>
<td>.001</td>
</tr>
<tr>
<td>Interaction</td>
<td>6.264</td>
<td>.014</td>
</tr>
</tbody>
</table>
Again, the dotted and solid lines represent the nursing and designing participants. The control groups are shown on left side of the figure and the experimental groups are on right side. The numbers analyzed are the sum of the two raters’ scores for each participant.

![Figure 23: Means Plot Quality of the Claims](image)

5.5. Results of the Study Time

*Total Experiment Time*

We analyzed the means of the total study time for each group. The results show that the Context-Centered Design group took the longest time and the subjects in the regular design group spent least time. See Table 18.
Table 18: The Total Time Spent on the Experiment by Groups in Minutes

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (min)</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>45.03</td>
<td>11.73</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>41.39</td>
<td>14.02</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>36.24</td>
<td>11.80</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>40.10</td>
<td>14.40</td>
<td>29</td>
</tr>
</tbody>
</table>

Two-way ANOVA analysis of expertise (nursing vs. design) and instruction (regular vs. context-centered) on the total study time each participant spent on the study yielded a main effect on the independent variable instructions, F (1,115) = 4.38, P<0.05. The context centered groups’ spent (M=43.31, SD=12.89) significantly longer time than the regular groups (M=38.17, SD=12.19). However, the main effect participants F (1,115) = 0.002, P>0.05, and the interaction effect F (1,115) = 2.43, P>0.05 were non-significant for the total time.

Table 19: Statistical Results Total Study Time

<table>
<thead>
<tr>
<th>Factors</th>
<th>F (1, 115)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>4.379</td>
<td>.039</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>0.02</td>
<td>.963</td>
</tr>
<tr>
<td>Interaction</td>
<td>2.425</td>
<td>.112</td>
</tr>
</tbody>
</table>
Figure 24 is the plot that resulted from two-way ANOVA analysis where the dotted line represents nursing participants and the solid line is the design groups. The regular groups were shown on the left and the Context-Centered groups were on the right side. The numbers on the figure are the mean of the total time participants from each group spent on the study.

![Figure 24: Means Plot Total Study Time](image)

**Training time**

We compared the means of the training time in each group. Participants in the Context-Centered Design group spent longest time on the reading the instruction and did the practical exercise. And the regular design group spent shortest time. See Table 20.
Table 20: The Training Time Spent on the Experiment by Groups in Minutes

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (min)</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>16.32</td>
<td>5.66</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>15.43</td>
<td>5.82</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>11.97</td>
<td>4.20</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>13.93</td>
<td>4.04</td>
<td>29</td>
</tr>
</tbody>
</table>

The main effect instructions also resulted in a significant longer time for the Context-Centered groups (M=15.90, SD=5.70) than the regular groups (M=12.95, SD=4.20), F (1,115) =10.00, P<0.05. The other main effect participants, F (1,115) =0.34, p>0.05 and interaction effect F (1, 115) 2.39, p>0.05 were non-significant for the training time.

Table 21: Statistical Results Training Time

<table>
<thead>
<tr>
<th>Factors</th>
<th>F (1, 115)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>10.007</td>
<td>.002</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>0.335</td>
<td>.564</td>
</tr>
<tr>
<td>Interaction</td>
<td>2.387</td>
<td>.115</td>
</tr>
</tbody>
</table>

In Figure 25 the dotted line represents nursing participants and the solid line is the design subjects. The regular groups were shown on the left and the Context-Centered groups were on the right side. The numbers on the figure are the mean of the training time for each group.
Figure 25: Means Plot Training Time

Main Task Solving Time

The descriptive statistics of the main task solving time for each group were shown in Table 22. The Design experimental groups took a longer time on the main task than the design control group. But interestingly, the experimental nursing groups spent even less time than the control group.
Table 22: The Main Task Solving Time Spent on the Experiment by Groups in Minutes

<table>
<thead>
<tr>
<th>Group</th>
<th>Time (min)</th>
<th>SD</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-Centered Design</td>
<td>28.42</td>
<td>8.05</td>
<td>31</td>
</tr>
<tr>
<td>Context-Centered Nursing</td>
<td>25.96</td>
<td>9.10</td>
<td>28</td>
</tr>
<tr>
<td>Regular Design</td>
<td>24.17</td>
<td>9.01</td>
<td>29</td>
</tr>
<tr>
<td>Regular Nursing</td>
<td>26.17</td>
<td>12.74</td>
<td>29</td>
</tr>
</tbody>
</table>

Both the main effects were non-significant for the main task solving time, for the independent variable instruction $F (1, 115) = 1.22$, $P > 0.05$, for the independent variable participants $F (1, 115) = 0.2$, $P > 0.05$. The interaction of the interaction and expertise was also non-significant $F (1, 115) = 1.49$, $P > 0.05$.

Table 23: Statistical Results Main Task Solving Time

<table>
<thead>
<tr>
<th>Factors</th>
<th>$F (1, 115)$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effect Instruction</td>
<td>1.224</td>
<td>.271</td>
</tr>
<tr>
<td>Main Effect Expertise</td>
<td>0.016</td>
<td>.901</td>
</tr>
<tr>
<td>Interaction</td>
<td>1.489</td>
<td>.225</td>
</tr>
</tbody>
</table>
The dotted line represents nursing participants and the solid line is the design subjects. The regular groups were shown on the left and the Context-Centered groups were on the right side. The numbers on the figure are the mean of each group’s main task solving time.

![Graph showing main plot main task solving time](image)

**Figure 26: Main Plot Main Task Solving Time**

5.6. Summary

We described the data rating process in this chapter, including the evaluation metrics and raters of the study. The main measurements of the study were three evaluation metrics judged by two raters. Additionally, the total experiment time, training time and task solving time were also recorded and analyzed as the dependent variables of
the study. These measurements were analyzed using two-way ANOVA on the two independent variables: background (Design vs. Nursing) and instruction (Context-Centered vs. Regular). The results of the statistical analyses were reported in this chapter.

The next chapter covers the implications of the results presented here. We discuss why these results have been shown in our data set, what these results mean in the study and how support the proposed hypotheses of the empirical study as well as the research question of this dissertation. The limitations and contributions are introduced in the discussion chapter as well.
CHAPTER 6: DISCUSSION

In this chapter, we will discuss the implications of the results and how these results support the proposed research questions and hypotheses. The experiment intended to evaluate the following two hypotheses. Hypothesis 1 was intended to measure participants’ understanding toward the problem domain and hypothesis 2 aimed to judge the effect of the framework on the design process.

H1a: End-users who have solid understandings of their working environment perform better than the system designers.

H1b: Designers could improve their understanding towards the problem domain through using Context-Centered Framework.

H2: Designers produce better design products through using Context-Centered Framework in the early system design stage.

6.1 Implications of the Experiment Time

We will discuss the implications from the results of the study time. These implications may help us better interpret the main measurements.

Total Study Time

The analysis on the total study time found that subjects spent significant longer time using Context-Centered instruction than the regular instruction. There was no statistical difference for both the main effect expertise and the interaction effect. These results indicated that for both design and nursing participants, the intervention caused them to spend a longer time on the study. Since the only difference was that the context-
centered instruction included four more sentences of contextual guideline, in this case, it seems that providing the contextual guideline made participants’ think analytically more deeply and thoroughly during the experiment process than regular instruction. This concurred with the objective of the study of using intervention to let participants take a longer time to think more thoroughly and carefully.

Even though the interaction effect wasn’t significant for the total study time, the data presented a trend showing that intervention may exert a bigger effect on the designers than the nurses. Compared to the experimental and control groups in the same expertise condition, the designers took 8.79 minutes more and the nursing students only spent 1.29 minutes more. This suggests that the intervention used in the study may be more sensitive to the designers and let them take longer time to think and write the claims.

Merely examining the total study time is not conclusive for this study. We still want to explore how did participants spent their time and which steps of the experiment made participants spend different amounts of time. We divided the total study time into training time and main task-solving time in order to find out whether subjects spent more time on the learning process or the real claim writing process.

*Training Time*

Training time included the time spent on reading consent form, filling in the per-experiment questionnaire, reading instruction/examples and practicing the hands-on exercise. Here subjects received different instructions to read and wrote one claim following the instruction. We considered this time slot as the learning time for the study where participants first got exposure to the instruction and did their first trail writing.
The results found that Contextual-Centered groups took a significantly longer time than the regular groups, whereas there were no significant differences on the expertise factor, and so does the interaction effect. This indicated that the participants in the experimental groups took more time to learn how to write claims using the Context-Centered instruction and they spent a longer time thinking about the contextual considerations during the hands-on exercise process. In other words, subjects did take time to consider the contextual considerations listed in the instruction, as we expected in the experiment design.

Although the interaction effect was non-significant in this study, there was a trend that the instruction may have affected designers more than nurses. The data showed that designers spent less time than nurses in the regular condition, whereas they spent longer time than the nurses in the experimental group. This indicated that instruction may help designers think more deeply and thoroughly during the study than nurses, but it is not conclusive.

*Main Task Solving Time*

The main task solving time was spent on reading task scenario, writing four claims and filling in the post-experiment questionnaire. The major part of this time went to the claim generation process. Subjects received the same materials in this stage, but contextual-centered groups followed more complicated instructions with additional information in the writing process than the regular groups. Therefore, participants in the experimental and control groups analyzed the pros/cons on different rationales.
Surprisingly, there was no statistical difference found for the main effect of instruction and expertise as well as no significant level of an interaction effect. This means that even following an instruction with additional guidelines, the context-centered group did not spend a significantly longer time than the control groups. This can be explained as participants all learned the writing process in the training session. And after participants grasped the analytical method, they could generate the claims in the same amount of time using a more complicated instruction.

Though the result was non-significant, a close checking of the data found a very interesting phenomenon in the result. The nursing experimental group spent 0.21 minutes less to write claims than the regular nursing group, indicating that the Context-Centered instruction didn’t cause nursing participants to think more carefully and thoroughly during the study. Combined with the result from the training time, nursing participants took longer time to learn how to use Context-Centered instruction. But the instruction did not push them to think more once they understood the instruction. Design participants, meanwhile, spent 4.25 minutes more in the experimental group than the control group. This concurred with our expectation that the additional guideline forced designer spending more time considering the possible consequences of the proposed features during the task solving process.

The context-centered instruction caused design participants to spend a longer time and nursing participants took less time during the main task-solving process. This may have leveraged the scores of the instruction effect and may be the reason for the non-significant result.
6.2 Implications of the Experts’ Rating

In this section we will discuss the results from the three main measurements of the study. We use domain understanding, usability concerns and the quality of the claims to represent metric 1, 2, and 3 respectively. Implications and the possible reasons will be explored here.

Domain Understanding

Evaluation metric 1 was intended to measure how well participants understood the problem domain of nursing handheld systems. Subjects received higher scores when their claims contained more perceived benefits and implications of the using the system with regard to the nursing working environment. Raters believed that this metric mainly measured, but was not limited to the pros side of the claims. The analysis of the rating scores on the expertise (Design vs. Nursing) and instructions (context-centered vs. regular) showed: (a) Context-Centered instruction groups received significant higher score than the regular groups, and (b) The interaction of expertise and instruction affected designers more than nurses.

The significant level of main effect instruction indicated that through using the Context-Centered instruction, participants included more concerns regarding using the handheld system in the nursing environment in their claims than the regular condition. These concerns were coming from an improved understanding towards the problem domain. Connecting with the previous discussion on experiment time, participants did not spend significantly longer time on the task-writing process. Because participants
preformed better in the same amount of time, we believe that the Context-Centered instruction helped participants understand the nursing handheld system problem.

For the interaction effect, it was shown that the designers’ score had a larger increase than the nurses when context became the focus of the experiment. The designers’ performance was lower than the nursing groups in the regular groups and it became higher than the nursing group in the context-centered groups. To explore why the intervention was more sensitive on the designer groups, we discuss the results in the following two possible explanations.

First, in the control condition, nurses received higher scores than the designers, indicating that nurses understood the nursing handheld system problem better than the designers. This understanding probably came from their past hospital working experience and from their real experience of interacting with other nursing handheld systems. The past exposure could have helped them speculate how to use the proposed task scenario in an environment they are familiar with. But for designers, although they had system design knowledge, it was not specific for the mobile system design and it was difficult for them to connect the system usages with the surrounded environment, which was essential for understanding the system usages in our study.

Second, when context became the center of the concern, designer group’s score was much higher than the nurse’s. In other words, nursing students’ performances only improved a little compared with no contextual guideline, but designers had a large enhancement. From the nursing participants’ perspective, this is probably because they are already familiar with the task environment; they could naturally include the necessary
information about the working environment in their claims and providing the contextual
guideline did not make a big difference. This little improvement might be a result of the
additional information provided in the Context-Centered instruction, which led them to
write a few more consequences. Additionally, the results on experiment time also
indicated that nurses spent even less time on the claims writing process, indicating that
either they did not make an effort to think more during the task or the instruction would
not help their thinking process much.

In contrast, the design group with contextual considerations had a pretty large
enhancement in their scores compared to the control condition, which resulted in their
average scores being lower than the nurses in the regular group and higher than nurses in
the context-centered group. One obvious reason to explain this is that participants in the
design context-centered group spent more time on the claim-generation process, meaning
that they were able to consider the desirable/undesirable consequences more carefully.
Other than the time spent on the study, a few other reasons also accounted for the fact
that the designers with context-centered instruction received highest scores.

• Task Scenario

The less domain-dependent task scenario deployed in the study may have allowed
designers to understand the task equally as well as the nurses. Some design
participants mentioned that they were quite familiar with the task scenario via
watching the popular TV shows such as *House* and *ER*, through their previous
hospital visits or through their relatives who work in hospitals. Since these were not
first-hands experiences, it wouldn’t naturally come to the designers in the control
condition. Whereas in the context-centered condition, the additional information
pushed designer to think more slowly and the extra guidelines guided them to think more carefully in analyzing and distinguish the various types of concerns; these caused designers to recall the related nursing knowledge and they included them into their claims.

- **System Knowledge**

  To understand the perceived benefits and the possible implications of the handheld system features, not only was nursing domain knowledge needed, but design knowledge was needed as well. Design participants’ general knowledge about information system plus the improved understanding of the nursing environment could possibly make designers understand the nursing handheld system problem even better than nurses.

- **Methodology**

  Scenario-based design and Claims Analysis are HCI design methods that require that subjects speculate the possible system usages described in the task scenario. For participants who had previously learned about similar concepts, they could quickly grasp the method and apply it to the task solving process. But for the nurses who were less familiar with these kinds of discount design methods, they may not easily have gotten the results through the short training session. As suggested in previous results, nurses spent longer learning how to use the Context-Centered instruction than designers, but they actually spent less time in the real task solving process. This result indicates that it is more difficult for nurses to learn how to write claims and also how to apply the contextual guideline into their design process. This explains why the
instruction affects nurses less than the designers and why the two nursing groups received relative similar scores.

The results of evaluation metric 1 suggested that the context-centered instruction caused designers to largely improve their understanding toward the nursing handheld applications in the problem domain. However, there was no discernable difference for the nursing groups because they were already familiar with the environment. The results support the argument that the Context-Centered framework helps designers better understand the nursing working environment.

Usability Concerns

The 2nd evaluation metric was proposed to evaluate the ease of use of the system. Ease of use is a commonly recognized HCI principle (Nielsen, 1993) and in this study, we use this to represent system design quality. The writing claims can be used to direct system design, but they are actually not the real information systems. In this case, we proposed to evaluate the usability concerns embedded in the claims. The usability concerns could either be represented as desirable or undesirable consequences, but the raters both thought usability concerns were mainly covered on the con side of the claims. It is notable that raters only received medium level consensus here, indicating the difficulty of evaluating design quality. Even narrowed down to only usability concerns, raters’ perception still varied largely.

The results showed that among both the designing and nursing participants, context-centered groups had significant higher scores than the regular groups. And the
interaction between two independent variable expertise and instructions affected designers more than nurses.

The main effect of instruction shows that the Context-Centered groups included more usability concerns than the regular groups. This supports our hypothesis that designers could improve the quality of their design through following the context-centered framework during their design process. Few reasons contributed to this improvement:

- First, since this study was not situated in a real nursing working environment and the scenario was not a real interactive system that participants could use during the study, it was very difficult for students to imagine a whole picture of the possible consequences. The additional contextual guideline served as a checklist pointing to the relevant contextual information that participants should pay attention to and the tagging categories process pushed them to consider the contextual considerations during the design. This helped participants connect the system features with the situated environment and by doing so, they revealed more usability problems.

- Results of metric 1 showed that the context-centered groups understood the problem domain better than the regular groups. The better the domain understanding, the better the chances that participants could connect the system usages with the real working environment. In this sense, good understanding of the problem domain was a foundation for conceiving usability related concerns.

The interaction effect was also significant, suggesting that the intervention affected the designers more than nurses. This effect caused designers’ average score to
range from slightly lower than nurses in the regular condition to much higher than nurses in the context-centered condition. To interpret why designers with Context-Centered instruction had such a big improvement, we discuss in the following two aspects.

On the control condition, though statistically non-significant, the nursing group received a slightly higher score than the design group, indicating in a situation where context hasn’t been to set as the focus in the design, domain experts could naturally come up with more usability concerns than the designers. This is probably because they were familiar with the system situated environment, nursing workflow, involved personnel as well as personal experience using these systems. It also supports the importance of knowing the task domain for system design. And pure system design knowledge is not sufficient to produce a good design as proposed in the notion of ‘symmetry of ignorance’ (Rittel, 1984). In this case, domain experts were able to come up with more slightly more usability concerns than the designers.

For the experimental groups, the nursing students’ rating enhanced a little compared with the regular group. This could be explained in two ways: (a) Additional information made participants think more during the task solving process, and (b) With an improved understanding towards the problem domain, nurses can recall more of their past experience of using information system and picture more possible system usability issues on top of that. On the contrary, designers had a much larger improvement using intervention than the nursing participants. An obvious reason accounting for this big increase is that designers took a longer time in the task-solving process, but nurses spent even less time. This suggested that designers did consider the contextual information and
incorporated the related concerns into their design through using the Context-Centered Framework.

Though it was considered a design task, designers had no experience with using the handheld systems and the task scenario was relative technology free. In this case it would be very interesting to see why the intervention didn’t help the real users, who worked in the hospitals, have used similar systems, and have experienced system problems previously. A close checking of the data found that the way participants expressed their ideas affected the apparent usability concerns on the writing claims and further influenced the perceived scores. We summarized four types of consequences, which all contained usability concerns, but in different levels of effects for system design.

1. Detailed usability concern with the proposed solution, such as ‘the system allows nurse to contact specific roles such as the doctor in charge, any doctor, or any nurse using different alarms’. This type of pro/con had the highest value for system design since this can be transferred to design concern directly.

2. Only concrete usability concern, such as ‘but system may not support sending and receiving multiple calls’. It indicated the possible conflicts that a system design should avoid without pointing to the solution. This kind of pro/con was also valid since with a concrete problem, designers should be able to get a solution themselves.

3. Generic concern without specific information such as ‘system may encounter some technical difficulty’ and ‘the system may fail’. These concerns did point out problems that the system may face, but they were too general to be translated to design concerns.
4. Useful concerns but not relevant to the current system feature.

Raters deemed type 1 and 2 equally useful and better than type 3 concerns during their rating process. Irrelevant concerns weren’t counted in this case. It was quite interesting that most designers’ concerns were either type 1 or type 2, but nurses’ consequences often fell into the type 3 “too generic” category. And as a result of that, the nursing group hardly achieved a big improvement even though they were provided with a contextual guideline. This indicated that the nurses may have been as aware of the system design issues as the designers were, but they barely reflected their thoughts in writing.

The results for metric 2: usability concerns supported the arguments that context was an essential element that affected system design and designers did produce better designs when they were required to consider and include contextual considerations. To sum up, the results from rating metric 2 indicated that the context-centered framework could help designers to consider more usability concerns in the design process and it could lead to a better a design product. The nursing participants still had difficulty in understanding and articulating their system design concerns in the design process.

Concerns about Inter-rater reliability

In the inter-rater reliability part, the two raters didn’t achieve a high level agreement for metric 2: usability concerns (ICC=0.55). We examined the rated data and the proposed evaluation metric in order to find out why the reliability was lower than the common acceptable level. To find out the reasons for lack of the high agreement between raters, we checked the data and picked up the ones in which the two raters’ scores differ on more than 1 level on usability concerns, like rater A=5, rater B=3 or rater A=2, rater
The examination of these data provided us with some insights on why their scores differed and how raters interpreted the question during their evaluation process.

The data we examined showed that the two raters’ focus differed during the evaluation. Basically, one rater was concerned only with usability issues that were particular to this system and for the given task scenario. The other rater adopted a broader view towards usability concerns; he/she included not only the concerns restricted to the nursing handheld system and described in the task scenario, but also included the concerns that might affect more people, more devices and other factors. In other words, in general, how the system impacts the situated context and how the people, tools, devices co-located in the context affect system use. To better understand how the scores differed, we selected a few usability concerns examples that appeared in the writing data.

<table>
<thead>
<tr>
<th>System Oriented</th>
<th>Context Oriented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. But the system may not support sending and reserving multiple calls</td>
<td>1. The alarm tool may not be loud enough, or may interfere with other noises on the equipment in the rooms.</td>
</tr>
<tr>
<td>2. But clinician may not be aware of priority of messages and calls</td>
<td>2. Take away from the personal interactions between nurses and doctors.</td>
</tr>
<tr>
<td>4. But the system does not allow the clinician to know if the messages are being responded to.</td>
<td>4. Would require more reliance on hospitals network to get internet in all areas of hospital, including areas that have thick or lead walls</td>
</tr>
<tr>
<td>5. Are alarms sent to specific clinicians or are they unit-wide?</td>
<td>5. Different clinicians will have different skill levels in using technology</td>
</tr>
</tbody>
</table>

Figure 27: Selected Usability Concerns for Feature Send/Receive Alarms, Message and Calls
| System Oriented | 1. But images may hard to be read on the small tablet PC  
2. No notification of time stamps or previous retrievals of specified document  
3. When information is requested, it could overwrite any previous work displayed on the screen of it takes up the whole screen.  
4. It may take longer to retrieve information than it would to go in person and requested, if they are not alerted well  
5. Cannot display full sized pictures. Some images are better shown full scale rather than scaled down digital pictures. |
|---|---|
| Context Oriented | 1. Clinicians may not get the chance to interact with people in the lab who might be able to provide insight into the test results  
2. Other staff that assist the nurses would not be able to access lab information as easily and will not be as involved in the patient’s condition  
3. HIPAA information/lab results can be seen by others if not careful  
4. Special request maybe harder  
5. In the event of an imminent medical condition such as convulsions, the tablet might be dropping and damaged by personnel attending to the patient. |

Figure 28: Selected Usability Concerns for Feature Request Lab Results to be transferred and displayed on the Tablet PC

| System Oriented | 1. Clinicians may not want to view patient information automatically  
2. It may override a previous check up note, therefore lose important data information.  
3. Maybe confusing in multi-patient rooms  
4. If the patient got moved and it wasn’t updated in the device, that could increase errors.  
5. System may not allow the input of certain chart results because they represent invalid values (e.g. very low/high pulse) |
|---|---|
| Context Oriented | 1. Entering assessment findings at bedside might take away pt-clinician interaction  
2. Allows for less collaborative or findings  
3. Violation of HIPAA if in another patient’s room that isn’t your patient.  
4. Clinicians who are not technological educated may be resistant to change  
5. There is nothing mentioning about collaboration for multiple tablet PC updating 1 specific patient’s information. E.g. if two nurses are helping one patient and constantly updating the patient’s information, can this cause a problem? |

Figure 29: Selected Usability Concerns for Feature Automatically Display Patient Information when Clinician Enter Patient Room and Update the Record after Check-up
| System Oriented | 1. But the system has no way to ensure the message are heeded  
   2. The nature of a whiteboard is to erase it if it’s full, therefore, no history of previous notes on it is kept  
   3. The message board does not allow the message leave to assign rights to message (anyone can delete or change)  
   4. The message board may become cluttered and disorganized  
   Only allows one way communication |
|----------------|--------------------------------------------------------------------------------------------------|
| Context Oriented | 1. Less personal interaction, same thing may be overlooked  
   2. Handwriting on the electronic whiteboard might not be legible  
   3. Certain aspects of care are better communicated person-person  
   4. Take away from collaborate of personal  
   5. Next shift could interpret information differently and give improper care |

Figure 30: Selected Usability Concerns for Feature Leave Notes on Electronic White Board for the Next Shift Nurses

As shown in the above examples, the system-oriented usability issues focused more on how a particular feature on the system would support/limit specific users, in this case, nurses’ work. For example, the concern regarding only sending one alarm/call. System oriented concerns included set priorities in the alarms, dealing with multiple incoming calls and provided feedback. These were all problem residing on the tablet system itself and that would affect clinicians’ regular work.

By comparison, there were other concerns also influencing the overall system usability but not limited to the system-user interaction itself, such as the alarms sounds may hardly be distinguished with other noises from other equipment. This would definitely affect system usage. Even though the design of the system perfectly avoided the issues on the system itself, the influences from the surrounding environment would make it difficult to use. This may not be important in a regular office setting, but it needed to be heeded in the hospital environment, which is saturated with all types of
equipment. There were other concerns about thick or lead walls in lab settings affecting the alarm (wireless) application and it was less likely to encounter this in another context.

The reason accounting for this confusion might be that the term usability itself has many different interpretations. There is no unified or common standard to judge or define it. The term commonly refers to how easy it is to learn and use the interactive systems (Mayhew, 1999). The scope of the terms evolved along with the technology development and as more attributes have been added to the usability notion, usability has been characteristics has effectiveness, efficiency and satisfaction in ISO 9241 standard (ISO, 1998; Nielsen, 1993) outlined five major concerns about usability: learnability, efficiency, memorability, errors, satisfaction. The term may include more attributes when the design scope extended to recent collaborative and ubiquitous computing fields.

### Table 24: Definitions of Usability

<table>
<thead>
<tr>
<th>Author</th>
<th>Usability Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 9241</td>
<td>“The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO, 1998)</td>
</tr>
<tr>
<td>ISO 13407</td>
<td>“Human-centered design is characterized by: the active involvement of users and a clear understanding of user and task requirements; an appropriate allocation of function between users and technology; the iteration of design solutions; multi-disciplinary design” (ISO, 1999)</td>
</tr>
<tr>
<td>Nielsen, 1993</td>
<td>“It is important to realize that usability is not a single, one-dimensional property of a user interface. Usability has multiple components and is traditionally associated with these five usability attributes: learnability, efficiency, memorability, errors, satisfaction” (Nielsen, 1993)</td>
</tr>
<tr>
<td>Mayhew, 1999</td>
<td>“a measurable characteristic of a product’s user interface that is present to a greater or lesser degree” (Mayhew, 1999)</td>
</tr>
</tbody>
</table>
We found out that in the data where two raters’ scores differed largely, rater A’s scores were higher than rater B when there were more context-oriented usability concerns and fewer system-oriented concerns; whereas, when the data contained more system-oriented concerns but fewer concerns with the surrounding context, rater B tended to give higher scores than rater A. Since the rating scores were just raters’ opinions, there was no exact correlation between the types of concerns and the rating scores, but the trend shows that rater A adopted a broader view of usability that included the concerns about the relevant contextual information and rater B was stuck on the traditional system-user boundary.

It had been suggested through the data that the question proposed as an evaluation metric may not have been specific enough due to the broad meaning of the term “usability” in the HCI field. These caused the two raters to put emphasis on different aspects of usability concerns during their rating process, which led to a relatively lower reliability between them. The question raters used to guide their evaluation process for metric 2 was: **How well the claims contribute to design a useable system?** We proposed this question to ask raters to judge the general usability concerns/ease of use of the system being designed. However, we found that the raters may have interpreted the question differently based on their backgrounds and understandings. The term “design a useable system” was too generic in this case. “Design a usable system” could either mean designing this particular system as described in the task scenario or in a more broad way, designing interactive systems for nurses in general. Even though both raters were HCI experts, they had their own research/design emphases during their practices. And bounded with their own specific expertise, they would naturally consider whatever
applied to them as usability concerns when they were presented with an ill-formed question. To avoid the confusion, the question should have been rephrased to make sure that both raters got the same message. Specifically, it could have been “How well do the claims contribute to design a useable nursing handheld system for the given scenario? Or in a broader way, “How well do the claims contribute to design useable nursing systems in general?”

The lack of consensus between raters on the usability concerns also reflected the truth that context also matters in the evaluation process. The claim rating process was actually an evaluation process conducted by HCI experts. And it was suggested in the data that considering context makes a big difference to the evaluation results. To assess whether a system is good enough to fit into the situated environment, the evaluation guideline needs to be broad enough to cover the contextual information relevant to the user activities too. By doing so, system inspectors would be able to detect problems with associated with the context of the system use.

The Quality of the Claims

The 3rd evaluation metric was intended to assess the claims from a perspective of how well it could be applied to system design. The term ‘quality’ here was not for the implied system quality but the quality of the claims themselves, including whether the claims related to system design; whether the claims were clear enough to be used and be understood by a designer; and whether the claims included sufficient information (completeness).
The raters, who had HCI/system design expertise, evaluated the quality of the claims separately. The scores were summed up and analyzed on participants’ expertise (nursing vs. design) and the instructions used (context-centered vs. regular) to explore which independent variable affected the quality of the claims more. The results showed that the context-centered groups had significantly higher scores than the regular groups and designers also received higher ratings than the nurses. There was no interaction effect on the quality of the claims.

This result shows that the claims produced by the Context-Centered groups had a higher quality than the regular groups. It indirectly indicated that using a Context-Centered Framework could help participants to better formulate their thoughts to be clearer, more complete and more appropriate to the system feature. The improvement may come from a few reasons. First, the additional information required participants to categorize pros/cons and they tended to write a more clear regard of this. Second, contextual groups understood the problem domain better and conceived more usability concerns during their design. As a result of these two elements, they may have been able to represent their thoughts in writing well.

Unlike the previous two results, in metric 3, the main effect expertise was also significant. This result suggested that it is still difficult for nursing participants to produce claims that are valuable for system designers. In other words, when the audience was system designers, nurses did not know to express their thoughts in a way that would be easily understood by them. To find out why this was happening, we discussed the difference between the expertise of the two groups of participants and their working habits.
Instruction

The whole experiment design was based on a well-known HCI design approach. The system side of training made it easier for the designers to adapt the instructions. Even though the nursing participants displayed no problem in understanding the instruments, they might have needed a longer time training to be able to apply the method into the design process.

Working Habit

Design students major in either Information Systems or Software Engineering. The system design principles and experience made them aware of how important documentation is for constructing a system. Therefore, it was not a surprise that their claims were clearer and more complete because they tended to write as concretely as they could. But for nursing students, nursing documentation is much different than the system documentation. Nurses’ work is often interruptive, time-constrained and mobilized. This determined that their documentation tends to be simple and concise. This pattern was reflected in collected data, where designers often chose to write in complete sentence and the nurses’ claims usually only contained phrases or even words. Nurses also used a lot of acronyms and symbols to represent some actions such as MD=doctors, RN=nurses, ↑= increase, ↓= decrease, w/t= with. This indicated that they prefer to write quickly with key notions instead of complete sentences.

The interaction effect of the two independent variables: expertise and instruction was also significant for metric 3: the quality of the claims, meaning that the intervention caused the quality of the designers’ claims to improve more than nurses. The bigger
improvement may also have resulted from the fact that the Context-Centered Design
group did spend eight more minutes during their analytical process but the Context-
Centered Nursing group spent even less time than the control group. The claims
generation process included both the thinking process as well as the actual time spent on
writing. The nursing participants didn’t spend longer on the writing process after using
the intervention. It is reasonable that even given the contextual aspects, their claims were
still less clear and contained incomplete sentences compared with the designers.

Also, as indicated by the time spent on the study, the instructions and the
scenario-based design process may have been more difficult for nurses to understand
since the concept of depicting system consequences on the scenarios were less intuitive
for nursing students. They would have preferred to have had actual system in hands
during the study time and to see how the system works. The less effective instruction
caused nurses’ performance to improved less in this case.

One major problem found was that nursing students actually are not familiar with
the system design approach used in the study and it was hard for nurses to express their
thoughts in a way that could be understood by system designers. One potential way to
help nursing participants better understand the system design process and express their
ideas in a way that can be appreciated by designers is through a Participatory Design
approach (Greenbaum & Kyng, 1991). Participatory Design includes real users in the
design process to improve the quality of work life for the users of the technology
(Jeanette & Austin, 1990). Participatory Design differs from other technologies of only
inviting users to a design meeting, or soliciting their requirements through an interview or
questionnaire. End-users get more involved and engaged in the design process through
collaboratively working with system designers over a relatively long period of time.

Designer & end-user collaborations are considered to be a key element in the Participatory Design process (Jeanette & Austin, 1990).

Chin, Rosson, & Carroll (1997) reported a case study of using a Participatory Design approach in collaborative learning tools. This study also used scenario-based design and claims analysis approach to solicit user requirement. Teachers and students contributed significantly to the analysis process. One thing that might contribute to the benefits to end-user participants is that the study was carried out over a few weeks. In this way, designers and end-users could take time to understand the design process. Designers and end-users could also communicate during the collaborative discussion session regarding ways to compensate for lack of design understanding. In this case, the weeks-long design workshop teaches end-users what the design process is and builds a collaborative environment for designers and end-users’ easy communication. This suggested to us that it is feasible to enhance nurses’ performance through bringing them together with designers in a participatory approach design session. This would eliminate the drawback of participants reading instructions and make sure nurses could express their real thoughts without the help of system designers. By doing it this way, nurses would take a more active role in the design process. Using the Context-Centered Framework as a guideline would help them better understand and express the ideas associated with the context of the system use.

The results of metric 3 suggested to us that context-centered instruction caused participants to improve the quality of the written claims. And interestingly, due to the working habits and their prior knowledge, nurses who were familiar with the problem
domains and were well aware of possible usability problems of the systems could hardly express their thoughts in a way that was beneficial to the actual design.

### 6.3 Supporting Hypotheses and Research Questions

After interpreting the meaning of each individual result, we synthesized the results to explore how these results support the proposed hypotheses of the study.

- **H1a**: End-users who have solid understandings of their working environment perform better than the system designers.

- **H1b**: Designers could improve their understanding towards the problem domain through using Context-Centered Framework.

Hypothesis 1 was mainly designed to test whether the contextual information could be used to alleviate the symmetry of ignorance issue. Symmetry of ignorance stands for the phenomenon stating that designing a complex system needs both domain understanding and design expertise (Rittel, 1984). But when the task becomes complex, it is usually hard for designers and users to share a common language. For the current study design, the gap we intended to narrow is the understanding between the designers and nurses. The hypothesis can be further divided into two sub-hypotheses.

For **H1a**, we predicted that nursing students understood the problem domain better the designers and used evaluation metric 1 to assess this. As we discussed, in the control groups, nursing participants did understand the problem domain better than the designers. This supports the argument of symmetry of ignorance that designers had difficulty in understanding the end-users working environment.
But surprisingly, the results also showed that when context became the focus of the design, designers demonstrated an even higher level of understanding on their writing. An easier way to explain this phenomenon is that the problem domain in this study not only involved nursing domain knowledge but also required a certain level of design knowledge. As we discussed in the first metric, the task scenario and instruction were both easier for the designers to adopt. In this case, an improved domain understanding plus the system expertise helped designers achieved a higher understanding toward the nursing handheld system domain.

For hypothesis 1b, designers received even higher scores when they were asked to use a Context-Centered Framework to guide their design as opposed to the control condition. This supports the arguments that designers’ understanding towards the problem has been improved by considering the context guidelines embedded in their instruction.

As we discussed, evaluation metric 3 implied that nurses still have difficulty in representing and expressing their ideas to the designers. This concurred with the norm of symmetry of ignorance where a two-way communication barrier between end-users and designers exists. Designers may not understand the problem as well as end-users and similarly, end-users do not know system design enough to express their thoughts in an understandable way. Even though we narrowed the gap from the direction of design to nursing; it appeared in the discussion of metric 3 that using the framework can hardly narrow down the gap from the nursing to design.
H2: Designers produce better design products through using Context-Centered Framework in the early system design stage.

The second hypothesis aimed to verify whether consider contextual information in the design process could lead to better design. Context is no doubt an important aspect for system design, but there is no proof of whether providing contextual information does improve the system design and how it benefits the system design, especially for the early stage design when the product has not been applied to the real working environment. When we say better design, the “better” represents better system quality. The meaning of quality could be very broad and include all aspects of the system design. It is nearly impossible to measure the quality of the system design. Also, what we presented to the raters was not a real information system that could be tested in various ways. For the written claims, we only evaluated the usability concerns embedded in the claims. The usability concerns would lead to design a more useful system later.

The result from metric 2 shows that the designers’ score was slightly lower than the nurses’ in the control group but that they received higher scores than the nursing group when they used context-centered instruction. This concurred with the expectation of the study that the context-centered framework could help designers to include more useful usability concerns. The results indicated that it is possible to improve system design quality by providing designers with an easy to use operation design method to focus design on context and force designers to consider context issues during the design process.
6.4 Contributions to HCI and the System Design Field

This study contributes to the HCI community both practically and theoretically. For the practitioners, it provides an operational method assisting designers in designing for the context of system use; for the researchers, it explores and proves the importance of contextual information for early stage system design.

For Practitioners

For system designers, this research offers a fast, easy to use and operational method to emphasize system design on the context of system use. Context is a well-recognized factor that affects HCI design, but only a few studies articulated the nature of context as an interactive property and there is no inspection design method focusing on context of system use. Using an activity-oriented approach to examine context in the system design process breaks the boundary of the traditional physical limitation of the context and provides a way to examine the context as a dynamic and changing property. Context-centered framework can be used at several points during the system development lifecycle: during the requirement gathering, prototyping/system design phrase as well as the system evaluation phrase to solicit, incorporate and assess the relevant contextual information needed for designing interactive systems.

Design and evaluation activities are often intertwined (Wania et al., 2006) and oriented by the overall objective of the system design. The overall design goal determines the methods to be chosen and the same rationale can be applied to a direct design process and can guide the evaluation activities in the iterative design process. From this sense, the Context-Centered Framework could also be beneficial in multiple phases during the design process. In this study, the experiment we conducted was on the stage of early
system design and the user requirements gathering stage where the actual interactive system has not been built yet. The same rationale can be adapted to inform and facilitate system inspectors to do a quick check of whether the system will fit into the surrounding environments.

For the Research Community

Context of system use, in many ways, has no universally agreed upon definitions; it has no easy way to be represented when it is viewed as an interactive property that interacts with and influences system applications. The common way to study and design for the context of system use is to conduct field study and observe the actual system/user activities. But in many cases, what is exactly the context of system use is less defined and studies focus more on the actual design of a specific product. An understanding towards the context of system use on the whole is not enough for people to generalize the possibilities of applying it to other cases. In this study, we built upon a previous understanding towards context of system use and borrowed from classic HCI theories; we explored a way to extract contextual information that is relevant to system applications and incorporate contextual information into the design process. This was a first step in capturing contextual information from real fieldwork and trying to use a discount method to represent relevant information instead of doing a field study. It may provide us more insight as our research continues.

This experiment empirically explored the value of adding contextual information in the interactive system design. Although HCI research has previously recognized the importance of context in design, many current research projects are carried out to study the context-aware issue. There lacks empirical evidence to show how contextual
consideration could lead to a better system design. Our controlled experiment verified the role of using contextual information in system design. More importantly, how the framework can be used to help designers better understand the domain in which the system is situated. This provides a solution to help designers understand a complex and knowledge-intensive field such as clinical medicine.

6.5 Contribution to Medical Informatics

This research also contributed to the following two areas within the bigger scope of medical informatics: clinical informatics and nursing informatics.

This study provides a way to improve EMR system design and proved the importance of HCI design in the clinical informatics field. The framework proposed within can be used to increase design quality from directly increasing usability concerns and indirectly through helping system designer analyze, capture and understand the clinicians’ working environment. Clinical Informatics aims to provide better clinical care through information technology. Hospital computerization through either hospital information systems or electronic medical record systems intends to bring fundamental changes and many benefits to the clinical care. But in many cases, the systems implemented are failing to realize the intended benefits due to the system design flaws. Lack of formal HCI design method and awareness of HCI design is a major concern that leads to problematic system design. System design in many other fields usually follows HCI principles such as a user-centered design approach, but there isn’t enough awareness of the importance of these principles in medical system design now. The empirical study we conducted could support the importance of HCI in clinical information system design.
The experiment showed that the contextual information also leads to designing a more useable system, thus enhancing design quality. A useful and usable system is a basis to guarantee successful system implementation, adoption and clinicians’ satisfaction. In a critical, time-constrained environment, ease of use can often increase working efficiency and decrease medical errors. These elements would largely benefit clinical care and patient bed care and would contribute to a higher quality of healthcare delivery overall.

The empirical study also contributed to the designing of the nursing documentation system. A nursing mobile tablet system is believed to be a key solution for documentation in a highly mobilized, interruptive and collaborative environment. In the field of clinical informatics, research on the mobile system design is still focusing more on its functionalities. This study adapted four commonly used nursing tasks and collected claims with real users. The claims produced by the system designers and actual users would be helpful in refining the existing features and in reconstructing the use scenario later. The usability concerns embedded in the pros/cons will also be a good resource for us to build nursing handheld system prototypes for later research.

6.6 Limitations of the study

The concept of using contextual concerns in system design ideally should be tested within groups of real designers and nurses. But due to limited resources, the current study only recruited students with basic design or nursing knowledge and used a relatively easy nursing task. The gap between participants’ domain understanding and design expertise is not as big as we expected. It was suggested that many design-side participants also had some understanding of the medical field through popular medical
television shows or have had experience with previous hospital visits. Nursing students also had some basic system design understanding in training and daily experience. It would be interesting to test the concept with the real users in a more clinical, domain-oriented task.

Secondly, the life-critical system implemented in the hospital follows not only the general HCI design principles, but also must follow the special requirement of the healthcare domain, such as the privacy and confidentiality issues required by HIPAA regulations, as well as have an error-free design requirement in clinical care. These have not yet been included into the results. One reason we did not rate these elements is that while the raters of the study were considered to be HCI experts, they did not have sufficient knowledge to rate medical-related criteria. To ensure the correctness of the results, raters only rated the data on general HCI criteria. It is possible to leverage the results and measure the medical side of criteria through examining the writing document.

6.7 Summary

In this chapter, we discussed the implications of the results and how these implications support the proposed hypotheses. It has been shown in the data that a two-way symmetry of ignorance situation did exist in our control groups, where designers and nurses could hardly understand and communicate with each other. The Contextual-Centered Framework assisted designers in gaining a better understanding toward the problem domain, but not to the end-users. Also, the results support the second hypothesis that designers can achieve a higher quality design through using the context-centered framework in the early system design stage.
CHAPTER 7: CONCLUSION AND FUTURE WORK

In conclusion, this dissertation has explored the concept of context in interactive system design for a system situated in a complex, ubiquitous and mobile environment. The current research is situated in the field of Medical Informatics to inform systems implemented in the hospital environment. The research project was also motivated by the overall difficulties of designing for hospital use and also the gap between end-users’ understanding and system designers’ designing expertise. We believe context of system use is a communication pathway to bridge the gap between designing expertise and understanding of clinical work. We developed the Context-Centered Framework, which has been developed as the theoretical framework in this study to help designers understand the clinical working environment and incorporate contextual information into the design considerations and we carried out an empirical study to explore the effectiveness of the framework. The results from the empirical study showed that the context-centered framework could serve as a communication breakthrough for designers to better understand clinicians’ working environment and lead to a more useful system design. The method only focused on solving the one-way “symmetry of ignorance” and facilitated designers understand of clinicians. Clinicians still have difficulty understanding system design.

A few related projects for this study have been raised during the discussion. we briefly introduce what these future works are and how they are related to the current study. It is suggested in the current study that the context-centered framework could be used for novice designers to capture clinicians’ domain understanding. A follow-up study for the experienced system designers would bring more insight and provide
supplementary information to the current study. If similar results have been found in the experiment with real designers, it could indicate that this framework is equally important for both novice and experienced designers. And if there is no improvement by giving contextual consideration in the real designers group, it would indicate that the design expertise accumulated from the years of work experience in the real designers groups may allow them to better appreciate the value of context in their design more than novice designers.

The proposed Context-Centered Framework could be used as a communication breakthrough in helping designers understand clinicians’ work. In a simple task situation, as we experimented with in the current study, it is possible for designers to use the framework and outline the contextual information needed for system design. But when it comes to more complicated and clinical oriented task, it would be interesting to see if designers can really use the framework communicate with clinicians. In other words, whether designers using the context-centered framework work collaboratively with clinicians could help them understand the task better than without the context-centered framework. By bringing the designers and clinicians together on the experiment, it would also contribute to the field of CSCW.

Although the controlled experiment showed the value of contextual information in system design, a more detailed and deeper understanding towards the mobilized, highly interrupted and ubiquitous clinical working context is needed. Ethnographic research in hospital units such as intensive care units or emergency rooms could help gain more insight into understanding the dynamic of the context and observing the influence of mobility and interruption in healthcare delivery.
Though the main propose of the study was to test the effectiveness of the framework of a nursing system, there is rich data from the nursing students and designing students on the positive and negative consequences of the nursing handheld system. A prototype or even a system developed on top of these data will reflect the real need of users and embed the usability concerns provided by the system designers.

Medical Informatics is a fast growing area and it leaves many opportunities to hold HCI research. Though we focused only on a small part of EMR design in the current study, there are many more chances to study how context affects EMR system usages in hospitals; things such as interruption, mobilization, and ubiquitous system applications will all be worth studying in the future. Also the recent trend of exploring the value of personal health records to promote the quality of clinical care provides another challenge to the system design. Context of system use is also important for virtual environment design and also to home therapists when technologies become more pervasive and ubiquitous.
REFERENCES


Appendix A: Background Questionnaire

Please make checkmarks for the appropriate answer or fill in the blanks.

1. Are you? ____Female ____Male

2. What is your age? ____ Years

3. What is your current major (or department)? ________________

For Nursing students, complete questions below:

4. Did you take the Nursing Informatics course before or are you currently taking it?  
   ___Yes ___No

5. Which year you are currently enrolled?
   a) Sophomore of the regular co-op program or the First quarter of the ACE program
   b) Pre-junior of the regular co-op program or the Second quarter of the ACE program
   c) Junior of the regular co-op program or the Third quarter of the ACE program
   d) Senior of the regular co-op program or the Forth quarter of the ACE program

6. How would you describe your knowledge of the nursing field? (nursing student only)
   a) _____ Not familiar at all
   b) _____ Basic understanding
   c) _____ Intermediate understanding
   d) _____ Advanced knowledge
7. Do you have prior nursing or medical practice experience and educational degree?
   _____Yes    _____No

   If yes, please briefly explain:
  
   __________________________
   __________________________
   __________________________

   ___

   For IST students, complete questions below:

8. Which year you are currently enrolled?
   a) Sophomore
   b) Junior
   c) Senior
   d) MS first year
   e) MS second year
   f) Doctoral program

9. How many Human-computer interaction courses you had before?
   a) _____ None
   b) _____ 1-2
   c) _____ 3-5
   d) _____ > 5

10. Do you have prior information system design experience or educational degree?
    _____Yes    _____No

    If yes, please briefly explain:
    __________________________
    __________________________
    __________________________
    ___
Appendix B: Instruction- Context-Centered Group

Scenario-based design (SBD) uses narrative stories to describe tasks users carried out in the real world to inform the system design. There is an evaluation process associated with SBD called claim analysis. A claim asserts that a given feature of an artifact in a situation of use can have various specific consequences for a user. Consequences may be either positive (pros) or negative (cons). Both positive and negative consequences are judged on the basis of the claim schema or the goal of the evaluation.

Here is the claim schema we will use in today’s study:

5. **Goal**: the motivation and intended outcome

6. **Setting**: Setting is a place where participants perform the activity: it could be either a virtually or physically located place
   a. **People** involved in and their **Roles** in solving the task
   b. The **Properties of the Context** which related to the task solving process.
   c. The available **Tools, Artifacts** and **Resources** for conducting this task.

7. **Rules and Constraints**: the rules or constraints for using these tools and resources. E.g. time preference or Jim has priority to use the system.

8. **Awareness**: an understanding of the actions, people, artifacts and time in the context of system use. The system should provide this understanding in order to keep people aware of what is going on and what has happened.

A claim is in the following structure.

(Feature of use)

*Cause* (pros which emphasize the above four aspects)

*But may also cause* (cons which inhibit the above four aspects)
A claim analysis example

Three middle school students have elected to work together on an assignment. The three group members need to jointly interpret some data they collected before. They will communicate through a video-conferencing system and use an electronic white board to annotate their assignment.

Note:

1. Please specify the types of consequences according to the claim schema. One consequence may apply to more than one category.
2. You may write consequences other than the above four types.
3. Leave it blank if you think there are no pros or cons for a claim.

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Group members use video conferencing system to discuss problems.</th>
</tr>
</thead>
</table>
| Pros      | + allows group members to collaborate remotely (goal).<br>
             The feature supports the goal of the activity which is to facilitate students’ discussion.<br>
             + provides a shared environment for group members to meet (setting)<br>
             All the discussion activity is situated in the video conferencing system.<br>
             + provides audio and video communication (setting-tool)<br>
             Video conferencing system provides tools for students to communicate.<br>
             + allows synchronous communication (rule)<br>
             The properties of the video conferencing system support synchronous communication.<br>
             + allows participants to be aware of the ongoing discussions (awareness)<br>
             Students participating in the discussion session know what others are doing right now. |
| cons      | - BUT the system doesn’t assign the leader to the group (setting-people)<br>
             Without specifying people’s roles, especially the session leader, the discussion will go chaotic. |
- BUT the system may provide poor sound or video (*setting-tool*)

*Poor sound and video tools may affect students’ communication.*

- BUT the system may not support asynchronous communication (*rule*)

*This is a constraint of using audio and video communication.*

- BUT students may lose track of what has happened (*awareness*)

*Students cannot trace back to see what others said before in the video system.*

<table>
<thead>
<tr>
<th>Feature 2</th>
<th>Using an electronic white board to annotate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pros</td>
<td>+ allows the data analysis process (<em>goal</em>)</td>
</tr>
</tbody>
</table>

*The E-board supports the primary goal of the activity of analyzing the data.*

+ allows a salient space for collaboration (*setting*)

*The E-board is the environment where students can annotate and exchange ideas together.*

+ supports sharing of text and images electronically (*setting-tool*)

*The E-board has the function (tool) to attach files or email files to group members.*

<table>
<thead>
<tr>
<th>cons</th>
<th>- BUT the student may erase or overwrite others’ work (<em>awareness, rule</em>)</th>
</tr>
</thead>
</table>

*If a person isn’t aware that someone else is annotating the same point now, she/he may accidentally erase others’ annotation.*

*The system should have rules to prevent two people to annotate the same problems at the same time.*

- BUT the system may support limited media or imports from other applications (*rule*)

*Other relevant materials like hand drawn pictures or 3-D simulations may not be shown in the e-board system.*
Scenario-based design (SBD) uses narrative stories to describe tasks users carried out in the real world to inform the system design. There is an evaluation process associated with SBD called claim analysis. A claim asserts that a given feature of an artifact in a situation of use can have various specific consequences for a user. Consequences may be either positive (pros) or negative (cons). Both positive and negative consequences are judged on the basis of the claim schema or the goal of the evaluation.

In general, a claim schema is looks like the following:

3. Positive consequences or pros would facilitate, enable or increase the current activity.
4. Negative consequences or cons would inhibit or decrease the activity.

A claim is in the following structure.

(Feature of use)

Cause (positive consequences or pros)

But may also cause (negative consequences or cons)
A claim analysis example

Three middle school students have elected to work together on an assignment. The three group members need to jointly interpret some data they collected before. They will communicate through a video-conferencing system and use an electronic white board to annotate their assignment.

**Note:**

1. *You may include any consequence you have in the claims.*
2. *Leave it blank if you think there are no pros or cons for a claim.*

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Group members use video conferencing system to discuss problems.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>+ allows group members’ remote presence.</td>
</tr>
<tr>
<td></td>
<td><em>The feature supports communication when students are not co-located together.</em></td>
</tr>
<tr>
<td></td>
<td>+ allows a more vivid discussion experience.</td>
</tr>
<tr>
<td></td>
<td><em>Video system provides both audio and video functions which can simulate the classroom discussion.</em></td>
</tr>
<tr>
<td></td>
<td>+ enables students more engaged into the problem solving process.</td>
</tr>
<tr>
<td></td>
<td><em>The video mediated discussion helps students discuss problems by seeing and talking to each other.</em></td>
</tr>
<tr>
<td></td>
<td>+ creates a discussion environment which is natural to students.</td>
</tr>
<tr>
<td></td>
<td><em>By seeing others, students have a discussion environment similar to the classroom discussion before.</em></td>
</tr>
<tr>
<td><strong>cons</strong></td>
<td>- BUT the system may provide poor sound or video.</td>
</tr>
<tr>
<td></td>
<td><em>Students may be hard to talk if the audio or video is not clear.</em></td>
</tr>
<tr>
<td></td>
<td>- BUT students may feel frustrated when technical problems occur.</td>
</tr>
<tr>
<td></td>
<td><em>The technique problems may interrupt students’ discussion.</em></td>
</tr>
<tr>
<td>Feature 2</td>
<td>Using an electronic white board to annotate assignment.</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Pros      | + provides a space for collaboration.  
            | *E-board provides a shared space for students to annotate their paper.*  
            | + supports sharing of text and images  
            | *Students can transfer or attach the text file or images through E-board.* |
| cons      | - BUT students may erase or overwrite each others’ work.  
            | *The previous annotation may be overwritten by later revision and it’s hard to keep track of the revision history.*  
            | - BUT it may support limited media or imports from other useful applications.  
            | *Other relevant materials like hand drawn pictures or 3-D simulations may not be shown in the e-board system.*  
            | - BUT it may distract students from other activity.  
            | *Students may wait to see others’ reply and loss their own time to do homework.* |
Appendix D: Hands-on Exercise

Please write a claim for the following scenario based on the instruction you have.

Mike is a student in an online course which is organized by the “Virtual classroom system.” He is requested to make a presentation about his term project during tomorrow’s class through the presentation function in the system. During the presentation, he will use interactive sharing area to display his slides, images and other related materials to the rest of the class.

What are the pros and cons of using the “interactive sharing area”? You may write it down or simply think about it. You may ask any question during the process.
Appendix E: Task Scenario

Mary is a nurse in a local hospital. This hospital has recently applied a hospital wide wireless-based hospital information system (HIS) system. Clinicians could have access to the HIS system through either a regular desktop or a tablet PC.

Mary was on duty in the morning shift today. She brought her tablet PC with her to the second floor where the patient rooms are located. While she was checking the patient’s condition in room 203, suddenly the alarm on her tablet PC went off. It showed that patient Tony needs help. Mary rushed into Tony’s room. Right after she entered the room, Tony’s record was automatically displayed on her tablet PC. Mary found that the patient was not responding well to the medication and was vomiting now. She sent out an alarm through her tablet PC to request a doctor to come over for a consultation and sent a message to the main doctor Davis asking about the patient’s dose of Warfarin. She indicated that she needs an immediate reply. She then requested the lab results to be transferred to her tablet PC and to the doctors who are responsible for this patient. She checked the vital signs of the patient and updated the record through her tablet. Mary left a note on the electronic white-board which is embedded in the HIS system and reminded nurses in the afternoon shift pay more attention to Tony.
Appendix F: Post-Experiment Questionnaire

Part 1: Please indicate the degree to which each statement applies to you. Indicate your choice by circling the appropriate number: the larger the number, the more you agree with the statement. There is no right or wrong answers. Work quickly; just record your first impressions.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It’s very easy to write the desirable consequences (pros) for the claims.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. It’s very easy to write the undesirable consequences (cons) for the claims.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3. I was very familiar with the task scenario before the activity.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4. I was very familiar with the system features before the activity.</td>
<td></td>
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<tr>
<td>5. The training session was helpful to me. I clearly understood the instruction.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6. I followed the information in the instruction when I wrote my claims.</td>
<td></td>
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</tr>
<tr>
<td>7. Knowing the task environment helped me when writing the claims.</td>
<td></td>
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</tr>
<tr>
<td>8. Knowing system design principles helped me when writing the claims.</td>
<td></td>
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</tr>
</tbody>
</table>
9. I included all the possible consequences that might happen in the claims.

<table>
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<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>Disagree</td>
<td>Agree</td>
<td>Agree</td>
<td>Agree</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. What factors helped you come up with the pros and cons for the claims?

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

11. What other information would have been helpful for you to complete the task?

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
VITA

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Education

Ph.D. in Information Studies                     2008
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Selected Publications


