A Cognitive Work Analysis of Physician Ordering in Pediatric Inpatient Medicine Teams

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A dissertation
submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

University of Washington

2010

Program Authorized to Offer Degree:
Medical Education and Biomedical Health Informatics

University of Washington
Graduate School

This is to certify that I have examined this copy of a doctoral dissertation by

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Abstract

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Clinical work, including ordering, is known to be interruptive, multitasking, collaborative and distributed yet current clinical computer systems emphasize linear, normative and solitary work. Although the evidence of a work-technology disconnect is well documented by researchers, there is less understanding of the origins of this disconnect. Currently engineers and designers build systems based on descriptive or normative approaches. However, the increasing complexity of clinical work environments make predicting work patterns and work flow more challenging, if not impossible. Therefore, this suggests that new approaches are needed to build flexible systems that can support unanticipated work. The growth of health information technology investment presents an even more urgent motivation for building systems that can achieve high user acceptance and that are responsive to these complex socio-technical environments.

This research uses a mixed-method approach consisting of a qualitative field study of physician ordering that collected documents, observations and interviews of pediatric

inpatient physicians working in teams. Inductive analysis identified emerging physician work themes. Deductive analysis was used to characterize the larger contexts in which ordering occurs by using Cognitive Work Analysis (CWA) - a holistic systems analysis framework that indentifies constraints on work at multiple levels from the work environment to the worker. These combined results lead to visualizations and design implications for future systems that can support flexibility, cooperation and adaptation to unanticipated work situations.

This work seeks to examine physician work more broadly from a systems perspective through two primary goals. The first is to apply the multi-dimensional cognitive work analysis framework to systematically characterize the work of pediatric inpatient teams including the visualization and technology design implications of the results. The second is to explore how CWA can be generalized to a clinical domain and extended to other clinical work environments and workers.

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Years ago, when I thought I was on the path to unlimited career heights and riches, I lost the job that at the time defined who I was. As with all the setbacks of youth, it was a disaster of epic proportions, a blow to my ego and surely the worst thing that could possibly happen. Ever. But as those with the wisdom of perspective know and the rest of us eventually discover, it was not the end of the world. Being forced out of that path only allowed me to reflect and proactively choose another. I did and this dissertation is the result of that journey. As I reflect back, I know that I have the power and, thankfully, the resources to choose the direction of my own life – something I didn't understand then.

First, I thank my wonderful parents who have been patient and positive, who shared all my anxieties but kept it to themselves and who never questioned the difficult choices that I have made. My deepest gratitude goes to Ben Robbins for his love and support, who never gave up on me and who picked me up when I was depressed about the prospect of ever finishing. I am also indebted to him for creating the graphics that gave the visualization ideas the professional look they needed.

I thank my dissertation committee at the University of Washington, especially my committee chair, John Gennari, for his unwavering support when the short road turned into the long road, for helping me into the program in the first place and for demanding that I stand by my intellectual beliefs. I am grateful to Raya Fidel for introducing me to Cognitive Work Analysis, questioning my results and showing me a new way of thinking about systems and about myself. I am indebted to the physicians on my committee, Mark Del Beccaro, Tom Payne and Paul Nichol, who paved the way for working at their respective hospitals, mentored me in clinical research and continue to encourage me and help me explore practical applications for these ideas.

I owe much to the dedicated staff at Seattle Children's, and especially to Bonnie Ramsey who sponsored my research and Glen Tamura who allowed me to work with his staff. I could not have asked to work with more generous people. I'm especially grateful to the residents who bent over backwards to make time for interviews and permitted me an honest window into their chaotic, sleepless and emotional work. There just aren't enough bagels in the world to repay you guys.

To my friends and fellow Biomedical and Health Informatics students, I thank you for your humor, intellectual insights and cynicism. I couldn't have one without the others. Thanks to Kari Stephens who cracked the whip and let up on the reigns just at the right time and thanks to Peter Tarczy-Hornoch and Ira Kalet whose research assistantships and fellowship opportunities supported me throughout my research.

I can't possibly list all the friends and colleagues who have helped and inspired me and continue to support me as I move onto the next step in my career. I only hope that I can pay it forward.

DEDICATION

To my parents and Ben.

Chapter 1: Introduction

In 1999 the Institute of Medicine released its report, "To Err is Human" stating that medical errors and poor patient safety contribute to between 44,000 and 98,000 deaths annually. The subsequent publication, "Crossing the quality chasm: a new health system for the 21st century" suggested one measure to improve safety: "the use of automated systems for ordering medications can reduce errors in prescribing and dosing drugs."(Kohn, Corrigan et al. 2000; Institute of Medicine (U.S.). Committee on Quality of Health Care in America. and National Academies Press (U.S.) 2001) These systems are known as Computer Practitioner Order Entry (CPOE) which is defined by the Agency for Healthcare Research and Quality as:

> *An application that allows health care providers to use a computer to directly enter medical orders electronically in inpatient and ambulatory settings, replacing the more traditional order methods of paper, verbal, telephone, and fax. CPOE systems can allow providers to electronically enter medication orders as well as laboratory, admission, radiology, referral, and procedure orders. Strictly defined, it is the process by which providers directly enter medical orders into a computer application.(Agency for Healthcare Research and Quality 2009)*

CPOE systems have been shown to save time, streamline processes and above all reduce medication prescribing errors and adverse drug events and can offer clinical decision support features at the point of ordering. (Ahmad, Teater et al. 2002; Mekhjian, Kumar et al. 2002; Han, Carcillo et al. 2005; Steele, Eisert et al. 2005; Del Beccaro, Jeffries et al. 2006; Lindenauer, Ling et al. 2006). Meta-analysis suggests that institutions that have implemented CPOE outperform their counterparts in significant quality measures.(Yu, Menachemi et al. 2009) In pediatric settings, hospitals with CPOE have been shown to have fewer reported adverse drug event.(Yu, Salas et al. 2009) CPOE is thought to save money by reducing inpatient bed days and unnecessary tests.(Tierney, Miller et al. 1993; Bates, Kuperman et al. 1999; Mekhjian, Kumar et al. 2002) The elimination of handwriting, decision support to prevent adverse drug events and guidelines to encourage appropriate dosing have also been shown to reduce errors.(Evans, Pestotnik et al. 1998; Teich, Merchia et al. 2000; Potts, Barr et al. 2004) The most widely cited study conducted by Bates et. al reported a 55% reduction of medical errors after the implementation of BICS at Brigham and Women Hospital.(Bates, Leape et al. 1998)

Despite these potential benefits, CPOE remains a poorly adopted technology in most United States hospitals.(Classen, Bates et al. 2010) Ash and her colleagues report a 6% adoption rate among US hospitals in 2002.(Ash, Gorman et al. 2004) Yu et. al report a similar penetration rate of 6% among hospitals that care for children with children's hospitals (odds ratio OR=6 ; 95% confidence interval [CI] = 1.5-23.9), private hospitals (not-for-profit OR=10.2 , 95% CI = 1.2-85.4; for-profit OR=26.5 95% CI = 3.1-224.8) and urban teaching hospitals (OR 3.9 ; 95% CI = 1.7-8.8) reporting higher rates of implementation.(Teufel, Kazley et al. 2009) Nevertheless, the potential for better patient outcomes, increased patient safety and reduced errors have led CPOE to figure prominently in the American Recovery and Reinvestment Act of 2009/ Health Information Technology for Economic and Clinical Health Act (ARRA/HITECH) Electronic Health Records (EHRs) financial incentives program for hospitals. (Classen, Bates et al. 2010) This policy will likely strongly incent the adoption of CPOE going forward.

I was motivated by the well-documented difficulties of CPOE implementation and recognizing the increasingly strong forces pressuring for rapid deployment of CPOE in the coming years. I was additionally motivated by the fact that illnesses of hospitalized children are becoming more complex and severe and frequently require subspecialty consultation.(Percelay and Committee on Hospital Care 2003) This medical complexity is further increased by the employ of modern team-based care that involves complex coordination of care between multiple providers and services. Charles Perrow summarized the consequences of complexity:

> *As systems grow in size and in the number of diverse functions they serve, and are built to function in ever more hostile environments, increasing their ties to other systems, they experience more and more incomprehensible or unexpected interactions. (Perrow 1999)*

Perrow's data comes mainly from nuclear power plant safety failure reports. However, his warning is applicable to clinical environments that are growing in complexity and increasing their investment in technology.

In the published research outlining principles for successful CPOE installations, there is more documentation for managing the expected upheaval to work and workers than in prospectively shaping the future system to fit work practice.(Ash, Fournier et al. 2003; Ash, Stavri et al. 2003; Sengstack and Gugerty 2004; Kaplan and Harris-Salamone 2009) This omission may be because of the prevalence of commercial rather than home grown CPOE systems that customers can minimally influence, but nonetheless represents a rich area for new research. My dissertation is an attempt to address this gap in knowledge.

In this dissertation, I will discuss how I performed a field study of inpatient physicians collecting observations, interviews and documents at Seattle Children's Hospital, a 250-bed pediatric, academic, urban teaching hospital located in the Washington State. I analyzed the field study data using an ecological systems framework that has been used successfully in other high-risk socio-technical domains such as nuclear power and chemical engineering..

I set out to study CPOE systems and order-entry because of the existing modularization of electronic health records that segments orders into its own data category. My intent was to study the work-technology disconnect between actual physician work and CPOE systems. However, it rapidly became clear that the first step in understanding this disconnect was to understand the nature of the work itself regardless of any CPOE system, including the current system in use at Seattle Children's. By systematically analyzing the larger contexts in which ordering occurs using a specific framework, I was also able to connect the results of understanding physician work to clear systems requirements and design implications in order to bridge the gap between work and technology. The results of this study focus on ordering, but as part of a larger, richer system physician work.

1.1. Unintended Consequences of CPOE

Despite many positive reports, all is not rosy for adopters of CPOE. Some researchers believe more statistical data on the effects of CPOE on care is needed before concluding CPOE is clinically and economically beneficial.(Berger and Kichak 2004; Reckmann, Westbrook et al. 2009) Koppel et al identified 22 different types of CPOE failures related to medication errors and their.(Koppel, Metlay et al. 2005) Han reported finding higher mortality rates coincident (but not causal) to the implementation of CPOE in a critical care setting (though

Del Beccaro and his colleagues found no increase in mortality rates after CPOE installation).(Han, Carcillo et al. 2005; Del Beccaro, Jeffries et al. 2006)

Several studies criticize CPOE systems design for not conforming to workflows and recommend that successful CPOE systems must follow or consider existing workflows.(Sittig and Stead 1994; Miller and Gardner 1997; Teich, Glaser et al. 1999; Murff and Kannry 2001; Ash, Stavri et al. 2003; Bates, Kuperman et al. 2003; Ash, Sittig et al. 2007) A survey of physicians at 2 hospitals in Massachusetts reported that only 22% felt that the CPOE system supported their workflows.(Lindenauer, Ling et al. 2006) The literature also suggests that physician satisfaction with a CPOE systems is highly correlated to "tasks being performed in a straightforward manner" and efficiently.(Sittig, Kuperman et al. 1999; Murff and Kannry 2001) However, healthcare workflows are not linear processes with sharply demarcated steps, roles and information processing.(Ash, Berg et al. 2004; Aarts, Ash et al. 2007; Niazkhani, Pirnejad et al. 2009)

Ash and her colleagues have studied installation of CPOE across several organizations and identified "unintended consequences" of CPOE. While some of these consequences can be beneficial, there are of many unintended consequences that are considered detrimental and many of her important findings indicate areas where the information system did not meet and match the work demands. Uncovered unintended consequences include inconsistencies with current workflows, negative emotions, new work demands and communication issues.(Ash, Sittig et al. 2007)

1.2. The need for new engineering methods

Progress in developing appropriate medical systems must be a product of collaborations between human factors professionals and medical practitioners.(Nemeth, Cook et al. 2004) Nemeth's work brings to light the emerging belief that fieldwork is necessary to studying complex work systems, a belief that was once contentious and is still not employed universally. In her ethnographic study of medical informatics methods in the 1990's, Forsythe concluded that it was "almost unheard of" for the design team to study work in-situ.(Forsythe 2001) Instead, she reported that design is more often based on what designers or experts "know" about models of work or work settings and the resulting software reflects the intuition and introspection of the designer. If the designer is not a medical professional, they rely on the advice of a single expert whose perspective is taken as representative of the entire field. Kushniruk and Patel similarly call for new approaches studying health systems using "methods (that) represent a shift from a focus on the design of software and system components to gaining a better understanding of the interaction between health care information systems and end users in conducting day-to-day tasks."(Kushniruk and Patel 2004)

Often left out of the field of medical informatics is the exploration of the cultural assumptions that inscribed in the design of technical systems.(Forsythe 1999) The user perspective and conscious reaction to the system, the impact of systems on actual, emergent use is a critical determinant to its incorporation into clinical care.(Forsythe 2001; Kushniruk and Patel 2004) Based on this belief, I chose to conduct a field study of physicians in situ to understand the perspectives of physicians, but only what they do, but their values and the constraints that shape their work.

Forsythe, Kushniruk and Patel all strongly recommend new research methods that shift away from the tradition epistemological stances of medical informatics which focuses on formal biomedical knowledge, controlled experiments, facts and figures. In engineering this perspective translates into developing systems based on the belief that there is a single, value-free reality that can be empirically observed, predicted and controlled.(Forsythe 1996; Potts and Newstetter 1997) Furthermore, these assumptions lead to systems that are functionally accurate but prescribe singular paths of work or workflows (even based on analysis of in situ work or workers).(Bader and Nyce 1998) Reports that CPOE does not conform to workflows from researchers such as Ash not only support this design philosophy, but also reveal its flaws. Thus I chose an analysis framework and interface design perspective that does supports flexibility and constraint-based descriptions of work rather than instruction-base descriptions.

I chose the methods for this research in order to challenge existing beliefs in medical informatics and software engineering. My goal is to explore whether alternate approaches c an yield different, and ultimately superior results.

1.3. Research Questions

My long-term research questions are motivated by the known struggles of implementers and the convergence of a multi-disciplinary perspectives to develop and refine methods for studying clinical work and designing systems. It is also an opportunistic time to explore these questions given the political intent of the federal government and payors to invest substantial resources into the development of CPOE and health information technologies. My long-term research questions are:

1. How can we *systematically* analyze the work of ordering in clinical settings using cognitive system engineering and fieldwork techniques?
2. Can ecologically designed interfaces and systems better support work in complex socio-technical hospital settings?
3. How can informatics develop *practical* and *teachable* methods that bridge the multiple disciplines required to build, evaluate and improve CPOE and health information systems? These disciplines include, but are not limited to, medicine, software engineering, anthropology and cognitive systems engineering that each bring a different set of values and assumptions to the table.

I am particularly interested in developing methods to challenge the assumptions of the software engineering profession. Introducing a new epistemological perspective to engineering can be particularly challenging because as Rogers says, "Engineering is an overwhelmingly practical field, traditionally much more concerned with worldly outcomes than philosophical reflection."(Rogers 1983) Rogers suggests that engineers often concern themselves with the development of practical artifacts rather than an examination of engineering activities that could lead towards a philosophical re-orientation of the engineering methods. Instead engineering is seen as a derivative field where the artifacts created are the realizations of discoveries in other sciences.(Hinds 2008)

In the following sections (1.4 and 1.5) I will address the first research question by formally classifying clinical work as a complex socio-technical system. I will discuss why I chose Cognitive Work Analysis (CWA) as the systems engineering approach in this study. I will explain CWA in detail in Chapter 2, however, it important here to understand why I used

CWA to explore my first research question and systematically analyze physician work. I will present ecologically designed interface suggestions in Chapter 5 to further research question 2. Finally I will explore research question 3 through the analyses and models presented in Chapter 4 and the methods used in Chapter 5.

1.4. Why ordering a complex socio-technical system

In Section 1.8 I will introduce the specific aims of this research that include using an ecological work analysis approach, Cognitive Work Analysis (CWA) to address the research question in Section 1.3. Vicente and Rasmussen developed CWA specifically to address engineering for complex socio technical systems.(Vicente 1999) First, I will explain why inpatient work (the work that includes ordering) is a complex socio-technical system using Vicente's socio-technical systems classifications. By showing that inpatient work is a complex socio-technical system, I believe it well-suited for CWA, the work analysis method I have chosen.

1.4.1. Large Problem Spaces

Complex socio-technical systems have many components and forces, and engineers must permit users access to the vast problem space without overwhelming them. The large number of diagnoses, therapies, variability in patients in addition to the social and financial diversities that influence diagnoses and treatment create complicated and vast problem space.

1.4.2. Social

Complex socio-technical systems are comprised of many people who work together and must communicate and coordinate to succeed. Hospital settings including multiple clinical specialties, services and professionals that coordinate patient care.

1.4.3. Heterogeneous Perspectives

Workers in a complex socio-technical systems have different backgrounds, values and goals complicating social negotiation. Workers in clinical environments include, physicians, nurses, pharmacists, administrators, staff and of course patients who may not share the same priorities, even amongst their own professional colleagues.

1.4.4. Distributed

Workers in complex socio-technical systems are often distributed in disparate geographical locations. I will describe Seattle Children's, the study setting, in more detail in Chapter 2. However, for my purposes here, it is worth noting that as the only tertiary care pediatric facility in the Washington, Wyoming, Alaska, Montana, Idaho (WWAMI) region, Seattle Children's coordinates care with providers and patients across a wide geographic area.

1.4.5. Dynamic and Time-Delayed

The consequences or actions associated with decisions in complex socio-technical systems may not be known for long time periods so workers must anticipate future states before deciding actions. For instance, when ordering an MRI, the physician must take into account the availability of radiology services on the weekends or evenings or the timing of a medication order.

1.4.6. Hazard

Mistakes in complex socio-technical systems can lead to a high degree of potential hazard. Workers must carefully consider decisions or actions because the consequences of errors can be catastrophic. Particularly relevant to this study, potential drug errors have been found to be 3 times more likely in pediatric settings.(Kaushal, Bates et al. 2001)

1.4.7. Coupling

Complex socio-technical systems contain many interacting subsystems that make it challenging for workers to predict the consequences of actions. How does scheduling a new therapy affect a patient's existing medications, their procedure schedule or their stay in the hospital? Workers must navigate these subsystems to avoid undesirable outcomes yet meet goals.

1.4.8. Automation

Vicente claims most socio-technical systems are highly automated (e.g stock market, chemical plant control) with computers controlling the work domain while the workers monitor. At first, this may not seem broadly applicable to the medical domain as the penetration of EHR and CPOE systems in United States hospitals remains low and much of the work still employs paper and human-controlled and monitored. However, Seattle

Children's employs an enterprise level clinical computing system and automation is well-represented. While introduction of a clinical computer system provides a certain level of automation, workers must still compensate for the failings of the system, monitor abnormal behavior or situations the computer cannot handle. Unlike process control or chemical plants, these monitoring behaviors are primarily perceptual and cognitive in nature rather than psychomotor.(Vicente 1990)

1.4.9. Uncertainty

There is a high degree of uncertainty in the data of complex socio-technical systems. That is to say, workers do not have full confidence in the data in the domain and any computer display of such data may not be an accurate representation of the current state of the system. In the medical setting, data may not be accurate because of the natural variability in physiological measures or because much of the needed data is not available electronically. For instance, weight or surface area based dosing is necessary for most medications yet weight and body surface area vary greatly in the pediatric populations and change as they grow.(Sullivan and Buchino 2004)

1.4.10. Disturbances

Workers in complex socio-technical systems must improvise and adapt to unanticipated events quickly to maintain system goals e.g. patient health or timely care delivery. When disturbances occur, existing workflows do not apply and workers must invent new patterns. Information technology systems must support idiosyncratic and rare situations as well as the normal, common workflows. In Chapter 3, I will describe work behaviors to adapt to variability and disturbances in common workflows such higher than normal patient loads, lower than normal staffing or unanticipated admissions.

1.4.11. Mediated Interaction

Finally, a key aspect of complex socio-technical systems is that workers cannot typically use natural human perception methods to measure the outcomes of their actions. For instance, physicians may input orders, but they cannot directly see if that order was received or processed or delivered. They cannot physically see blood pressure changes. This is in contrast to systems where manipulating the computer interface has a direct perceptible effect on the environment such as the interface for a graphics design program. The supporting computer system and interfaces must accurately represent the situation without using normal human perception methods. Instead they must rely on higher perception functions.

Wears and Berg summarize broadly the incompatibility of many CPOE systems with clinical work: "Clinical work, especially in hospitals, is fundamentally interpretative, interruptive, multitasking, collaborative, distributed, opportunistic, and reactive. In contrast, CPOE systems and decision support systems are based on a different model of work: one that is objective, rationalized, linear, normative, localized (in the clinician's mind), solitary, and single-minded."(Wears and Berg 2005) This characterization of clinical work should look very similar to the socio-technical dimensions I outline above. In the next section, I will reflect on the latter part of Wears and Berg's statement and why an ecological approach to the study of CPOE is needed.

1.5. Why order-entry is different from word processing

The fundamental question that arises from the design of human-computer interfaces is whether to give priority in the design process to the needs of user or to the system with which the human is attempting to interact. The third category of design philosophy, a normative approach that gives privilege to neither the user nor the system, but on the intentions of the designer is rarely recommended.

"User-centered" approaches are justified based on the design philosophy that the purpose of the system is to serve the user. Therefore the first task of the designer is to understand users.(Gould and Lewis 1985) On the other hand, giving privilege to the system emphasizes the global context of work in which the user certainly is an important element, but only one element of a larger system. Vicente in fact comments specifically on hospital information systems:

> "information technology in a hospital is ultimately intended to increase the organization's' capabilities to achieve its goals, not to serve the idiosyncratic goals of each doctor or nurse using the system. If the organization as a whole is to function effectively, the immediate goals of the individual users need to be subservient to, or at least consistent with, the overall purposes of the organization. Consequently, if information technology is to contribute to

> effective operation, the design of human-computer systems must begin by considering the functions of the global setting in which work takes place."(Vicente 1990)

Vicente makes the distinction between correspondence and coherence work domains, of which hospital systems are an example of the former. Correspondence-driven work domains contain goal-relevant, dynamic constraints that influence human-computer behavior and therefore in order to perform successfully, the worker's beliefs about the system must correspond to the actual state of the world. In addition to hospital systems, correspondence work domains also include automobiles, airplanes and nuclear power plants. How best to relay information and the structure of the environment to the user are critical choices in the design of computer systems to support these domains. When computer systems do not relay information that corresponds accurately to the environment, accident occur such as the Three-Mile Island nuclear disaster where operators were led to believe a critical valve was closed when it was still open.(United States Nuclear Regulatory Commission 2009) An example of environmental errors are described by Koppel as "Late-in-Day Orders Lost for 24 Hours" errors when patients leave surgery or are admitted late in the day and orders are requested for "tomorrow" when it is technically already "tomorrow" in the early morning and patients do not receive medications until the following day.(Koppel, Metlay et al. 2005) Kaushal reports dosing and frequency errors as the most common type of pediatric inpatient medical errors.(Kaushal, Bates et al. 2001) If the computer system better reflected the environment of what was ordered and administered, perhaps these errors could have been prevented.

In contrast, coherence work domains do not contain physical or social realities outside the worker and the computer.(Vicente 1999) Examples of coherence work domains include chess or word processing. One can argue that users are influenced by external contexts that drive the need for word processing, but those needs are not inherently time-driven or dynamic and could be programmed into the system as (changeable) static constraints. I illustrate this distinction between the two types of work domains to set the stage for employing a systems-based, ecological analysis framework for the study of clinical work and ordering that has been miscast as a coherence work domain when it is in fact a correspondence work domain.

1.6. The need for a formative, constraint-based, "ecological" approach

Clinical work, including work related to physician decision-making and ordering, is correspondence-driven, influenced by external social and physical demands and subject to unpredictability and hazard. Understanding the work environment and work context will allow for designs that include accurate representations of environmental variables and relationships. The best way to represent the data gathered about the work environment is in terms of constraints.

Rasmussen identified three general work analysis approaches that have emerged in the systems engineering and human-computer interaction field: normative, descriptive and formative (Vicente 1999).

The *normative* approach employs the perspective of the "one best way" to perform a task or work. It is often defined as describing how the system *should* behave by defining a set of instruction-based models describing tasks. This approach is most successful in highly regular work settings, but is neither flexible nor adaptive enough for complex socio-technical environments.

The *descriptive* approach analyzes current work practices or how the system *currently* behaves. While this analysis is valuable, from section 1.5 it should be apparent that the distributed and dynamic nature of complex socio-technical systems, both in terms of work and in terms of the unpredictability clinical situations, necessitate new methods of work in order to maintain system (i.e. patient) safety. Because the descriptive analysis focuses on the current state, it does not ask whether the current practices are the best practices or just habitual practices and work-arounds, and it also assumes that the entire system can be represented by descriptions of its parts.(Vicente 1999) In addition, the introduction of new computerized systems intrinsically changes "current" work and immediately requires a new analysis of work.(Carroll and Campbell 1989) This phenomenon has already been noted in implementations of CPOE, most notably as Ash et al's "unintended consequences." research (Aarts, Doorewaard et al. 2004; Wears and Berg 2005; Ash, Sittig et al. 2007)

Because of the limitations of the normative and descriptive analysis, Rasmussen and Vicente advocate a third option, a *formative* approach. The formative approach to analyzing work focuses on identifying social and physical requirements that must be satisfied to perform the work successfully. It is often described as analyzing how the system *can* behave. This approach does not describe a set of tasks, idealized or existing. Instead, it defines a set of constraints to support and promote future work practice.(Vicente 1999)

Constraint-based approaches should have the flexibility to handle unpredictable events because it lays out a set of safe and possible actions for the user to choose a path towards goals. Users' need to make choices based on their contextual situations because complex socio-technical systems are pre-disposed to unanticipated events that cannot be predicted at the time of system design. The term "ecological" is used to describe such approaches because of their origins in Gibson's Ecological Psychology that describes a relationship between human perception and behavior in the relationship between the human and his or her environment.(Gibson 1979; Gibson 2000) The perceived environment affords resources and properties that the human may or may not use. The affordances are primarily facts about actions and interactions, not perception. For instance, as Gaver explains, paper affords multiple input methods (pen, pencil, printers, brushes) while computer systems have one input, typing, resulting in far less flexible affordances for input.(Gaver 1996) Paper affords portability and transformational properties (folding, tearing etc.) that computers do not. Therefore the constraint-based approach I have chosen is ultimately describing the affordances of multiple physical resources that permit the human workers to achieve goals flexibly.

I have now explained why I chose a formative, constraint-based analysis method (CWA) for this research. As with any study, it is important to define the boundaries of the phenomenon of interest, hereafter called the "work domain." The work domain is the unit analysis of a work analysis study and in the next section I will define the work domain of this research.

1.7. Unit of Analysis

The intention of this research initially was to focus on ordering and decision support systems for ordering based on my previous work on CPOE alert override rates(Lin, Payne et al. 2008). However, after preliminary observations at Seattle Children's, I decided to focus on the work of the team and on ordering as a multi-faceted task within a larger system of team-based care.(Lin and Gennari 2007) The team-based nature of decision making and order entry necessitated the shift away from ordering and towards the team and how they work together and make decisions that ultimately end in orders. To quote Wears and Berg again, while hospital settings are complex, dynamic and social-technical, "CPOE systems and decision support systems are based on a different model of work... Such models tend to reflect the implicit theories of managers and designers, not of front-line workers."(Wears and Berg 2005) It was this contrast between system intention and work environment that motivated me to study the work of inpatient teams not individual physicians. Similar to Hutchins' seminal work on the study of aviation cockpit crews, my goals was to examine a socio-technical system, not an individual mind, as a primary unit of analysis.(Hutchins 1995)

According to Singer and Churchman and the subsequent work of Mitroff and Linstone, problems in complex and dynamic environments or organizations are multi-disciplinary and highly integrated.(Churchman 1971; Mitroff and Linstone 1993) In addition to poor drug-drug alerting, resident burnout, depression, physical and emotional exhaustion, interruptions and inexperience may also lead to medication errors and poor decision-making.(Thomas 2004; Institute for Safe Medication Practices 2008; Stucky, Dresselhaus et al. 2009) Fatigue has been shown without a doubt to impair human performance and to be the equivalent of alcohol intoxication and residents report that fatigue is a common complaint among residents and a cause for errors.(Gaba and Howard 2002) Improved inference engines are among the possibilities for addressing these issues, but other recommendations include better familiarity with the environment and better sign-out procedures which fall into the category of environmental and social changes rather than specific human-computer displays.(Volpp and Grande 2003) I will discuss this further in Chapter 5 Design Implications, but this research analyzes clinical work and patients as intentional systems rather than as a technical (i.e. biological) system. The latter is saved for future research as part of integrating biological and pharmacological decision support into order-entry systems.

1.8. Specific Aims of this Research

I have introduced the motivation for this research, my long term research goals and presented a case for using new methods for analyzing clinical work. I have explained why clinical work requires a formative, constraint-based approach to work analysis. I will now outline the specific aims and work products of this dissertation.

AIM 1 – Perform a qualitative field study of the work of inpatient, pediatric medicine teams using a formative, constraint-based, systems framework, Cognitive Work Analysis and qualitative field methods.

AIM 2 – Analyze the data using each of the five phases of CWA focusing on ordering.

AIM 3 - Illustrate ecological interfaces to clinical work based on a constraint-based approach.

The overarching goal is to demonstrate a cycle of a software design process beginning with a qualitative field study of a subset of the clinical workers and ending with design products. The goal of the field study and subsequent analysis was to characterize and cast the work of inpatient physicians and to study ordering and understand the environment in which ordering occurs.

It is important to acknowledge that hospital systems are very large and complex with multiple users from technicians to clinicians to administrators and increasingly, patients. Ordering directly or indirectly influences or is influenced by all of these roles, and from an ecological perspective of work analysis, there are many legitimate work domains for a study of an inpatient ordering. In large systems, one set of users may not realize the effect of other users of the same system, hence from a systems perspective, it is incumbent upon the researcher or engineer to identify the totality of the ecological landscape and capture all the necessary data.

1.9. Outline of this Dissertation Document

In Chapter 2, I shall first outline the methodology and specific methods of this work. I will provide background and a theoretical explanation of Cognitive Work Analysis. I will discuss the fieldwork done for this study including the participants of this study, how I gathered data and the types of data gathered. I employed observations, interviews and gathered documents and physical artifacts and then analyzed these data using multiple methods to provide stronger validation. I used both inductive and inductive methods of coding. I employed "open coding" deductive techniques for examining the data and discovering themes and phenomena. However, I also used an analysis method that I will discuss in this chapter, Cognitive Work Analysis, a socio-technical framework developed from the study of complex systems that formed the basis for my deductive coding.

In Chapter 3, I will discuss the qualitative results of the inductive and deductive analysis of the interviews, observations and document collection. I will present several key themes from data about the work of inpatient physicians. The three themes are: Patient Project Management, Team Management, Personal Time Management and Education. These themes represent the functions of the inpatient medicine team.

The four themes integrate directly into one of the CWA work products I will introduce in Chapter 4. In this Chapter, I will present results from each of the five phases of analysis in CWA that begins with modeling the work domain independent of tasks, strategies, roles and people and ends with worker competencies. To support developing practical and reproducible methods using CWA in healthcare domains, I will illustrate the creation of system and software requirements based on CWA work products. While the primary qualitative results are presented in Chapter 3, I will where applicable, present additional qualitative data to support specific modeling choices.

Chapter 5 contains a potential interface designs for software to support the work domain. It is a reflection of the results of this analysis, but as I will discuss, it is an illustration only one potential approach to this problem space. I will show how this design supports the systems requirements and the ecological and holistic approach of Cognitive Work Analysis to support workers and provide flexibility and responsiveness to unanticipated events.

Finally in Chapter 6, I will discuss the implication of this research and reflect on the experiences of this research and discuss the extension of this work in order to move towards a practical implementation of these results. It was my intention to develop a method for the practical employment of Cognitive Work Analysis, and in some respects, I have shown how CWA could be employed. Here I will discuss whether these methods can be generalized to create an easily reproducible engineering method.

1.10. Concluding Remarks for Chapter 1

In this chapter, I have introduced the motivations for this study that include the work-technology gap between CPOE systems and their benefits with low adoption rates and reports of poor support of work. My work aims to study and propose solutions for this gap using a constraint-based analysis approach. I have made a case for why a constraint-based approach is appropriate for the study of CPOE and instruction-based approaches are inadequate and cannot adapt to unanticipated situations which a major source of accidents in complex systems. I introduced my long-term research goals and the specific aims of this dissertation. Now I will present the results of this research, beginning with a discussion of the background and methods in Chapter 2.

Chapter 2: Background and Methods

The goal of this study is to understand how clinicians in an inpatient medicine service in a major urban children's hospital work and to specifically focus on the work surrounding orders and ordering. In Chapter 1, I outlined the motivation for this work as well as why new approaches are needed. I explained why clinical work can be considered a complex socio-technical system and I have provided an argument for using an ecological, constraint-based approach to systematically analyze clinical work. I briefly touched up on the method I chose, Cognitive Work Analysis (CWA). Here, in Chapter 2, I will now describe Cognitive Work Analysis and its background and history.

In the latter half of this chapter, I will explain the methods and procedures of this research. I will describe the participants, the data gathering methods and analysis methods. I will discuss how I began with CWA as a conceptual framework, gathered qualitative data and analyzed the data.

2.1. Cognitive Work Analysis

Cognitive Work Analysis is an analytical framework for the analysis of complex socio-technical systems and the human system integration of the design of supporting technical applications.(Rasmussen, Pejtersen et al. 1994; Vicente 1999) Growing out of work in Task Analysis, Rasmussen and his colleagues at the Risø national laboratory in Denmark studied the safety in the nuclear power industry (especially in the wake of accidents such the Three Mile Island in 1979) using observations and interviews. Combined with subsequent studies of aviation and manufacturing, their realization that complex socio-technical systems must be analyzed from multiple perspectives (e.g. organizational values, the work domain itself and the capacities of the workers that I will explain below) represents the evolution of task and work analysis.(Crandall, Klein et al. 2006)

At the core of seeking a new ecological perspective on order entry and physician work is the belief that the problems humans face are complex. These ideas are predicated on Edgar Singer's systems approach and C. West Churchman's extension to Singer's work to a modern systems approach.(Churchman 1971; Mitroff and Linstone 1993) Singer supposed he was measuring the distance between A and B. The simple action would be to get out a ruler and measure. However, this reduction of the problem overlooks potential human psychological or biological issues of the measurer or communication and political issues if there are teams of measurers. It would be too much to discuss Singer and Churchman's philosophies in great detail here, but as described by Mistroff and Lindstone, "Singer showed that every one of the sciences and professions known to humankind was involved in the act of measuring the distances between A and B."(Mitroff and Linstone 1993) Furthermore, Singer believed "there were no elementary or simple acts in any science or profession to which supposedly more complex situations could be reduced." No science is superior or subsumes any other science. This leads to the belief that since the problems of humans are complicated, their complexity must be recognized and *managed as a system,* and when models fail to explain a phenomenon, new variables and laws are "swept in" to provide guidance and overcome inconsistencies while not sacrificing quality or integrity.(Nelson 2003; Parrish Jr. and Courtney 2009) In the context of this research, the study of CPOE cannot be wholly explained by statistical analysis (Bates, Teich et al. 1999), informatics (this work), cognitive psychology (Horsky, Kaufman et al. 2004), organizational analysis (Ash 1997; Lorenzi and Riley 2000), communication (Gorman, Lavelle et al. 2003), and anthropology (Sittig, Krall et al. 2005) to name a few of the sciences that have a played a role in understanding ordering and CPOE. Thus, the CWA approach is multi-dimensional from work domain to worker competencies that focus on mapping behavior-shaping constraints that influence information behavior but cannot be changed by it. A constraint-based approach leaves degrees of freedom (but not total freedom) for the worker to "sweep in" and out the variables that they need to resolve conflicts and explain phenomena.(Fidel and Pejtersen 2004)

Sanderson in (Sanderson 1998) summarizes the key attributes of CWA that differentiate it from other human factors methods:

- It relies upon the integrated input of the methods of multiple disciplines (the 5 dimensions of CWA with in the work environment as seen in Figure 2.1 represent different disciplines within engineering or human sciences) rather than being connected to a single discipline.
- It is a systems-oriented rather than psychologically-oriented approach, even though in many places it uses psychological theory.

- It is ecological in motivation. Rather than modeling activity and mental models and using the results as a basis for design, it models the ecology in which activity and conceptualization is possible. The ecology systematically constrains activity while offering possibilities for action.
- It models not just activity, but also the context in which activity takes place. This arises from a recognition that the ecology in which humans act exercises a strong determining role in the possibilities for action (e.g. through Gibson's affordances)
- It supports the design of "ecological" interfaces that support human activity in as workload-free a manner as possible through direct perception. (I will explore these interfaces in Chapter 5)
- It allows design of new systems to proceed in a way that is relatively independent of previous technical solutions. Therefore it is a form of analysis that is neither normative (actively dictating how activity should proceed) nor descriptive (passively describing existing activity), but instead might be called "formative" because it points to the future form of an interface, with the intention that the interface will be formative in leading the human to the most effective behavior.
- It aims to design interfaces that are uniquely suited to support human activity in situations previously unencountered, particularly where those situations may involve high risk.

One of the criticisms of CWA remains that the concepts behind the models are not easily understood and therefore gathering information to construct CWA work products as well as understanding the concepts behind the constructs can be challenging. (Lind 2003) I will next describe the six dimensions of CWA shown in Figure 2.1 The Work Environment is a the 6th level, but it is a boundary condition that does not have its own analysis methods.

2.1.1.1. CWA Dimensions

Cognitive Work Analysis (CWA) approaches system engineering in complex socio-technical environments a framework developed using a constraint-based approach rather than a task based (instruction based) approach.(Vicente 1999) In order to provide the proper constraints for the actors, CWA provides a conceptual framework that provides 6 inclusive levels to perform work analysis as seen in Figure 2.1. Proceeding from the broadest (Work

Environment) to the most narrow (Worker), each level must obey the constraints of its parent levels and together comprise a complete work analysis description of the system. I will now briefly discuss each level and what aspects of the system it describes.

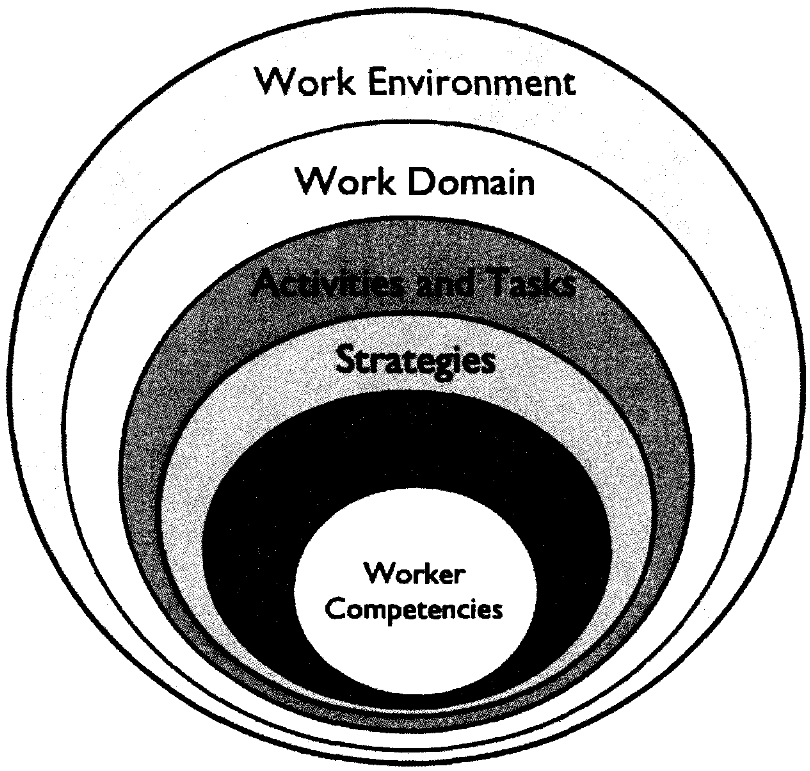

Figure 2.1 The Dimensions of Cognitive Work Analysis. Adapted from Vicente and including Rasumussen's transition from Work Domain to Tasks through Activities Analysis.

Work Environment: This level is the broadest and defines the constraints in the environment that cannot be affected by workers. Elements in the work environment include physical buildings and rooms, laws and other external social constraints.

Work Domain: This level asks, what are the overall system dependencies and linkages independent of any actors, tasks, goals? This domain includes descriptions of the work domains' purpose, physical resources and measurements independent of tasks used to do work. This level focuses on the *nouns* associated with the work domain and describe goals, physical resources and the functions that link to the two.

Activities and Tasks: This level focuses on what work or tasks needs to be done to fulfill the purpose of the Work Domain. The tasks are independent of how or who fulfills them. This level is specified to support actors to deal with known, recurring classes of situations.(Naikar 2006) This level focuses on the *verbs* associated with the work domain.

Strategies: This level asks how the Control Tasks can be achieved independent of any actor. It recognizes that there could be many strategies to achieve a particular Control Task and that actors may use one or several simultaneously. It is important to note that as with every level, Strategy should support all the strategies possible, not just the optimal strategy (normative) or the ones in current use (descriptive).

Social-organizational Analysis: This level focuses determining how work is allocated in the social domain as well as how workers coordinate, communicate and work collaboratively. Hutchins study of naval crews showed that workers are not isolated in their information processing.(Hutchins 1995) Rather, workers collaborate and communicate in order to accomplish tasks.

Worker Competencies: This level focuses analyzing the cognitive capabilities of the actors in terms of skills, rules and knowledge-based activities.

2.1.1.2. Focusing on the prototypical

In CWA the primary focus is to define prototypical cases. We must identify and support the prototypical work and separate these actions from the work-arounds that are temporary stop-gaps on the way to achieving goals. For instance, in the case of ordering, entering the order in the computer, checking past order history and reviewing dosage are prototypical work actions. Calling the nurse to be sure an order was executed or calling a consulting physicians to verify an order are work-arounds. By modeling the prototypical and proper function of a system, workers can better identify unanticipated events and faults. Subsequently, they will be able to recognize when the system has returned to a normal functioning state through new strategies and actions.

2.1.2. Cognitive Work Analysis in Multiple Domains

Cognitive work analysis was used in its earliest forms as Rasmussen's Cognitive Systems Engineering for the development of a Dutch library system, The Book House and then later as CWA in the development of a thermohydraulic process control system, DURESS.(Pejtersen 1992; Vicente 1999) Vincente is clear that not all dimensions and analysis methods of CWA need to be used equally in the design of systems, including DURESS which is built using work domain analysis and worker characteristics analysis. Because WDA is most mature and well-understood analysis method within CWA, including forming the basis for ecological interface design, most studies that use CWA focus on this level and control task analysis, the second phase of CWA.(Bisantz and Burns 2009) CWA has been applied to early stage system design of naval ships (Bisantz, Roth et al. 2003), designs for air defense systems including training and evaluation (Naikar 2002), air traffic controller weather displays (Ahlstrom 2005), comparing military contractor design proposals (Naikar and Sanderson 2001), nuclear power (Olsson and Lee 1994) and manufacturing (Higgins 1998). The majority of these work domains are highly structured domains that are governed by the laws of nature. As seen in Figure 2.2, these work domains fall to the right side of the spectrum while on the other side are social and actor-intentioned domains such as The Book House library system.(Pejtersen 1992)

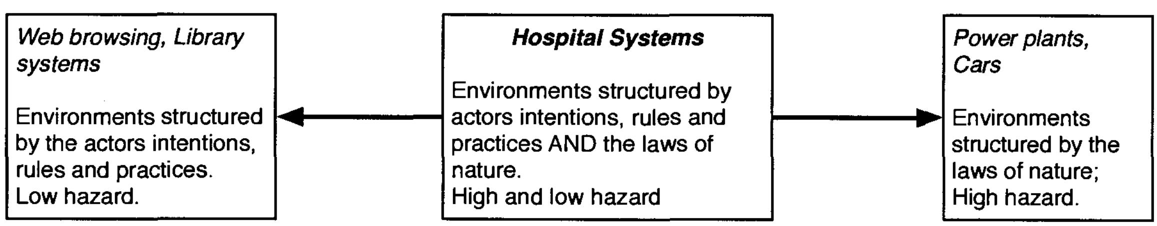

Figure 2.2 The balance between low hazard intention driven environments and highly structured, hazardous environments governed by the laws of nature. Hospital systems tend to fall in the middle as they contain both intentional practices and policies of patients, providers and administrators as well as the laws of nature such as biological systems and pharmacological interactions. In addition, hospital systems contains both lower hazard work such as transporting patients or hospital administration, but also the high hazard work of treating patients.

More recently, researchers have been focusing on further developing techniques and research frameworks for the final three stages of CWA, the Strategies Analysis, Social-Organization and Worker Competency Analysis, but these areas are still in development.(Bisantz and Burns 2009)

2.1.3. CWA in medical domains

Previous application of cognitive work analysis and work domain analysis to medical domains have focused on investigating whether or not biological systems can be modeled using a framework derived from the study of control systems. Miller and Sanderson argue that biological systems are intrinsically different from the industrial process plants that were the basis for CWA primarily because the control mechanisms in a biological system reside in the organism whereas in a control system (i.e. nuclear power), the operators are able to control the system.(Miller and Sanderson 2000) Examples of CWA application biomedical domains include Hajdukiewicz's work modeling biological functions and Sharp's work describing the biological functions necessary for neonatal ICU monitoring and Effken's work in ICU displays.(Sharp and Helmicki 1998; Hajdukiewicz, Vicente et al. 2001; Effken, Loeb et al. 2008) More recent applications of CWA in medical domains include characterizing patient falls (Lopez, Gerling et al. 2010), inpatient medication management(Pingenot, Shanteau et al. 2009) and cardiac care nurses.(Burns, Enomoto et al. 2009)

2.2. Methods

In this section I will outline the study methods I used in performing this research including participant recruitment, electronic tools and approaches to analysis and validation.

2.2.1. Defining the Work Domain

The first step in a cognitive work analysis study is determining the boundaries and scope of the phenomena under scrutiny, that is define the boundary of the work domain. In Chapter 1, I explained that I decided to focus on ordering within the context of the work of the physician team. Thus, the definition of my "work domain" is the inpatient medicine teams at Seattle Children's. The teams consists of physicians and supporting administration staff and have regular interactions with other clinicians such as pharmacists, nurses, nutritionists and multiple subspecialities. Since the focus of this study was motivated by improving physician ordering, I limited my study participants to the work of physicians and only the physicians directly on the team. I did record the interactions with other team members such as administrative staff and nurses, however the interactions were analyzed as part of the work domain that focused on the physicians.

2.2.2. Study Design

The culture and experiences of workers and a workplace cannot be easily quantified. The data cannot be easily gathered in a laboratory or controlled experimental environment. It was central to the goals of this research that the data be gathered in-situ, that is, in the workplace itself with the workers behaving naturally. Trends in decision making research showed that expert decision making in naturalistic situations diverges significantly from the behavior observed in artificial laboratory settings.(Roth 2008) However, what does it mean to gather data "naturalistically?" No one source of data is able to provide a complete and comprehensive perspective of the phenomena or in our case, the work domain of general inpatient medicine teams. Multiple data sources also allowed me to triangulate and validate my data. Thus, I chose to three data collection methods: observations, interviews and document collection.

- *Observing* the participants as they work allowed me to see how they behaved. It is possible that my presence changed their behavior. As the only researcher for this study, it is possible that I was unable to see everything and all tasks, especially tasks that involved use of the computer as without interfering in a crowded workroom, I typically did not intrude upon the participants as they performed computer work and only observed from afar.
- *Interviewing* the participants using a semi-structured interview method allowed me to explore the emotions and thoughts of participants, something I could not ask while they were working. It also allowed me to verify what I saw and discuss the reasons and thinking behind observed behavior. I could also compare what participants say they do with what they actually do.
- *Collecting Documents* is a method for understanding how things "should be." That is to say, how a procedure should be carried out, what the official policy of the hospital is. It also allowed me to understand the types of information resources, note taking methods of the participants as well as how they used documents to communicate with each other.

These methods are part of a larger body of methods for eliciting requirements for software that are influenced from the anthropology domain.(Nuseibeh and Easterbrook 2000) (Maiden and Rugg 1996) These techniques have also been used in medical informatics studies to evaluate CPOE systems (Ash, Gorman et al. 1999)and to develop new health informatics technologies.(Gorman, Ash et al. 2000)

Qualitative fields studies including observations and interviews were employed by Rasmussen to develop the original CWA framework.(Rasmussen, Pejtersen et al. 1994) Pejterson also employed observations and interviews of library patrons in one of the earliest uses of CWA to develop a library retrieval system.(Rasmussen, Pejtersen et al. 1994) , Effken, Burns and Fidel also employed observations and interviews in their CWA work.(Fidel, Davies Rachel et al. 1999; Effken 2002; Burns, Enomoto et al. 2009) Not all CWA studies employ fieldwork as many rely only on domain experts to develop CWA work products or technical schematics. However a combination of document analysis, work setting observations and informant interviews will help the researcher uncover constraints.(Naikar, Robyn et al. 2005)

2.2.2.1. Observation Data Collection

The purpose of observations is to "learn what is taken for granted in a situation and to discover what is going on best by watching and listening."(Richards and Morse 2007) I started my time with each team with observations so that I would have some context for the interviews as well as make the participants feel more comfortable with me as a researcher.

As I am not clinician, my approach to observations was as an outsider. The decision to do so was both because it is impossible for me to be a professional insider, but also because the strength of this research comes from the ability to see the work that clinicians do not as a mysterious scientific endeavor, but as specialized work. Forsythe has also argued that ethnography (which I did not *explicitly* perform) is best carried out by outsiders with considerable insider experience.(Bader and Nyce 1998; Forsythe 1999) She argues that it is not the job of the researcher to replicate the insider's perspective, rather to analyze it through comparisons between inside and outside views.

However, I adapted the anthropological perspective to fit into the work setting without using disruptive data gathering techniques. I found the best way to take notes was both by hand when using the computer was impossible, but also to write on my computer unobtrusively when the team was working quietly in the team rooms. I discovered that if they felt I was looking at them, they would become very uncomfortable so it was necessary for me to blend in by looking as if I were working along with them on the computer.

While I would spend a lot of time in the team rooms, I used the following methodology to guide where I would probe further and do more specific observations:

- Following **participants**

  I followed a participant, first focusing on interview participants and then by role as times permitted
- Following a **case**

  If a particular patient case resulted in a unique ordering work flow or work experience that I followed it, independent of which team members were working on the case.
- Following an **artifact**

  Workers used a combination of computerized records and physical records. I followed a particular physical artifact as it changes hands and was used by workers.
- Observing a specific **event**

  There are well known events where unique ordering cases occur such as admitting, discharging or during rounds. I specifically observed these events with a variety of participants.

Observations permit studying participants working naturally and behaving in ways they might not be able recall accurately during an interview. One challenge however was to remain attentive on a particular observation focal point. The team is large and there are many simultaneous tasks and actions being done by all team members consisting of phone, computer and written work. The junior physicians are very busy, tired and harried and it was often that I was reluctant to interject and ask them to take the extra time to explain what they were doing or think aloud. I preferred to take notes and ask at a later time or during the interview.

I spent a total of twenty-one (21) full days observing in the hospital including weekdays, nights and weekends. Weekday observations usually began at 8am and ending in the afternoon or when the night shift would begin roughly at 6pm. I spent two nights with the on-call team, sleeping in their overnight rooms and attending midnight patient meetings and observing night work. I also spent time in the hospital on the weekends.

There was no individual compensation for the participating in the interview study. I reported to the IRB that I would bring the team snacks to thank them for participating. For each two-week rotation I observed, I purchased assorted food such as bagels, juice and fruit. This was greatly appreciated by the teams.

2.2.2.2. Interview Study

I interviewed as many of the physicians in the observation studies as I could. I used the technique of semi-structured, open-ended interviewing which "enables the researcher to understand and capture the points of view of other people without predetermining those points of view through prior selection of questionnaire categories."(Patton 2002) I prepared an Interview Guide to "ensure that the same basic lines of inquiry are pursued with each person interviewer... the interviewer remains free to build a conversation within a particular subject area, to word questions spontaneously, and to establish a conversational style but with the focus on a particular subject that has been predetermined."(Patton 2002) An additional reason for picking the Interview Guide approach as opposed to a more structured approach where the questions are rigidly delineated or more loose informal conversational approach was that it provided enough structure so I was able to focus on the areas I needed to focus on while simultaneously providing enough flexibility that I could quickly edit the interview based on the time allowed.

Work Environment	What are the values of the institution? How is the hospital laid out?
Work Domain	What is the purpose of the team? What physical or information resources do they have access to? What are the goals of the teams?
Tasks	What are the things that must be done to carry out the goals of the work domain?
Strategy	What things do the workers do to make decisions or to carry out the tasks.
Socio-org	How does the team function? How are decisions made? Who does what?
Worker	Who is the physician? What is their background? Experience? What information resources do they prefer?

Table 2.1 General Knowledge Elicitations Questions for CWA Dimensions.

I started with a core number of basic questions that reflected the CWA framework derived from the experiences and prior questions of Dr. Raya Fidel from her CWA work. In the course of the interview, I then asked follow-up questions both to probe deeper into answers and for clarification, but also to triangulate on answers from other interviews or observational data. The core questions were submitted an approved by the IRB committee. Table 2.1 shows how the questions relate to the CWA dimensions. The complete interview guide is presented in the Appendix.

While I started with a large number of questions related to each of the 6 dimensions of CWA, one of the most pressing variables during the interviews was definitely time. Although I wanted forty-five minutes to an hour of time per interview, often the physician could only carve our a few moments for me during the day, usually fifteen to twenty minutes. Even during that time, pages or calls would constantly interrupt us so the interview was not contiguous. In one rare occurrence, an emergency page interrupted an interview and that physician needed to drop everything and respond. He returned 10 minutes later and we resumed the interview, but we had lost that time, and I had to adjust re-focus on the most important questions.

Interviews with attending physicians were scheduled as some participants had more time as well as individual office space. Interviews with most participants took place on an ad-hoc basis. I knew that I would not be able to schedule any time and as a result would simply ask every day (possibly ad nauseam) if they had time. If they did and were willing, I found a private space to conduct the interview.

Interviews were audio-taped and transcribed by myself.

2.2.2.3. Document Collection

I was granted staff access to the documents available to the physicians. I was able to download files off of the hospital intranet, CHILD, as well as collect paper forms that the physicians use in their day-to-day work. I did not have access to patient files nor was I able to record any documents with patient information on them. Physicians have unique methods for managing their data so those physician data management records are described only in my notes.

The intranet contains documents that are available to all Seattle Children's employees. These documents reflect the culture, business goals and quality improvement programs that contribute to the understanding of the work environment and values of the institution. In addition, business procedures and medical guidelines are also stored on the intranet. I was able to copy or photograph public documents such as paper record forms including daily progress note forms and admission forms.

2.2.2.4. Journaling

Through out the study I kept personal notes on my experience so I will be able to return and reflect on my feelings as an observer and researcher. I also took notes on any small changes or questions on methodology I had or particular questions I wanted to make sure I asked in an interview. Changing my observation method to working in the team room unobtrusively was a change in methods.

2.2.3. Study Setting

The setting for this study was Seattle Children's, 250-bed pediatric teaching hospital located in an urban setting in Washington State. Seattle Children's provides 54 speciality and subspecialities services available to patients on an outpatient (non-hospitalized) basis. In 2009 there were 14,106 admissions representing 75,708 inpatient days.(Seattle Children's) In Chapter 3, I will present more data regarding Seattle Children's as a finding of this study.

2.2.4. Participant Profiles and Sampling

Seattle Children's a large and dynamic work environment with a large number of workers contributing to the work of the institution at any given time. I will now discuss how I sampled this work place to collect data for this study. I will also profile the workers who agreed to participate. I will discuss sampling, inclusion criteria and participant profiles separately for the observation and interview studies.

2.2.4.1. *Sampling for the Observation Study*

I used a combination of maximum variation purposeful sampling(Patton 2002) p234 and opportunistic sampling (Patton 2002) p240 for the observation portion of this study. Maximum variation allows common patterns to emerge from heterogeneity thereby underscoring their values as prototypical experiences – the goal of CWA. The inpatient medicine service is divided into three teams, each with different team rooms and covering different subspecialties, and I followed at least one rotation of each team. However, within a team, I observed an opportunistic sample of clinicians based on the immediate willingness of the team members. Recruiting was first done through email messages sent to identifiable potential participants followed up by an in-person consenting process of the clinicians who reported to work on a given observation day. Due to illness or other unforeseen circumstances, teams can be dynamic. I re-presented my study to the team members at the beginning of each period of observation and asked for participants and as new team members reported for work, replacing other members, I invited these new workers to participate as well.

2.2.4.2. *Inclusion Criteria for Observation Study*

To be included in the observation study, participants needed to be assigned to work on the designed team for a given observation period. Primarily, this included physicians, but teams are assigned supporting staff and can included students and other observers as necessary.

In order to keep the scope feasible, I only considered physicians on the general pediatric inpatient medicine service as part the participant pool. An inpatient service treats patients who have been admitted to the hospital as opposed to those who are seen in clinic or in an outpatient setting. General pediatrics is the service that covers patients not otherwise admitted to a specific sub specialty (i.e. Psychiatry, Cardiology) or a specialized level of care (i.e. Neo-natal Intensive Care Unit (NICU), Medically Complex Child (MCC))

Participants were employees of Seattle Children's, enrolled in the Graduate Medical Resident Training program or students and employees at the University of Washington. In addition some participants were enrolled in medical training programs at other hospitals and working temporarily at Seattle Children's to gain pediatric experience.

While certainly the generalizabilty would be better proven if the scope of the study were wider and considered all physician roles and specialities, this would be the goal of a more comprehensive, future study. The choice of a general pediatric inpatient medical service provides a feasible enough scope, but with enough potential participants since all residents must rotate through this service to provide a large enough sampling pool.

Observation Participants

A total of forty-six (n=46) workers agreed to participate in the observation portion of this study and forty (n=40) of those were physicians or medical students. Tables 2.2 and 2.3 show descriptive statistics of these participants. 69.6% (32/46) of the observation study participants were female and 30.4% (14/46) were male. The majority of participants were physicians (31/46) or medical students (9/46). The remaining participants consisted of three registered nurses and three support staff members who were also part of the team during the observation period.

Female	32	32/46 (69.6%)
Male	14	14/46 (30.4%)

Table 2.2 Participant Genders

Nurse	3
Intern	14
2nd year Resident	4
3rd year Resident	9
Attending	4
Total Physicians	31
4th year medical student	4

3rd year medical student	5
Total Medical Students	9
Care coordinator	1
Team coordinator	2
Total Staff	3

Table 2.3 Participant Roles (total n=46)

2.2.4.3. Sampling Strategy for Interview Study

For the interview study, I interviewed a smaller, convenience sample of physicians and medical students who participated in the observation study. I sent emails to the attending physicians who were able to find office time after their service was completed. For residents, scheduling interviews proved exceedingly difficult and I discovered the best way to recruit these busy physicians was to make myself as available as possible and immediately conduct interviews if they were able to find any time at all. Thus the interviews were conducted in any private meeting or conference room convenient our current location.

A qualitative approach promotes flexibility, an important factor in this research. I designed my interview instrument to be completed in an hour, but this was not always possible given participants' busy schedules. In reality some participants were able to speak for over an hour uninterrupted, while others could only give 15 minutes or even half an hour with several high priority interruptions. Thus, I had to adjust my interview questions to focus on the key concepts to suit the allotted time. It was important that I convey to the participants that I was flexible because otherwise they would not have spoken to me had they thought they needed to commit an hour.

2.2.4.4. Inclusion Criteria for Interview Study

The participants in the interview portion of the study were a subset of the observation participations. Specifically, I focused on physicians. Any physician I observed qualified as a potential interview participant. While I could have expanded this portion of the study to include physicians I had not observed in situ, I felt it was necessary to have watched them work in order to have a better understanding of the context of their answers.

2.2.4.5. *Interview Participants*

A total of eleven (n=11) physicians and medical students agreed to participate in the interview study. This included nine (9) male and two (2) female physicians. Four (4) of the participants were attending physicians, one (1) 3rd year resident, two (2) 2nd year residents, two (2) interns, one (1) 4th year medical student and one (1) 3rd year medical students. I also spoke informally to two nurses to discuss communication methods with physicians, but I did not record those interviews and do not consider them part of my data set. Instead understanding the work of nurses remains part of future work.

2.2.5. Data Analysis

I employed both inductive and deductive analysis of the study data. I started with deductive analysis, followed by inductive, followed more deductive analysis as the models and representation became more concrete and validated by external researchers and subject matter experts. I used AtlasTI 5.0, a computerized qualitative analysis tool, to develop my codes, code families and quotations.

2.2.5.1. *Deductive Analysis*

I began coding with the six dimensions of CWA as outlined in Table 2.1 to begin to understand the data within the dimensions of CWA. After the broad coding using the core six CWA dimensions, I then coded for specific CWA analysis products. For instance, the abstraction decomposition model includes the physical resources of the work domain (i.e. computers, tables, phones) so I returned to the data to examine those elements. The decision ladder template specific to tasks includes data analysis processes that activate the need for action and data gathering and research processes so I returned to the qualitative data again to code for those dimensions after I had determined tasks through other CWA methods.

2.2.5.2. *Inductive Analysis*

Next I performed open-coding to discover major themes and ideas within the data. Where appropriate, I linked these themes back to the six dimensions of CWA. For instance, through open-coding, I uncovered a Project Managing Patients theme that I will discuss in Chapter 3. I then linked this code back to the Work Domain code as it is a function and purpose within the work domain and appropriate to that representation.

2.2.5.3. CWA Work Products

As stated in the introduction to this chapter, it was important for this research to use the representations that had already been developed for CWA. Of course, even those models are intended to be guidelines and so I allowed myself to adjust those models where I saw fit. Five of the six dimensions of CWA contain representation and analytical models. The three most well-developed representations are the abstract decomposition space used to analyze the work domain dimension (Chapter 3), the contextual activities template and decision-ladder used to analyze activities and tasks and social-organization analysis. (Chapter 4).

I also chose to use CWA because of its emphasis on representation over knowledge elicitation. Lintern notes that the while the engineering disciplines employ representation extensively, the behavioral sciences employ representation less, and then in an improvised fashion.(Lintern 2009) It was the intention of this work to lean towards the engineering audience that tends toward representation with typically less training in knowledge elicitation. This is not to say knowledge elicitation is less important and should is not in the engineer's purview, but it is my belief that without a representation goal, it will be difficult to translate collections of interviews, observations and discussions into meaningfully derived artifacts.

I used the Human Factors Integration Defense Technology's CWA Tool to develop CWA work products and graphical representations of analysis. This tool is described by Jenkins (Jenkins, Stanton et al. 2007) and available at http://www.hfidtc.com/cwa/cwa_tool.htm.

2.2.6. Validity

In order to verify my data, analysis and results, I used the following methods to validate my findings:

- *Triangulation of sources*: I checked the consistency of different data sources within the same type of data (interviews, documents, observations) and within participants of the same role.

- *Expert audit review*: I reviewed my findings with subject matter experts familiar with the methods, the field of study and the study setting. This consisted mainly of validating the representation and models due to the time constraints of the reviewers.
- *Theory/perspective triangulation*: As discussed above, I have used both inductive and deductive analysis methods. I used the CWA framework as the basis for my deductive codebook, but also open coded to discover new themes that fit within the CWA framework. These methods did not generate major conflicts, most likely because the work domain is so well-suited to the definition of Vicente's definition of a complex socio-technical system.

2.3. Concluding Remarks for Chapter 2

In Chapter 2, I further described Cognitive Work Analysis as a constraint-based approach. I detailed the six levels of CWA and I explained how CWA is different from other human factors methods through its emphasis on constraints and systems and departure from psychological methods. I describe the application of CWA in multiple domains including several medical domains. However, CWA literature remains sparse possibly due to its perceived inaccessibility. I have explained the design of my study including the types of qualitative data I gathered, the participants I interviewed and my sampling methods. I have also discussed my validation methods and deductive and inductive analysis methods. In the next chapter I will present my findings from the qualitative data analysis. I will begin with results from the deductive analysis and conclude with thematic results from the inductive analysis. The results of the additional coding based on CWA work products are presented in Chapter 4 as I describe the CWA results.

Chapter 3: Seattle Children's Inpatient Medicine Teams: Qualitative Data and Themes

To review what I have presented thus far: In Chapter 1, I introduced this study, my motivation and what I hope this research will address and discover. In Chapter 2, I discussed the background and theoretical underpinnings of this research and related work. I presented the specific methods and techniques I used to carry out the field study at Seattle Children's and the framework, Cognitive Work Analysis, that underlies this work. In this chapter, I will present the core data that was gathered during the field study. The data presented here will inform Chapter 4 and 5 where I present the models I developed using this data.

In Chapter 2, I explained the definition of each level of the CWA "onion" and the basis for the coding and codebook that I used in this analysis. Now, I present the data from the field study. The data are quotations from three primary sources: participant interviews, observational field notes and hospital documents including websites, posters and text documents. These excerpts of raw data are presented indented and in italics.

The results of this chapter are the presentation of the data from the two types of qualitative analysis I used, deductive and inductive. Deductive qualitative analysis is the analysis of data using an existing framework. In this chapter, the data are first presented loosely according to the CWA framework to reflect the deductive analysis I performed. The codes I used in this part of the analysis were derived directly from the 6 dimensions of CWA. I begin with Seattle Children's(3.1), and then I will follow with descriptions inpatient medicine teams (3.2) and finally an analysis of the physical resources (3.3). This chapter will introduce the bulk of the qualitative that I used to create the models and CWA results of Chapter 4. However, not all data included in the CWA products are presented specifically here. I will introduce quotes, observations and document data for specific CWA phases when I introduce those products in order to provide easier continuity between data and modeling.

Inductive qualitative analysis is discovering patterns, themes and categories as they emerge from the data. After presenting the data from the deductive analysis, I will re-orient the presentation of the data by discussing the themes inductively discovered through open coding. I will discuss the four work themes I identified, Project Managing Patients, Team Management, Education and Personal Time Management. These themes come directly from open coding of patterns in the data with a focus on examining work. These themes will reappear during the CWA analysis chapter that follows this chapter, making the final CWA analyses are products of a deductive and inductive analysis.

3.1. Seattle Children's

As seen in Figure 2.1, The Work Environment is the outermost layer of the CWA "onion." Very often, the data presented here would be described in a separate "study settings" section detailing the organization or site where the research was carried out or from where the participants were recruited and I have touched on the briefest of descriptions in those areas in my work. I conducted this study at Seattle Children's, a major tertiary-care children's hospital and research institute in Seattle, WA. The principle behind CWA is "modeling depends on identification of behavior-shaping constraints."(Rasmussen, Pejtersen et al. 1994) The outer most constraint on this work domain, is the work environment of the hospital itself within which the inpatient medicine service is subsumed. The work environment represents the outer most layer of constraints with the fewest degrees of freedom that influence behavior of the work domain itself in terms of its goals and functions which in turn influences the workers. Therefore, I present an extensive description of the study setting as data and findings, beginning with a discussion of the Seattle Children's.

3.1.1. Brief History of Seattle Children's

Seattle Children's was founded in 1907 and according to the institute itself was founded with the vision "to care for children regardless of race, religion, gender or a family's ability to pay." Since that time, the organization has expanded its programs, research and campus to become the 8th best children's hospital in the United States for General Pediatrics in 2008.(U.S. News & World Report 2008) Seattle Children's provides 54 speciality and subspecialities services available to patients on an outpatient (non-hospitalized) basis. The main hospital supports 250-beds including a Surgical Unit providing surgical , cardiac, nephrology and solid organ transplant services. Other units include a Level IV neo-natal intensive care unit (NICU) providing complete tertiary care NICU services and the highest level of care and Pediatric Intensive Care Unit (PICU), and a Medically Complex Child (MCC) unit evaluation and treatment for patients with disabilities due to illness, injury or congenital origin(Seattle Children's ; Committee on Fetus and Newborn 2004) and an Inpatient Psychiatry Unit. In 2009 there were 14,106 admissions representing 75,708 inpatient days.(Seattle Children's)

3.1.2. Patients

As a children's hospital, Seattle Children's provides medical care for patients from newborn until age 21. Although located in Seattle, Seattle Children's is the Washington, Alaska, Montana and Idaho pediatric referral center. Many families with children in the hospital have travelled and are temporarily displaced from their home communities. Patients may have chronic conditions or be admitted for a one-time event, but in general the illnesses of hospitalized children are becoming more severe.(Percelay and Committee on Hospital Care 2003) Lengths of stay in the hospital vary widely from overnight as a simple precaution to weeks and in 2009 the average length of stay was 5.1 days. Some admissions are known ahead of time such as a planned surgery or procedure and others are the result of emergency room visits or other unforeseen events. As a result of these variables and even though as I will discuss below, an aspect of the inpatient medicine teams is frequent staff changes, the physician experience with a patient varies from virtually no previous information to extensive familiarity with the families and medical case history.

3.2. Graduate Medical Education Training Program

The medical residency system of post-medical school training has been a long standing tradition in the education of new physicians (Roth 2003). Upon graduating from medical school, new physicians enter into an accredited training program for their first professional appointment. The length of the residency program varies from institution to institution and specialty to specialty. At Seattle Children's, the pediatric residency program is a three-year program and all enrolled physicians, known as "residents," are required to serve several rotations on the Inpatient Medicine Service during all of their three years. Residents in their first year are known as "interns" and physician in their second and third years are known as "seniors." The senior most physicians who mentor residents are known as "attendings."

In 1974, Seattle Children's formally adopted an affiliation with the University of Washington making it the primary pediatric teaching site for the UW School of Medicine. The 2008-

2009 Pediatric Residency Training program has 88 residents enrolled. In addition to general pediatric medicine and clinics, the he residents can receive additional training in adolescent medicine, allergy, congenital defects, child development, critical care, endocrinology, emergency medicine, genetics, hematology/oncology, immunology, infectious disease, neonatology, nephrology, neurology, pulmonology, rheumatology and teratology. To experience and learn a full range of pediatric medicine, a typical resident will spend a 4-week rotation on the general pediatric inpatient service (the "House" service), NICU, PICU, MCC and Emergency Department (ED) as well as rotations at other Seattle pediatric clinics and remote or rural clinics in the WWAMI area. Seattle Children's also provides pediatric residency experience for other residency programs that may not have pediatrics but require pediatric education in their programs. Thus the teams include both physicians who are part of the residency program together as well as physicians from outside the program with less familiarity with the hospital.

The residency training program is accredited by The Accreditation Council for Graduate Medical Education (ACGME) and as such must obey the work rules set down by the council. These include limiting duty hours to 80 hours per week, having one day in seven off duty. In addition, interns cannot be assigned on-call duties more than every third-night. These restrictions have shaped the assignment of resident hours including rules such as all post-call interns must leave the hospital by 1PM and interns are on-call every fourth night.

3.2.1. Physical Plant

The majority of clinical services (clinics, hospitals) are located at the Main Campus, a 24-acre site. Clinical research is located at two separate downtown Seattle locations and administrative services located in another building near the Main Campus.

The main hospital is a large sprawling building with five floors and five separate zones in a primarily residential neighborhood. The clinics are located in a separate zone from the inpatient wards. Within the hospital, the many physicians have their own offices, especially if they are employees. Residents however do not have individual offices, and typically work out of the team rooms and graduate medical education offices. The physician team rooms, spread over different parts of the hospital provide a central location for each of the physicians teams (I will discuss the teams and team members further on in this section). They also provide a temporary office for any physician needing workspace or a computer.

The décor of the hospital is very colorful from the decorations on the wall to the colors of the carpet. Each ward has a large animal statue or wall hanging indicating the theme and name of each hospital ward (i.e. "Giraffe", "Train", "Whale"). There are numerous other animal statues to create child-friendly atmosphere and generally the decoration style is cheerful and friendly.

The general pediatric hospital wards (separate from the NICU, PICU, MCC or Psychiatric Units) consist of a hub with a nursing station at the center and 4 or 5 rooms forming spokes off the wheel. The nursing station contains the patients' paper charts in a flip-top blue binder. Each nursing station has at one or two computers and additionally there are desktop computers nested periodically in nooks in the hallways. Some of the nursing stations are "island" designs, with tall desk chairs and standing height surfaces around which the clinicians can move 360 degrees while other nursing stations are situated like desks with low chairs and the nurses sitting behind the desk and the charts available in the front. Patients are not assigned physical locations in the hospital corresponding to the team responsible for their care so a given team's patients are dispersed across the hospital.

3.2.1.1. Team Rooms

I will now describe each team room in order to illustrate the primary work surroundings for the participants in my study who are assigned to one of three General Pediatric Inpatient teams ("House" teams) on a general pediatric inpatient rotation. The team rooms vary widely, but they all include table space, computers, whiteboards, bulletin boards, phones, a printer and basic office supplies such as pens and staplers and anti-bacterial hand lotion. Each room has a central table that in my observations usually also served as a food table, holding snacks or juice brought in by the physicians. There are no assigned office spaces since the teams change constantly. The team rooms are meant to generically serve whichever physicians are assigned to it.

The team rooms are busy and loud since they are shared, open offices. During the business week, it is a proverbial "hive of activity." As a shared office, there is constant communication from teammate, nurses or other staff who wander into the office to find people. As an example of how chaotic it can be, I followed one senior who at some point decided to avoid the team room. I observed:

> *[The senior] spends 15 minutes talking to the patients family but she doesn't want to go back to the team room because she says "she wants to get work done."*

I further observed that she meant she wanted to avoid the team room so she could focus on her tasks without interruption or distraction.

Team 1 Team Room

The Team 1 Team Room, located on the first floor of the hospital, is L-shaped with doors on opposite sides, one leading directly a nursing station and patient room block. There is very little space to move around and team members often bump into each other trying to navigate the room. The computers towards the rear entrance of the room face the wall while the computers in the main area face outwards like a classroom. On the walls hang two whiteboards, an unused x-ray illuminator and three bulletin boards. The team room is not orderly as shown in my field notes:

> *The room has coffee cups, Pepsi© cans and water bottles scattered throughout as well as the personal bags of all the doctors and toner cartridges stuck in one corner. The room is fairly stark and not very warmly painted and there are books and papers strewn throughout.*

Team 2 Team Room

Team 2's Team Room is by far the largest of the three team rooms and located on the second floor at the hospital. It is a square-shaped room with bench seating along one wall, whiteboards along another and tables with computer along the third and fourth walls. There are six computers and two phones but all the computers face the wall and there are no computers in the center meeting table. The one entrance to this room is down the hallway from the nearest nursing station. The center of the room holds a large meeting table comprised of two smaller tables pushed together with room plenty of space to walk around it. The personal bags and effects of the team are in a corner near the bench seating. As with all the team rooms, there are papers, bottles and cans strewn throughout but because of its size, the team room does not have the cluttered and more claustrophobic feeling of the other rooms.

Team 3 Team Room

The Team 3 Team Room is the smallest of all of the team rooms and is located on the second floor only a hallway away from Team 2's team room. The one entrance opens out to a nursing station. In my observations, this room appeared messier than the other team rooms, but it was possible that the small size of the room contributed to this observation. It is a cramped room with little space to move. Two walls have tables against them, and one a white board. The fourth has a small bulletin board and the door. A third table is located in the center of the room with the short end against a wall and the other end almost touching one of the chairs for the wall tables and holds a laptop computer. Together there are four computers and two phones.

GME Office, Overnight Rooms and Locker Rooms

For physicians needing to sleep overnight, the hospital provides small overnight rooms that contain a small bed and a computer. Resident meetings and teaching sessions are held in the Graduate Medical Education office. The meeting room is to the side of the administrative offices and has seating areas and computers.

3.2.2. Hospital Values

The "official" core values of Seattle Children's are published and available through the strategic planning and marketing materials online or through the public affairs office. The hospitals mission statement is:

> *We believe all children have unique needs and should grow up without illness or injury. With the support of the community and through our spirit of inquiry, we will prevent, treat and eliminate pediatric disease.*

Other core concepts in the hospital's vision statement include (paraphrased):

> *"excellent care with compassion and respect"*
>
> *"superior, accessible, cost-effective service"*

"attract and retain the best talent at all levels of the organization"

"be a top five pediatric research institution"

"be the nation's premier pediatric educators"

Although none of the participants I interviewed referenced the mission statement or strategic goals specifically, it was clear that many of the values presented in the official documents were nonetheless reflected in their work as they described their own sense of what they felt were organizational value especially family-centered care and efficiency. As I will discuss, among residents (physicians enrolled in the medical education program) cost-effectiveness was specifically not a goal.

3.2.2.1. Family-Centered Care

Children's prides itself on being strong advocates and employers of "Family-centered care," an approach embraced by the American Academy of Pediatrics that includes the families of patients as essential and central to the care of the child (Committee on Hospital Care 2003). The systematic inclusion of families in care discussions and decision-making is a key part of the philosophy of Children's and distinguishes them from other hospitals that may inform and discuss decisions with the patient and family, but not necessarily take steps to include them as part of the care giving team. It is worth noting that in the case of a pediatric hospital, by the nature of their patients, children, it is possible to include parents or guardians whereas with other adult patients, those caregivers might not be available so readily.

Family-centered rounds

The best illustration of the family-centered care philosophy of Seattle Children's is the family-centered rounds. Hospital rounds are a tradition in medicine, hospital care and the training of new physicians. During work rounds, the physician or physicians speak with the patient, perform a physical examination of the patient, determines the patients progress and any additional diagnostic tests or therapeutic interventions (Wray, Friedland et al.). In an academic teaching setting, work rounds also serve as an opportunity for teaching and training. Senior residents are able to lead and instruct interns on patient interactions, medical skills and communication and presentation of cases. Interns and medical students observe or participate with guidance and instruction their senior colleagues. The setting and context for rounds has been long discussed and debated in the medical teaching literature as there over the last 30 years there has been a decrease in patient examinations with the patients' ("bedside rounding") in favor of conference room rounds and discussions of laboratory and imaging results. However, the time to collectively discuss patients in a group setting remains a staple in medical culture and teaching (Thibault 1997).

At Seattle Children's, rounding is divided into two separate activities, "work rounds" and so-called "ward rounds" referred to only as "rounds" in the resident's handbook. Work rounds are conference room discussions of the patients that takes place in team room before and after the ward rounds. I will discuss activities and roles in work rounds further below. I will focus here on the ward rounds as an example of family-centered care. In February 2004, Children's instituted a new policy to round on the wards with an interdisciplinary team including nurses, care coordinators and discharge planner (team coordinator), pharmacists and social workers when before this time ward rounds consisted only of conference room discussions exclusively with physicians (Latta, Dick et al. 2008). This was to give the nurse who would explain the plan of care and physician thinking to the patients additional and more accurate information. Shortly thereafter, after a survey showed that the patients did not feel improved satisfaction, Children's changed their process of family-centered rounds directly including the families in the formal discussion and daily patient assessment. Families are informed when the discussion on their child is about to begin and they are invited to participate. Ideally this discussion will be held at the bedside of the patient (bedside rounds) to facilitate physician examinations and in-situ teaching, but this may not always be possible and the residents and attendings must determine and adjust the format and content of rounds based on the hospital census (how full the hospital is), the individual social or medical situation of the patient and the work load and time constraints of the team.

Patient and family surveys showed that the inclusion of families on rounds was an overall positive experience because of the ability for direct communication, better understanding of the child's plan of care and overall family empowerment. However, having a large interdisciplinary team including families can result in large discussion groups as the teams at times can have ten or more members not including families making for a difficult and crowded discussion environment especially if more than one of the teams, each with ten or more people are situated in the same confined area of the hospital. From my field notes:

There were 13 people on this team for rounds: attending, fellow, 2 seniors, 4 interns, family, CC, 3 med students 3 resident, pharmacist.

Additionally the effort to keep the language free of highly technical medical terms and concepts results in a trade-off between teaching the interns and medical students communication skills and medical knowledge.

The residents I interviewed who were the furthest removed from the strategic goals and missions of the organization seemed to have naturally absorbed these family-centered values:

We try to cater to families... It's very good for individual families to feel like they can make choices about their healthcare and it's good for the hospital because when people speak for the hospital they say they're at a place where they feel their needs are met.

I think it seems to me to be very catered towards patient satisfaction and towards quality of experience to patients and their families... I feel like there are a lot of efforts to make the families feel informed and comfortable a to make this not an intimidating place.

3.2.2.2. Continuous Performance Improvement and Strategic Mission

One of the key components to the operations of the hospital is quality improvement and the use of the Toyota Production System in a program known as Continuous Performance Improvement (CPI). The areas identified for continuous improvement are "Quality," improving the patient and family experience, "Cost" – maintaining financial health, "Delivery" – improving the access to services and "Safety" – providing a safe and healing environment. Examples of CPI projects include family satisfaction surveys and improving the process where patients are admitted into the hospital.

The five "pillars" of CPI at Seattle Children's are, Quality, Cost, Delivery, Safety and Engagement. As seen in Table 3.1, each of five pillars addresses a different area of improvement and is evaluated by different measures i.e. Quality is evaluated by family satisfaction rates while Cost is evaluated through financial calculations. In Chapter 4, and further in the appendix I will explain these quality measurements and how they are used in this CWA analysis and in the design proposals.

Quality Are we improving the quality of care and service we provide?	Cost Are we good stewards of our resources? Aare our services cost-effective?	Delivery Are we improving access o inpatient and outpatient services?	Safety Are we providing a safe and healing environment for our patients and families?	Engagement Are employees, faculty and referring physicians engaged and committed as we strive to attract and retain the best people?
Family Satisfaction	Clinical Division Cash Operating Margin	Inpatient Admission	Medication Reconciliation Rate (high)	Workplace Survey
Survival Rates	Cost per unit of service	Inpatient Days	Antibiotic Resistant Infections/Colonizations (MRSA, VRE, etc.)	
Adherence to Guidelines		% Inpatients Discharged Before Noon	Hand-hygiene compliance	

Table 3.1 Sample of Seattle Children's continuous quality improvement measurements. These results are included as Quality Measures of Success and Balances in the work domain analysis.

These processes were largely invisible to the residents that I interviewed. However, they did recognize that efficiency was an institutional goal. For physicians, one of the first indications of institutional support for efficiency is the availability of team and care coordinators to help the physicians manage their tasks and handle much of the bureaucracy. In addition, because Children's family-centered values, residents and interns are not pressured by attendings or senior staff to discharge patients and families if they are not comfortable even though it adds costs and takes up bed space in the overall system. For example:

It doesn't cloud our judgment in terms of we need to get them out because the hospital say so. We think of it as we need to get them out because the patient wants to go home.

Another resident expressed his favorable impression on the flexibility and generosity of the hospital:

Mom's nervous, that's totally a legitimate reason to stay. Whereas other hospitals they would have been like you're out, you know. Actually that was something that very much impressed me. Everyone was like, Mom wants to stay, Mom gets to stay.

It was clear from all sources of evidence, interviews, documents and observations that the physicians felt that care was not influenced by the ability of the patients to pay even though as several participants pointed out, novice physicians tend to order more tests to confirm diagnosis because they are unsure of themselves, thus wasting money. In fact, physicians specifically mentioned that an attractive quality of Children's is the large endowment and financial resources at their disposal. One attending remarked:

"...we have an incredible donor base. So, which may or may not be sustained in the current economy. But in general one of the great things about Children's is exactly that, that patients are never turned away based on their ability to pay, but of course that's not possible without tremendously generous donor base which we are blessed to have and other institutions are not."

3.3. Responsibilities of the General Inpatient Pediatric Service

"We're part of a group of docs known as primary care physicians. Family practice docs, pediatric docs, sometimes internal medicine docs can get lumped in there so within those 2 groups, you really have to know a little about all the body systems, so you have to know a little bit about the GI (gastrointestinal) system, neurology, cardiology, infectious disease to the level that you can practice effectively"

--Attending Physician

As part of the three-year residency program, all resident rotate through the general pediatric inpatient service as an intern in their first year, then as a senior in their second or third years.

The general inpatient pediatric team serves as a catch-all for hospitalized patients. This resident physician team, the "housestaff," under the guidance of an attending, cares for of all hospitalized patients who are admitted to the general wards, beds not in the PICU (Pediatric Intensive Care Unit), NICU (Newborn Intensive Care Unit), CC (Complex Care) and Inpatient Psychiatry services who treat the most critically ill patients needing more care. These patients may belong to the general pediatric "house" service or one the subspecialty services assigned to the team.

3.3.1. General Inpatient Team Goals

In this section I will discuss the general team goals. I will discuss the goals of individual roles in the Section 3.4. Not surprisingly, physicians reported the primary goal of the team was treating the patients admitted to the hospital and the secondary goals serving as a teaching hospital and educating residents and students. As discussed above, Seattle Children's actively engages in quality improvement program known as CPI that strives to improve Quality, Cost, Delivery, Safety and Engagement. Improving Cost and Delivery do not seem to play a large role in the goals of the team and their work functions. Although attendings are more cognizant and responsible for secondary factors of treatment such as cost or process improvement and in my observations would occasionally comment on treatment plans, the residents I interviewed readily admitted that while they knew that Seattle Children's emphasized efficiency and quality improvement, they felt no pressure to consider these factors for their work. Below are quotes from interns explaining that they do not feel pressure to cut costs.

> *Yeah, I have to admit I have no idea what most things cost, with a few exceptions, things like the ACTH we were hearing about that I realized was expensive but most things I really have no idea what they cost. (Intern 1)*

> *I've worked in other hospitals like you have to actually document every day. Day of hospitalization 4, patient's hospitalized because of... I don't feel that push there, but I'm sure it happens somehow because I know that you are, you know, our team or care coordinators, there was a utilization review, but it doesn't really filter down. It doesn't cloud our judgment in terms of we need to get them out because the hospital say so, we think of it as we need to get them out because the patient wants to go*

home. (Intern 2)

To support this feeling, the attendings I interviewed felt these factors should be secondary to learning how to diagnose and treat patients, especially interns although cost is a certainly a factor for them.

> *I don't think people should start their training trying to figure out how to be cost conscious. You start trying to be safe and have someone tell you don't need to do that. Whereas when you get more experience you start saying, well maybe we can get away with doing less.*

Seniors also reported that improving cost and processes where not very influential factors, but several seniors felt they should be considering these larger issues as part of overseeing the team. Table 3.2 shows contrasting priorities and methods for measuring those priorities. This is a reflection of the different responsibilities of each role. I will discuss how these different priorities can be modeled using CWA in Chapter 4.

Attending	Senior	Intern
So, first and foremost, the role of an attending is to maintain the quality of the patient. Make sure the right decisions are made. Make sure the communication is good. Yeah, that's basically it. The care and the communication. And then to make sure you get paid.	The pressure on the seniors is to run the team in an efficient way like lets get through rounds.	To be honest, I think it would be much better if we finished our notes like in the morning.

Table 3.2 Quotes from attendings, seniors and interns reflecting their different priorities.

However, maintaining the quality level of service and providing for the safety of patients were clear goals and influential factors. Following the institutional emphasis on family centered care, the team readily identified partnering with families, communicating with families and respecting family wishes as top priorities. Several residents cited incidents where care and a stay in the hospital was extended past medical necessity because the families were not comfortable or ready. The perceived dedication to the needs of families over business or financial goals was felt as a positive trait of Seattle Children's over other institutions and the physicians I spoke to felt very positively towards this aspect.

The housestaff are ranked by years of seniority in the program. The second and third year residents oversee the team. They ensure that the work is done by the team as well as communicate for the team with attendings or other senior physicians. The attendings I interviewed reported that they typically would contact the senior resident if they had questions or a request for the team rather than communicate directly with the intern in charge of the patient in question.

All team members engaged in education and teaching. The residents are officially tasked with education, the interns about the basics of diagnosing and managing patients and the seniors about managing the team and patient more broadly, the management of patients often requires the help of subspecialists or research requiring all physicians to gather new knowledge. Each team member would teach other members who had less experience. Attendings will teach all team members, seniors teach interns and students and interns teach students.

3.3.2. The work of the inpatient medicine team

The primary work of the inpatient medicine team is to manage patient care including the diagnosis, treatment and delivery of care to patient and communication with the family. The broad goal of this domain is to improve the health of the patient. Beyond this very general goal, interviews with participants and analyzing the institutional documents show that an emphasis is placed on patient safety, family satisfaction and efficiency and cost savings. Virtually all participants used the word "efficient" to describe their goals for their work.

However, it was clear that this goal was solely for their work to be efficient and not to be confused with pressuring patients or families into schedules or timeframes they might not be comfortable with. Managing patients encompasses management of the entire patient experience beginning with understanding their condition, their history to acquiring treatments or services to seeing them through the discharge process when they leave the hospital.

The most straightforward function of the inpatient physician team is to diagnose and treat patients in the hospital. Patient are admitted through the emergency room or through the direct admission process where the patient is admitted through an ambulatory care clinic or because the patient is scheduled for an inpatient procedure such as surgery. When a patient is admitted, the intern on-call and the intern, sometimes together, sometimes separately depending on work load, examine the patient, discuss the patient history, why they have come into the hospital and any other subjects such that the physician can make their initial assessment.

While all physicians make notes and data on each patient under their care, it is the interns who keep the most detailed list of patient tasks while the attendings may only make note of the patient status. The senior resident's interaction with managing the patient sits in between. Depending on the work situation and workload, they can help the interns manage the patient at the micro level, serving the intern role or maintain a macro level view of the patient management of the team.

Acquiring services for the patient is often a combination of social and technical tasks. Consults both require an official ordering paper trail, but often times the physicians make phone calls or initiate personal contact with the consulting service or diagnostic service in order expedite their request or to ensure that it's not ignored.

- 8:00 - 8:30 Work Rounds
- 8:30 - 9:00 Morning Report
- 9:00 - 9:30 Rheumatology 'Neurology
- 9:30 - 10:30 Post Sr. rounds w/ House Attending/TC
  On Call Sr. leads rounds w/o Attending
- 10:30 - 10:45 On Call Sr/Attending/TC Check In
- 10:30 - 11:30 Pulmonary
- 11:30 - 12:00 Work Rounds

[redacted]

Figures 3.1a and 3.1b. Examples of team schedule documents. Team morning schedules including work rounds, general inpatient (house) rounds and subspecialty rounds from the resident handbook as well as the written schedule.

Teams were constrained by the external legal regulations of medical care though most residents when interviewed did not explicitly know of any legal requirements other than Health Insurance Portability and Accountability Act (HIPAA) privacy rules. Internal policies and procedures were additional constraints. Each day has a set schedule for rounds, sign-in and sign-out. A typical weekday team schedule is seen in Figures 3.1a and 3.1b. A version of the schedule appears on in a pocket guide given to residents (3.1a) as well as on the team room white board (3.1b). However, there were slight differences in schedule on the white board, in the pocket guide and often the senior residents changed the schedule adjusting based on the needs of the patients in their care altering their work flow as appropriate.

Teams were also heavily constrained by time. The limitations of residency hours and additional duties for residents in ambulatory care clinics create a fluctuating team. In the mornings, during rounds, typically, the whole team is present. However in the afternoon, the team can lose several team members or in extreme case the majority of team members due to other scheduled work or unforeseen absences such as illness when the team could be reduced to one senior and the on-call intern.

While the hospital operates 24 hours a day, certain services are only available during business hours or should be handled during business hours unless of emergencies such as consults. This can cause difficulty for those unfamiliar with the hospital resources and rules who have learned one method but suddenly find that things have changed. For instance, an attending explained a particularly frustrating situation:

> *If you want a scan under sedation, the process at 4pm is completely different than the process at 6 o'clock, completely different and people get really frustrated 'cause they spent all this time learning how to do this process at 4 o'clock and they try to do it at 6 o'clock and it's saying well you can't do that. And they say, what do you mean I can't do that? I just did that 2 hours ago. Drives people crazy.*

Policy and institutional time constraints include residency work hours that are limited to 80 hours a week with specific limitations on hours of continuous work or on-call time. In addition, work schedules and assignments are pre-planned in advance and the team will be missing any number of team members due to other work commitments such as clinic (ambulatory care) rotations or possibly unforeseen events such as illness or other personal work conflicts.

An important part of the work of managing patients is communicating with families to engage them in the care of their children. This priority was clearly the result of institutional culture that was reflected throughout the hospital. While I observed all team members communicating with families, explaining decisions, answering questions or setting expectations during rounds or during physical examination, interviews with attendings revealed that they felt it was their primary job to serve as the communicator between the team and the family as the most senior physician.

I observed patients and families had an acute interest in the status of task items and overall trajectory of their child's care. Common questions during rounds where "when" and "how long" and typically the physicians were unable to give a specific answer to the question, only a general reassurance of the overall timeline of treatment.

3.3.3. Efficiency

Efficiency was a very common term and concept throughout the qualitative data. It was very clear why efficiency is such a problem given the workload and continuous time pressures and high patient loads I observed coupled with stress from long work hours. I observed two seniors on a team determining who they would be able to see that day:

> *[The seniors] are planning rounds and deciding who they want to see and who they can just talk about. For instance, Rheum[atology] has 6 patients and they only have half an hour so they decide they'll just talk in the team room. However, there is 1 new rheum patient who came in so they will have to see her. [Senior 1] said: "1/2 an hour is just not going to cut it" for 6 patients when there are normally 1 or 2.*

High patient loads with very little time are very common, and the number of patients on a service can vary as seen in the above example. If the schedule is organized assuming 1 or 2 patients, but at the time they have 6 and as a result, only the team only saw the one new admission. One attending went so far as to generalize and say that that the team is never able round and discuss all of their patients.

> *It never happens. It used to happen all the time, but now it never happens because we're too busy.*
>
> *The last 5 years we've added 2 transplant services and a whole new general medicine service while our numbers have increased 7% a year. I have one hour. I have 10-14*

> *patients. I have 4 new admissions. So the only thing we get through are the admissions.*

I noted that the residents were striving to be as efficient as possible and when interviewed readily stated this as a goal. Efficiency was noted as the key quality for a successful resident according to attending physicians. Most physicians I interviewed understood that institutionally, Seattle Children's through their CPI or LEAN measures is striving for efficiency and cutting waste.

Interestingly, the hospital rounding process design has one intern entering the orders on the computer while the team is discussing the patient in order to be efficient and streamline getting the orders into the system immediately. However, there are trade-offs to this design where not all residents will be able to hear the full patient story and also the intern at the computer must perform the data entry for all the orders before they move onto the next patient. This can cause communication and data entry problems. As one senior expressed:

> *Because you'll be the one standing at the COW in the morning, the orders are flying and you're not sure what the dosing is for, you know, phenytoin or for some random drug they use up on hem onc or something they use on rheumatology. You're saying, what's that, how do you spell it, got it. And thank god pharmacy calls you with dosing errors, um, because otherwise, we would all be in serious trouble.*

There is a constant balance between efficiency measures and providing enough time for education and ensuring no errors are inadvertently introduced due to time pressures. I will reflect these balances in the models I will introduce in the next chapter and further in Chapter 5 when I discuss software design, I will show that it is necessary to reflect variables and balances to the physician as they make decisions so they can prioritize based on individual situations.

3.4. Social Organization

Seattle Children's divides the housestaff into three teams, Team 1, Team 2, Team 3. Each team has a team room serving as a temporary shared office and each covers "house" or general pediatric patients as well as different subspecialities. Figure 3.2 shows the team

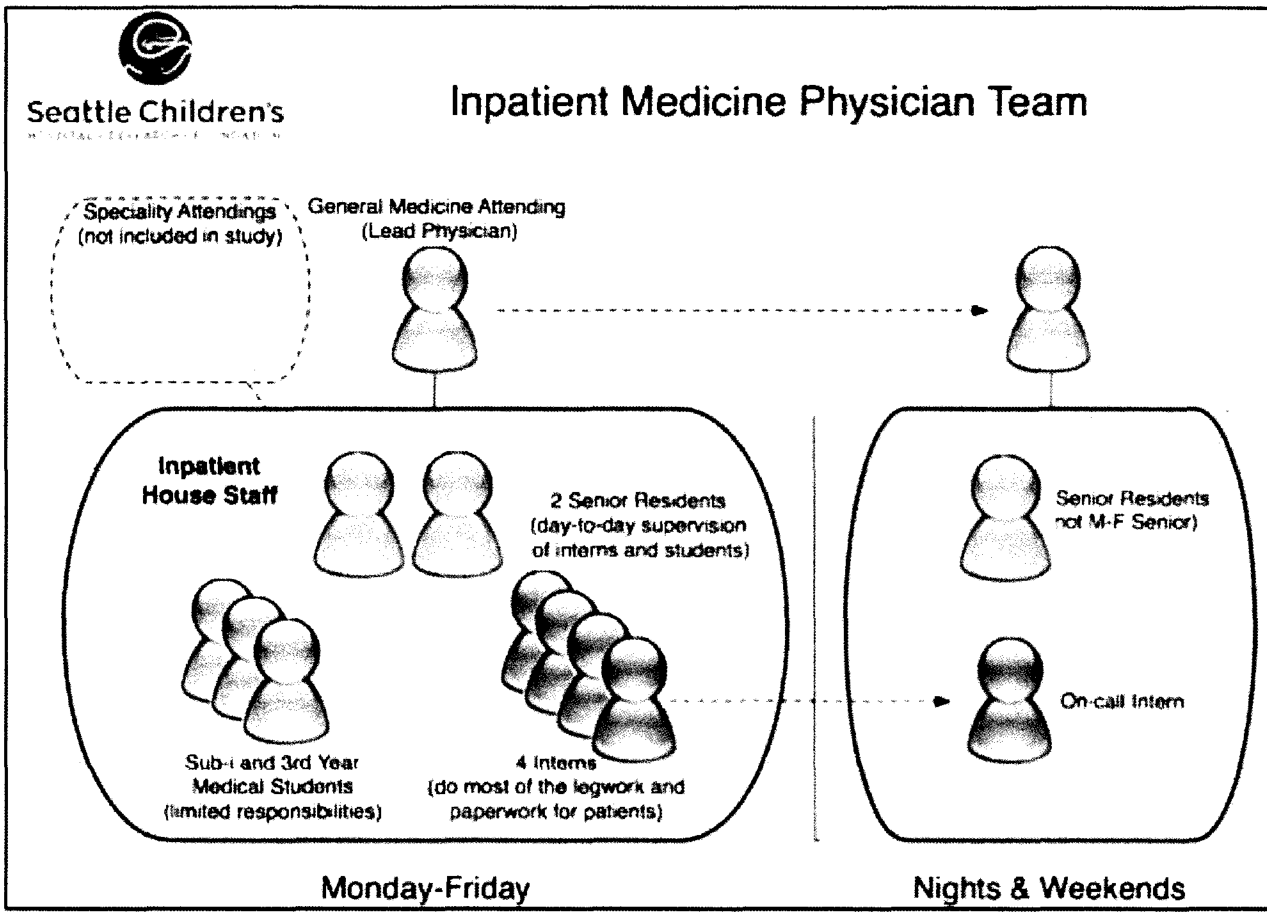

Figure 3.2 Structure of typical General Inpatient Medicine Team on both weekday and weekends. General Medicine Attendings are brown, Interns are red, Senior Residents are green and medical students are blue.

3.4.1. Interns

In the first year of training, residents are known as "interns." They serve as the first line of care for their assigned patients. These patients are assigned the patients to the intern who is "on-call" when they are admitted to the hospital. On-call is a term for being the admitting intern who covers a 24+ hour shift and is the intern with the overnight senior resident. Interns are recent graduates of medical school and this training program represents their first opportunity to practice as physicians with full legal privileges. They are new to the full responsibilities of being a physician as well as the environment. While most are enrolled through the University of Washington Pediatric Residency Program, many interns are rotating as part of other specialties such as Family Medicine so not all interns knew each other or had the same sense of familiarity. Of the participants I interviewed, many expressed desire to continue onto additional subspecialties requiring additional training indicating that a good performance as a resident and obtaining a good recommendation was an important goal. I sensed that the residents were very concerned about maintaining a good outward appearance towards senior physicians and families. I noted that one intern even during a grueling on-call night was still researching medical information because:

> *[The intern] wants to see a new patients that's come down from the PICU and she wants to know what the disease is because she doesn't want to look stupid or incompetent in front of the family and not know anything about the disease. She's brand new to renal and cards (cardiology) and doesn't know anything about these things. I show her the 'your friend the kidney' piece of paper on the board and she says, wow, she should copy that down. [The interns] are really looking for rules about what to do on these specialities.*

The intern is responsible for the "grunt" work of managing the patient, order entry and follow-up and also to be the central repository for all knowledge, clinical and social, regarding the patient. In a team-based setting, it was often challenging for the intern to keep track of everything as changes would happen at night or by other team members and services and not get communicated back.

In the morning before rounds is the "pre-round" period where interns must visit their assigned patients and prepare to present the patient for the team during rounds. Ideally they document their assessment before rounds as well. According to an attending, the role of the intern is to learn and get as much hand-on experience as possible:

> *I think the main role of an intern is to learn how to manage patients and be able to understand who's sick and who's not sick. You start an internship and all the patients kind of look the same. Who needs to go to the ICU? The intern usually doesn't have a clue when they first start. You hope you develop that judgment over the first year so that's one of the major reasons we want the interns to manage patients because you're not going to get good at that unless you're assessing patients.*

Obtaining learning and teaching from attendings was a pattern I observed from all teams. Every team wanted to take advantage of the specialty of the attending physician. Any pearls of wisdom seemed to be welcome, except when the team was pressed for time and long-winded attendings were viewed with annoyance. Despite the goal of providing the interns with hands-on teaching experiences, education and teaching at the bedside was a relatively rare occurrence given the high patient loads and even the attendings admitted that they were never able to discuss all of their patients let alone spend significant time at the bedside.

The interns, as the most junior physicians are still responsible for teaching medical students who are a year or two behind them in the education track. I watched interns teach students the basics of their job including how to document and write notes, introducing the students to their future role as interns. It was general agreement among participants that organization and checklists were the keys to being a successful intern. Getting work done without the senior physicians following-up was praised. Communication with seniors to update them was also a recognized good trait. I observed seniors whispering negatively about interns with what they viewed as bad attitudes and who didn't communicate their work status.

3.4.2. Seniors

Seniors are 2nd or 3rd year residents. Having finished the first year, they are only on-call once a week for a 24-hour shift including all permanent night shifts for a four-week period. They are not assigned specific patients, but instead in pairs, oversee the work of interns on the their team and provide a supervisory, administrative role. It is their responsibility to communicate with the attending and to ensure the work of the interns is done. They lead the teams and help the interns adapt to their new environment and responsibilities. One of the key responsibility besides knowing the general status of all the patients is allocation and re-allocation of tasks based on a fast-paced, changing environment. Factors that can cause a need to re-allocate include missing staff due to illness or clinic duties, a greater than normal number of admissions and more complicated patient requiring more work. It is the seniors job to guide the work of the team to be as efficient as possible. They will often do individual tasks for interns, but by an large the number of orders they enter and basic patient work is far less.

The seniors take on an important teaching role. On rounds the interns present the patients to the seniors, not the attendings because this is an opportunity for seniors to learn to teach and offer suggestions as attendings, but still with an attending's support. They are supposed to listen to the presentation, give feedback, ask teaching questions and help communicate with the family. I also observed seniors providing important emotional support for interns:

[The intern] admits to me that her confidence is shaken because of the patient dying. [The senior] is very, very supportive, but she also says she's shaken by the experience and at one point, I find them crying with each other in the hallway.

3.4.3. Attendings

I found that the role of attendings was the least well-defined beyond being ultimately responsible for clinical decisions and providing some form of teaching and mentorship. Attendings vary in their involvement and leadership style with the residents. One resident summarized this diversity:

I think there's some attendings who are very hands-on, and will become that organizational almost senior resident, but there's others who are mainly there for their advice and to be helpful.

I observed some attendings were interested in more patient details while I observed another explicitly instructing the residents that he only wanted to hear about complex or priority patients not the stable ones. I also observed that residents asking attendings what their preferred style is. It is a balancing act and one attending also commented that he had to adjust to Seattle Children's culture from a previous hospital:

I think of, and this took me a while, it really did, the residents didn't like the oversight I was giving so here I think of them as the ones in charge, unless there's a problem. I think of them as the doctor.

The participant interviews and my observations did show that broadly, the role of the attending was to communicate with families, teach and mentor. Two attendings emphasized communication in their role.

I can probably spend the most time with the families. So making sure they feel comfortable with the care that's been given. Clarifying any points of confusion. Making sure that they're comfortable with the care. (Attending 1)

So, first and foremost, the role of an attending is to maintain the quality of the patient. Make sure the right decisions are made. Make sure the communication is good. The care and the communication. And then to make sure you get paid. (Attending 2)

I observed attendings asking teaching questions during rounds, writing teaching notes and generally "quizzing" the residents and students. The residents were very eager to learn from the attendings especially non-hospitalists who could provide subspeciality expertise and more in-depth knowledge in a particular area. However, I also observed residents privately commenting that some attendings would "go on way too long" and they needed to manage their time with attendings in order to get work done.

Attendings at Seattle Children's and in my study were divided in to "hospitalists" whose primary specialty is caring for hospitalized patients and who have familiarity with their specific hospital system and physicians with other pediatric specialities who do not primarily work in hospital settings.(Bekmezian, Chung et al. 2008) I interviewed both hospitalists and non-hospitalists (see Chapter 2). This diversity of familiarity with the hospital system echoes the diversity of the residents, most of whom are based at Seattle Children's, but who may come from an outside program for brief rotations. In some cases, the attending may know more about the hospital system and procedures having worked in the institution for many years as a physician or administrator whereas another attending may have no familiarity at all and this leads to different attending-resident working relationships. As one resident observed:

> *Attendings don't put in orders and so there's that. And sometimes, I don't think they're being deliberately obtuse, it's that at rounds they assume you know how to get this done and a lot of time as an intern, you're afraid to say you don't know so rather you say, ok I'll figure that out yourself and you go and it takes you a long, long time.*

Regardless of familiarity with the hospital, attendings in general do not enter orders and rely on the residents to do the ordering and the work. One attending admitted during the interview that he did know any hospital procedures for discharge or ordering at all. Most of their interaction with the computer system is reviewing patient data. I observed that outside rounds, attending work was separate and parallel to the team. Each attending would visit the team room during the day, but attendings make their own private visits and examinations with the patients after rounds in the afternoon.

3.5. Resources in the work environment

Physicians have many resources at their disposal to help them in their work. Here I will describe them broadly. In Chapter 4, I will discuss how I input these resources in to means-ends models in order to map out how these resources relate to goals and functions, and also to see how resources that exist in the environment could be used to achieve goals in new ways. In this section, however, I will describe these resources and how they are currently used. I have followed Katopol's labeling of resources in the work domain: technological, physical, interpersonal and policy-related.(Katopol 2006) Table 3.3 shows some of the resources available in the work environment of each type.

Technology	**Physical**	**Interpersonal**	**Policy-Related**
CIS	Vital Signs	Pager	Morning Census
Online medical references	Daily Notes & A&P	Conversation	Protocols
Formulary	Teamroom white board	Work Rounds	Order sets
Internet/google/wikipedia	Personal notes	Team phone	Posters
Online medical references	Daily patient list	Email	
Primary literature	Forms		
Personal Digital Assistant/Calendar	Posters		
Amion.com	Books		

Table 3.3 Resources available in the work environment

Team members have at their disposal computers and the internet that allow them to use public resources such as Wikipedia or google to search for information on the internet. The team rooms, nursing stations and hallways have permanently situated desktop computers. However, to provide even more flexible access to computer software and data, Seattle

Children's also uses Computers-on-wheels (COWs) which are laptop computers with wireless devices attached to a tall mobile cart that can be easily pushed around the floors. These devices allow the use of the electronic medical record (described below) to access the patient's medical record or to order medications or procedures anywhere in the hospital. They are used extensively on rounds as the team moves quickly from patient room to patient room and the physicians need constant access to a computer. In addition, to the hospital provides proprietary information resources such as medical databases and primary literature licensed by Seattle Children's or the University of Washington. Pediatric medicine books as well as the internally developed Seattle Children's Survival Guide were also used as quick references to medical literature.

Seattle Children's employs a large commercial health information system developed by Cerner Corporation, Kansas City, MO and locally installed and known as "The CIS" or Clinical Information System. Introduced first in 2002, the current version of the system supports storage of demographic visit data, laboratory data, radiology reports and dictated documents and CPOE (first introduced in 2003) (Del Beccaro, Jeffries et al. 2006). The system can be accessed via computers in the hospital or via a web portal over the Internet. While many parts of physician documentation and hospital data are available through The CIS, significant data such as admission notes, daily nursing and physician progress notes and patient vital signs are written by hand and only available in the patient chart binder at the nursing station.

As I discussed in Chapter 1, the introduction to this work, one of the motivations of this research was the lack of acceptance for major health information initiatives such as CPOE. It is worth explaining why the existence of a CPOE and EHR system at this study site was not prohibitive in this research since one of the stated goals of this research is to provide requirements and design suggestions for a computerized ordering system. Regardless of existing technologies, I studied physician's goals and their work to achieve their goals. I will characterize this work without any bias towards existing or future technological solutions because a solution should not define the work to be done, but support it. Therefore, in the context of the CWA model, the CIS and its properties are static constraint in the environment

For calendaring and maintaining schedules, teams use a variety of resources. From the technology category, the online schedule database amion.com provides access to the residency schedule for the year. Each physician typically maintains some sort of personal calendar, whether a physical calendar or a digital calendar/PDA. In addition, the another source of scheduling is the team white board that displays the team members, their contact information and any pertinent scheduling information such as the team's daily schedule and when each member has clinic days.

While many resources were available online, and although Seattle Children's has endeavored to provide ample access to computers throughout the facility, many documents were still printed. The team's list of patients was accessed both online but also printed out in part to have a portable copy for team meetings, but also in order to annotate and use as a personal task list tracker.

I specifically asked physicians about communication and communication methods. One of the most striking commonalities I discovered was that most physicians preferred to use the phone when they wanted to reach someone, but preferred the pager of someone wanted to reach them. This is the result of expecting the immediacy of reaching the person they need while wanting to maintain control over who reaches them and permitting them to prioritize who they speak to. There are two portable phones assigned to the team, the senior phone and the intern on-call phone, and these cannot be ignored and are sure ways to reach the team, but do not afford the team members any way of screening or prioritizing the calls.

An important method of communication employed regularly is conversations. The physicians share the teamroom and have essentially an open office setting where they can converse readily and openly. Other hospital staff members will simply open the door and ask to speak to anyone on a specific team for a question or make a request because the patient in question is assigned to that team. One of the most interesting results of my data analysis showed a very low level use of email. Compared to other work environments where email may be the most common form of communication, team members rarely used email. While email is used by the hospital for official announcements or reports (and often ignored as reported by the participants in my study), I rarely saw it used for clinical purposes other than to transfer files or images from outside physicians such as a primary care physician. One senior offered a possible explanation that because email is a documented method of communication, there is an intrinsic fear of using it lest their mistakes be permanently recorded and used against them later. He added if he sees an incident or issue comes through via email, he gets very nervous and knows it's serious due the fact that they are willing to create a permanent email record. Hospital documents explaining sign-out procedures and my observations suggest that face-to-face communication is the most culturally acceptable and trustworthy method for transferring information. In addition, the requirement for a computer to read email may also hinder its employ as the physicians typically are very mobile.

Hospital policies and protocols are available as resources through out the hospital, both explicitly and implicitly. Detailed protocols for treatment are available on the hospitals intranet, CHILD, while new policies such as a changed phone number or protocols are communicated by posters in the rooms. An implicit resource for hospital policy and protocols are the ordersets, predefined order "packages" for specific situations or conditions that are pre-programmed into the CIS and available in the ordering functionality.

3.6. Qualitative Themes and Results

Heretofore in this chapter, I have presented the results of the deductive qualitative analysis following the application of the CWA framework and derived codebook on the fieldwork artifacts. In this section, I will discuss the inductive results and theme development. There is no one clear definition of theme in the qualitative analysis and anthropology. Rand states, "themes are abstract (and often fuzzy) constructs that link not only expressions found in texts but also expressions found in images, sounds, and objects."(Ryan and Bernard 2003) Themes can often be confused with patterns, and while Patton explains that there are no "hard and fast" distinctions between the two, "pattern(s) usually refer to a descriptive finding" while "theme(s) take a more categorical or topical form."(Patton 2002) In my open coding, I identified four themes derived from examining the open codes and looking at the patterns in the text.

From a software development perspective, my analysis perspective was to discover, broadly what work the participants in my study perform in their jobs in order to begin to frame the work and design. Therefore, the themes I identified were related to categorizing this work. Themes will become specific elements in the structured analysis I will present in Chapter 4.

3.6.1. Project Managing Patients

Through open coding, I noticed patterns in the data that I have categorized into an overarching theme of *project managing patients*. I developed the project management theme from a combination of certain recurring codes such as communication-related codes, team and resource management codes that were indicative of the industry definitions of project management. The purpose of combining the codes is to develop a guiding theme that can be explainable and recognizable by others including analysts and engineers

These codes developed inductively led me to develop the theme of *project managing patients*. Why did I choose to characterize this work in this way? The Project Management Institute (PMI) characterizes project management as "managing projects as entities... managing change and transition. And today, as never before, it is value driven. It is about meeting and exceeding customer expectations, about getting the best bang for the buck, creating value, and shortening implementation schedules."(Morris 1998) These project management goals echoed in my discussions with participants. In particular, in examining the PMI core competencies for project manager, they were similar to many of the open codes that I developed.(Project Management Institution 2002) I will now briefly define each of the PMI core competencies and give examples from my data that show that the inpatient medicine teams are performing this work. My descriptions of the core competencies are meant to capture the general meanings of these areas. Detailed descriptions can be found in the PMI documents.

3.6.1.1. Integration Management

Integration management is identifying through subject matter expertise which services are needed for the project and performing high-level assessment of organizational resources and requirements. In the medical context, this equates to determining what is the treatment and what are the services that the team is going to give the patient. This process includes discussing and analyzing historical information, both the patient history and general medical knowledge. At a high level, during rounds the interns present their assessment and their proposed plan. Below are quotes from several physicians that embody this idea of integration management when asked what they do when they order:

> *Physician 1: I mean, you sit down, and you think to yourself, ok this patient's here in the hospital, you know, what are my goals for the hospital stay.... It's like you're in the hospital, what am I going to do for you here.*
>
> *Physician 2: At the core of it, it's trying to get, coordinate the provision, space and time of something a kid needs to feel better. That's really the crux of it... It's all about coordinating those things in the right place at the right time for the right kid for a better clinical outcome.*

I observed the work of making a discharge plan for a patient. In addition to the discharge summary and other necessary documentation, I noted:

> *[The physicians] are making a plan for tomorrow's going home of a patient: transportation, social work, getting the ok from ortho[pedics] to make sure they (the patient) can go home.*

The work of these physicians is to determine what services of any type the patient needs for their stay and from the admission through the discharge, and even after discharge through follow-up care or home care.

3.6.1.2. Scope Management

Scope management is defining and managing the critical success factors of a project. When a patient is admitted, according to a hospital policy, a discharge criteria, the goals for the patient to leave the hospital, must be created. This policy is enforced through pre-determined ordersets and pre-populated for certain diagnoses with established care pathways. The criteria is in the medical record and also written visibly on the patient's room white board. The physicians review the discharge criteria daily and modify it if necessary. According to a letter to physicians, this policy was enacted "to optimize patient care, ensure family involvement and provide for timely discharges."

3.6.1.3. Time Management

Time management is the creation of a timeline, identification of milestones, understanding temporal expectations of stakeholders and managing variances and deviations from the timeline. The number of inpatient days per patient in the hospital is a key CPI measure of

Quality as seen in Table 3.1. Coupled with strict discharge criteria, the physicians must keep a general sense of the timeline and trajectory in the hospital and adjust for any incursions to the timeline. Physicians must understanding the steps in their plan and coordinate the timeline for execution of the plan whether it is procedures, tests, medications or consultations. Coordination of time can be critical to obtain services for the most critically ill patients. Social and other external forces can influence timelines. For instance, in my field notes I describe a situation where the team was unable to get a consult for a patient because they family had specific travel plans:

> *A family has a flight to catch back home and so they need ophthalmology to come right away. [The senior] says to [the intern] to give a page and then give a call to make it happen. They both feel bad that they didn't get this appointment taken care of because it got lost during sign-out. Someone deleted it from sign-out because there's only so much space, and it's not the primary problem of the patient... The ophthalmology fellow says they have clinic all the rest of the afternoon and won't be able to make it so [the physicians] are annoyed at themselves for not getting on this earlier and harassing them to come and see the patient [so] she could have been seen by an expert.*

In this case, miscommunication and a non-clinical scheduling constraint (the patient's travel plans) forced a change in the time schedule that the time team had to manage.

3.6.1.4. Cost Management

Cost management is identifying budget constraints and performing a cost benefit analysis at points in the project. Cost is a CPI measure as seen in Table 3.1. The organization has a goal of providing the highest level of service at the lowest cost. As I discussed in 3.2.1, the interns felt that cost was not a factor in their decision making. However, discharging patients efficiently is directly related to cost so they are not wholly removed from the financial portion of treatment. One attending remarked that while cost consciousness is not the first thing to teach trainees, it is a necessary physician skill:

> *I don't think people should start their training trying to figure out how to be cost conscious. You start trying to be safe and have someone tell you [that] you don't*

need to do that. Whereas when you get more experience you start saying, well maybe we can get away with doing less.

3.6.1.5. Quality Management

Quality management is determining the quality requirements and seeing that the project meets those goals. At an institutional level, quality is defined by measures such as family satisfaction, survival rate, adherence to guidelines and the number of primary care physicians called after hospitalization. Whether or not the residents consciously were ware of these core measurements, they were very aware of the institutional value on family-centered care and communication with families and were dedicated to this goal. They also understood that calling primary care physicians was a required task and seniors and care coordinators would follow-up to ensure these quality policies were acted on.

3.6.1.6. Human Resources Management

Human resources management is identifying the stakeholders and their needs and allocating task and responsibilities to those team members. As I have described, in team-based care, the entire team cares for the patient in addition to assigning them a primary intern and attending. Each evening and weekend the physicians hand-off their patients to a new physician who takes over the responsibility for the patient. Team members will allocated and re-allocate action items to each other depending on work loads adjusting their work flow. The theme I will discuss in 3.1.4 is Team Management which is a direct parallel to this project management competency.

3.6.1.7. Communications Management

Communications management is determining the format for information and disseminating status, progress to appropriate stakeholders. There are multiple methods for communicating among the team and outside the team. There are ad hoc communications and built-in communication procedures. Methods include technological (pager, phone, email), physical (conversation, white board message) and clinical (notes and orders) communication modes. Each method has advantages and drawbacks. Physicians often expressed a preference for receiving page, preferring asynchronous communication, but preferred conversation or calling when they needed to contact other team members. Understanding which method to use and then what the phone number or pager number or person to contact is a large part of environment education and often a challenge for new physicians. Similarly, finding the indirect, asynchronous communication that often occurs if communication is done through clinical documentation is a challenge. One resident noted the difficulty in determining if consulting physicians had seen patients:

> *if there are notes in CIS, then great. Some consulting services leave paper notes in the chart and neither dictate it into CIS nor call me to tell me they've actually seen the kid.*

A similar incident occurred when a team did not hear about a procedure done by another service and were upset about it and felt responsible for the consequences of other people's work they were not aware of:

> *[The residents] are upset that ortho is doing procedures without talking to them first because it's their patient and they feel they are left "holding the bag" when the kid is "pissy" after getting a procedure. They are pretty ticked off at ortho because ortho won't take the kid onto their service either.*

Communication requirements will also vary team to team and management style will vary attending to attending. I observed a senior determining the communication requirements for an attending just coming onto service:

> *[The Senior] asks [the attending] on his first day of service what his style is. Does he want to be informed for every admit? The attending says only the ones that they are worried about... He also wants to know about any PICU admits, but not any stable patients.*

Because this environment supports team-based inpatient care in an academic setting, there are built in communication requirements as patients are transferred between patients and discussed amongst providers. The process of "sign-out" where the patient's information and current situation is communicated verbally to another physicians occurs whenever physicians arrive or leave during the day and transition in and out of on-call. The evening sign-out as the day physicians transition to the night physicians is a particularly critical communication. I noted:

They eat dinner together in the cafeteria, the night seniors and (day) seniors, on-call residents from all the services and they sign-out. It's very, very loud. There's a computer in the room that they use to follow up on orders or basically continue working.

The family-centered care values of the institution discussed in 3.1.4.1 also require strong communication between care teams and families.

3.6.1.8. Risk Management

Risk management identifies risk events and develops a decision tree and probabilistic risk analysis. In addition to feasibility and cost, physicians must weigh the clinical benefits and risks of treatments and decisions. Below are two quotes from physicians, one expressing balancing radiation exposure of patients, the second weighing allowing the family to stay longer in the hospital against potential exposing the patient to infection:

I do think we focus on not trying to do things that are unnecessary, not just cost, but cost in terms of radiation to the kid, like do we really need another ACTH scan or how many more x-rays do we really need and trying to balance resources that way.

If a baby has an infection, they need 2 weeks of IV antibiotics, we'll put in a PICC line and we'll say you can do this at home. And if parents say no, I can do it, but I won't do it, we say ok you can stay in the hospital for 2 weeks and get antibiotics. That's very expensive. It's often times inappropriate in terms of exposing the patient to hospital infection and it takes up a bed that someone else could be using, but we don't say you have to leave and this is your option.

The need to understand the probabilistic risk analysis of a decision comes from the premise that using evidence-based medicine, the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients."(Rao 2008) I observed the formal teaching culture Seattle Children's teaching morning report includes teaching numeracy and the probabilities surrounds different treatments. Whether or not the residents use this information in their decision-making is not in the scope of this study, but risk assessment using statistics is a component of project managing patients.

3.6.1.9. Procurement Management

Procurement management identifies and reviews organization procurement policies and procedures, develops a procurement statement of work and assesses potential sources and evaluates them. A significant portion of resident work is procuring services and following-up requests. Orders themselves are used to procure services for patients. The communication with other departments, such as radiology, pharmacy and consultants and understanding the policies are also parts of procurement management. For instance, some consulting services offer "curbside" consults where they will informally offer advice. Others require a formal order and call. I observed many residents frustration in obtaining consultations and learning understanding how to obtain services.

> *"I think you heard my frustrations at some sub-specialties not being available which makes me feel silly, sort of absurd. We're the only children's hospital in the WWAMI [Washington, Wyoming, Alaska, Montana, Idaho] region, and we don't have pediatric dermatologist? We don't have an allergist? and I can't get IR [interventional radiology] to come in. What's up with that?"*
>
> *...someone will say, get that PICC line placed on their IR. Like do I call Fluoro or do I call IR. Because every hospital is different in terms of who will do that. So you end up thinking to yourself, hmm.... who should I call first?*

The hospital offers a wide-variety of services to clinically and socially support patients and the physician team is often responsible for obtaining non-clinical resources such as transportation, video cameras and interpreters.

3.6.2. Team Management

Another activity of the team is managing the team itself. This function cuts across the management of patients, management of personal tasks and education is the job of the senior residents.

Rounds present an opportunity to discuss their patients, impress attendings, communicate with families and receive bedside teaching. However, this is not always possible when the patient loads are high. In these circumstances, the team needs to "get through rounds" and discuss as many patients as they can within the finite amount of time allocated. The seniors decide whether or not the team will visit the bedside or discuss the patient in the team room or even bother discussing the patient at all due to time constraints. They need to provide teaching opportunities either themselves or with the attending and feedback for the interns without depriving the team of the time needed to complete their work. They are required to send the post-call intern home before 1PM (an environmental constraint discussed in the above section). Throughout the day, they allocate and reallocate patient management and tasks, adjusting for ad hoc work schedule changes such as when team members are sick, called away or overloaded with other patients.

> *If that interns post-call or trying get out the door for clinic, then we reallocate or somebody else picks that up that responsibility. In practical terms, that's not always possible. <Intern 1> is post-call and <intern 2> is getting called for lots of new patients and she's admitting even though she's not supposed to be admitting because <Intern 3>'s suposed to be admitting but Intern 3 is sick. <Intern 4> is supposed to be admitting, but <intern 4> is at clinic so that's the classic. So that's supposed to be Intern 1's kid but then it ends up being Intern 2's kid for the afternoon and Intern 4's kid for the evening and my kid for right now. – Senior Resident*

Allocating and re-allocating work is especially challenging since the primary method of assessing team work is "running the list" which is holding an in-person meeting where each team member reviews their task list and status and the group determines if they have overlooked anything and are working efficiently and prioritizing correctly. While this method does have the benefit of face-to-face communication, it is a time consuming and can be difficult to accomplish with the team room is especially noisy and chaotic. When team room is not busy, team meetings are more effective. I noted that Team 1's team room was less suited for team meetings given the dispersed layout of the tables and its proximity a busy nursing station and ward. This is in contrast to Team 2's team room which is much larger with a central meeting table and a more isolated location in the hospital. Another draw back of running the list is illustrated by a quote from a sub-i who noted that without knowing who they will be taking care of in the future, they can't determine which patients to pay attention to during the meetings.

...when we were running the list, we were running the list without me really aware of what role I was going to fill that day. I had my two patients, and I knew I was going to have to pick up slack, but I didn't know where... I think I would have listened closer had we started the day going, OK, these are your two, but these are going to be your four as well and then I might have stopped the sign-out resident to ask more details or questions to make sure I had a better understanding.

This sub-I's experience is an example of the re-activity rather than pro-activity of the team.

3.6.3. Personal Time Management

"It would be great if we all had the time... to present and then sit down and put in orders on our kids and really think about it. ...it's a different story when you have a half hour to put orders as opposed to 30 seconds."

For all the participants I interviewed, efficiency emerged as a central personal theme goal as well as a perceived institutional goal. All participants expressed goals to maximize efficiency in managing the multiple patients in their care or overseeing the team in the case of seniors not on well-being and health.

Participants felt success was measured by their level of efficiency, and senior physicians also felt that the successful resident was the most efficient. This attending summarizes his view how to succeed as a physician:

"First, and foremost, you have to be efficient. So you have to have an efficient way of thinking. I think the second thing is prioritization. So you need to be able to prioritize the most important issues and that have to happen now, and which can potentially wait so that's another huge thing. I think work ethic is probably the most important thing. You don't have to be the smartest, sharpest tool in the tool shed, you just have to be hardest working to succeed in medicine."

My findings support other research that shows resident work patterns are erratic and fragmented.[6] To compensate for the lack of time, tasks such as finishing progress notes are carried through rounds as interns attempt to multitask. However, multitasking during rounds comes at the price for being able to listen and learn about patients that they might end up managing:

"If we finished our notes like in the morning... you (could) listen in on rounds, you (could) put your own input in... There's patients I've never seen before that I've taken care of, you know. You like see them through the window but you don't actually get to go in." – Intern

The case load carried by an intern or a team varies by circumstance such as seasonal illnesses relating to a particular sub specialty. Much of my data gathering occurred during the winter months, a period of high incidents of pulmonary diseases. The hospital was at capacity for much of the time of my observations and the physicians often felt overwhelmed with the amount of work and responsibility. Sleep quality has been associated with higher stress scores in physicians and our data indicates that sleep and leaving work are also strong motivators for efficiency.[5] Medical residency is well-known to be a period of long work hours, little sleep and high responsibility for newly trained physicians. (Thomas 2004) Lasting several years, residency has been thought to contribute to physician burnout, resentment towards patients and risk to patient safety. Proponents argue that these results are not consistently true residency remains an important learning, bonding and self-sacrificing experience and path towards becoming a expert physician and their role as healer.(Green 1995) Regardless of the virtues or disdains of the residency process in general, sleep deprivation, stress and long work weeks are well-documented aspects of residency and part of the residency experience at Seattle Children's.

The interns in this study often did not sleep for their entire thirty-hour shift. The team joked that a particular resident who seemed to get the most admissions during her on-call shifts had "bad juju" and she confided in me that she felt "cursed." Often when workloads are high, completing daily required tasks is challenging and secondary priorities such as self-education or time at the bedside are dropped. In one instance when the number of patients and work were extremely high, after one senior put her head in her hands momentarily, she and her fellow residents agreed that their strategy for the day was to "push and get through it." The residency handbook itself is known as the "Survival Guide" which speaks towards the anticipated experience.

Physicians have multiple methods of managing their task lists and these are mostly done on paper. Some physicians use the daily printed team list as a baseline information sheet to record patient summaries, notes and to-do items while others use index cards or one resident had even made her own custom patient information sheet. Regardless of methods used, managing personal time and personal tasks is an important function of the team.

3.6.4. Education

> *What you know is ultimately the collection of your experience and how hard you've read and how tenacious you are about re-reading the things you think you already know about. That's the most important thing about being a doctor no matter what your training level is, is always recognizing that you have to actively learn for every patient. You have to go back and read. You have to go back and learn - even if you're a specialist. There's no way you can know everything about the subspecialty. It's virtually impossible. – Attending physician*

> *The main learning that an intern does is on the fly, on the job, day-to-day management, troubleshooting, and then they glean clinical decision making as well as learn it in an objective manner by reading and things like that, so that's your job to learn patient to patient what you would do in this clinical situation as well as what you do in the hospital to get things done, who do you call, what... you have put in the order. -Senior, 2nd Year Resident*

As a teaching hospital, education is an institutional goal supported formally by seminars, training and conferences, but informally by so-called on the job learning. Team members feel responsible to teach each other on an ad hoc basis, forming a strong culture of group teaching. Therefore, it was not surprising that medical education emerged as a clear function of the team. Education and medical training is the key purpose of the training program and from the interviews with attendings, education is an on-going process among all physicians through consultations, self-learning or formal learning such as presentations or grand rounds. The need for medical education and support of teaching occurs at all levels of training and situations. For example, an intern remarked:

> *I feel hesitant to put any order without double-checking with somebody. Even the most benign orders.*

This intern needs support from her senior or attending and we observed that discussing orders frequently led to opportunities for teaching as the senior and intern reviewed orders or decisions together in the team room. It is not always the case, however, that personal teaching can occur when it is needed. During family-centered rounds, it is hospital procedure for an intern to enter orders while another intern presents the patient. However, not all learning situations are ideal teaching situations:

> *"...you're ordering meds you're unfamiliar with all the time. All the time. The orders are flying and you're not sure what the dosing is... for some random drug they use up on HemOnc or something they use on Rheumatology. You're saying, what's that? How do you spell it?" – Senior, 2nd year*

Gaps in knowledge are not limited to the housestaff. I interviewed an attending physician whose primary subspeciality is well outside general pediatric medicine. He has never practiced general pediatrics and only serves 2 two-week shifts a year. He expressed great anxiety about his rotations:

> *"Honestly, I feel terrified every time I do it. I feel like a fish out of water for lots of reasons. I don't keep up with the literature. I don't practice it day to day. I don't converse with colleagues about [it]."*

This attending was very anxious about his lack of general pediatric inpatient knowledge and as a result relies heavily on the housestaff. Even if this is an extreme case, the increase in the complexity and severity of hospitalized children was cited by the attendings I interviewed for the necessity of consultations and peer-to-peer education.(Percelay and Committee on Hospital Care 2003)

I observed that lack of knowledge about the work environment such as how to arrange for an interpreter, the hospital-specific nomenclature of orders and the division of labor and responsibilities of hospital units were challenges team members faced. An senior resident shares a story:

> *We had a kid we had to start IVIg on for Kawasaki and the kid started to have a reaction... We had three different brains thinking about this, plus the house team, and none of them could tell me with any accuracy what the protocol is for reaction to*

IVIg. So finally after talking to Cards and ID and my attending, I called Rheumatology who has not ever consulted on this patient or even heard of their name. And I said, here's the deal and they were able to give me the protocol.

I think attendings are just as unaware of the protocols and pathways as the housestaff, so they're teaching the housestaff based on their personal experience, their way, their style, their art, and they're not teaching to pathways

This story illustrates a strategy, albeit a frustrating one, that this resident used to accomplish his goal of finding the protocol. Although familiarity with the work environment increased with experience and time in the hospital, we observed that the same interns on different teams supporting new subspecialties continued to discover gaps in their knowledge about the hospital. In addition, not all residents are part of the in-house residency program. A number of our participants were from family medicine residency programs fulfilling their pediatric inpatient training requirements and had no familiarity with the hospital.

In one case, an attending also expressed his lack of familiarity with the hospital environment:

I don't know how it gets done. I don't know how to put the orders in. I don't even know how to discharge patients.

The physicians, especially housestaff, uncovered work environment constraints by trial and error if the information was not readily available from team members. Attendings, if they are in-house hospitalists, can provide guidance and information on hospital resources or protocols, but as in this attending's case, they may themselves be as uneducated about the work environment and needing support themselves. One consequence of attendings' lack of experience in the actual environment is their inability to communicate decisions to interns who by nature of the hierarchy are unwilling to appear ignorant and ask questions. One senior observed:

Attendings don't put in orders and so there's that. And sometimes, I don't think they're being deliberately obtuse. It's that at rounds they assume you know how to get this done and a lot of time as an intern, you're afraid to say you don't know, so rather you say, ok I'll figure that out yourself and you go and it takes you a long, long time.

3.7. Concluding Remarks for Chapter 3

I have presented the raw data from the qualitative analysis portion of this dissertation. This chapter should give the reader the proper context for the analysis in Chapters 4 and 5 as well as provide the data for the models and work products that I will describe in those chapters. I first presented the deductive portion of my data resulting from coding according to the CWA framework. I then presented 4 themes that I identified in the inductive phase of my analysis, Project Managing Patients, Managing Personal Time, Education and Team Management. I will next show how I used these themes in the CWA modeling, system requirements and ultimately the design illustrations. Chapter 4 will contain additional qualitative data to illustrate specific choices for CWA work products.

Chapter 4: Cognitive Work Analysis Results and Information System Requirements

This chapter contains the Cognitive Work Analysis products derived from the 5 layers of CWA that have associated analysis phases as discussed in Chapter 2. Each of the phases of CWA produces an analysis product. Some phases are have more mature analysis techniques than others, but the systems and functional software requirements are derived from the results of all five phases.

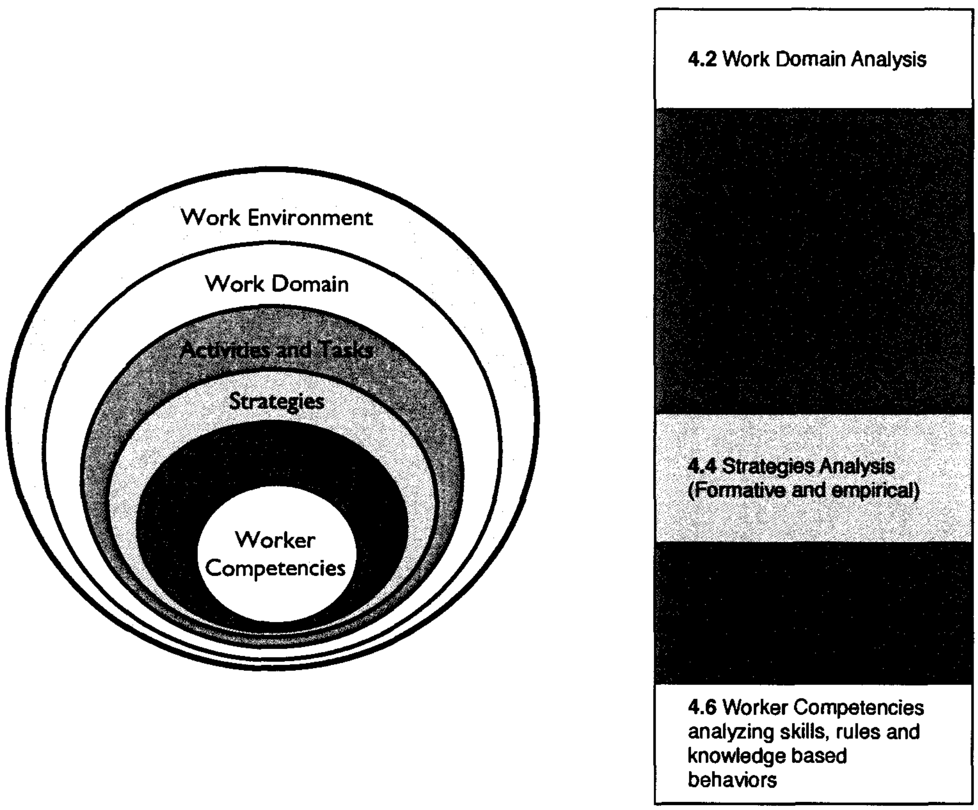

Figure 4.1. The Cognitive Work Analysis model revisited to guide the organization of Chapter 4.

I have presented qualitative data in Chapter 3 that focused on describing the work environment and developing themes for the inpatient medicine team's work. However, the motivation for this work was to examine the functional activity of order entry given the industry's motivation to develop and implement computerized order entry systems that so far have received a mixed reception. In this chapter, I will describe the CWA analysis of the qualitative data and show the role of order entry within the larger context of physician work.

I performed a progressive analysis beginning with the overall work domain (4.2) of the inpatient medicine team, focusing on modeling the work environment, the overall goals, general functions, the resources and the balances that the work domain uses to measure success and make choices. Work domain analysis discusses functions, processes and activities in terms of the work domain, noun-based means-end relationships unrelated to any tasks, actors or strategies.

From the work domain analysis, I continued to Activities (4.3) that focuses on activities and processes that the workers can use to control the work domain (known as control tasks). I identified the key work tasks and work situations of teams in order to define specific control tasks and activity elements that related to the broader definitions of ordering from my observations and interviews. I used Rasmussen's decision ladder template to tease apart specific data processing activities related to ordering.

In 4.4 I will discuss how WDA support multiple strategies for accessing the physical resources. These strategies may differ depending on the work situations and work tasks making strategies analysis closely related to Activities Analysis. I will also discuss two primary work organization strategies, prioritizing by patient and prioritizing by task. In 4.5 I will discuss the how the work is distributed among the team, discussing individual versus team work and human versus computer work. Finally, in 4.6, I discuss how the strategies can be described in terms of three types of human cognitive processing that each must be supported different in the resulting software design. Figure 4.1 summarizes the sections of this chapter and their relationship to the original layers of the CWA "onion."

I will conclude in 4.7 how each of the CWA analysis products or models can contribute to a systems and software design document. I will not present a fully detailed systems and software requirements document as much of the information contained in such document will have already been presented previously in the chapter. However, I will describe which pieces of the CWA analysis should be used to create sections of the requirements. A looming problem with CWA repeatedly reported in the literature is the difficulty in understanding the principles and the methods. It is one of the goals of this dissertation to enable the use of these methods in healthcare settings by tailoring the concepts to those that healthcare practitioners will understand. This will help future analysts understand these methods, but also encourage their re-use in alternate healthcare settings.

4.1. Work Domain Analysis

In this chapter, I will also show how the results presented in Chapter 3 inform the *work domain analysis*, (WDA), the first phase of CWA that develops a representation of the work system functions. In order to develop an accurate model of the system that can cope with novelty and multiple goal paths, we must first describe the context independent of any action. Vicente describes creating the map for which you then can have multiple sets of directions (the actions or tasks) in order to navigate the map and respond to new situations. Here, we are developing a "map" to the inpatient medical service at Seattle Children's Hospital. By creating a map of the work domain, we can design and analyze work from a formative perspective by examining all the objects and functions in the environment. This is in contrast to normative analysis that prescribes how work should be done and descriptive analysis that is limited to describing how work is currently done.

WDA is a structural means-end analysis of the work domain. Means-end relations represent goal oriented and problem solving representation connected by WHY-WHAT-HOW links. This is in contrast to "is-a" linkages where higher concepts are superset of lower concepts (Intern **is-a** Physican) or "part-of" linkages where higher concepts contain lower concepts (Intern is **part-of** Team). It is worth noting that WDA can identify processes or activities as structural objects in the analysis, but they are used as nouns, not as verbs.This is a critical point with regards to why Cognitive Work Analysis and the use of abstraction decomposition space is a unique approach to work analysis. As Lintern says, WDA is "a systematic and comprehensive representation of functional structure, and as yet there does not appear to be a plausible competitor."(Lintern 2009)

I will first describe the abstraction decomposition space which his the CWA method for representing the work domain in terms of functional constraints. In Chapter 5, I will present additional work domain analysis that describes functional constraints of the work domains that I recommend for computerized support. Thus, I consider this work domain analysis of the inpatient medicine team as "gestalt" view point that leads to further decomposition into other work domains that we will want to control through computerization.

4.1.1. Abstraction Decomposition Space

The work domain can be represented as two-dimensional grid known as the Abstraction Decomposition Space (ADS). The horizontal x-axis (part-whole) represents the breakdown of the work domain into its main system and subsystems. For instance, in a house, there are rooms that have smaller subsystems such as the contents of the rooms. The y-axis means-end analysis explores a why-what-how analysis of the work domain (means-end). Figure 4.1 shows a blank ADS. The leftmost column shows a set of modified general categories to define the means-end relationships of the work domain. Because work domains change constantly, this method reasons that only descriptions in terms of general categories, represented by prototypical examples, will make sense.(Rasmussen, Pejtersen et al. 1994)

I will first discuss how I modified Rasmussen's original means-end categories to suit this work domain and research project. I will also discuss the data and concepts that I included in each category. I will then discuss the decomposition or part-whole axis of the ADS. Finally, I will bring the two axes together for a complete ADS of the work domain of this study.

Decomposition (Part-Whole) →

System — Sub-Systems

Abstraction (Means-End): Why ↑ What ↓ How

Goals, Values, Mission, Policies and Regulations	WHY			
Quality Measures and Balances indicating Success	WHAT	WHY		
General Functions	HOW	WHAT	WHY	
Physical Functions		HOW	WHAT	WHY
Physical Resources			HOW	WHAT

Figure 4.2A blank abstraction decomposition space with my modified version of Rasmussen's five means-ends relationships. An illustration of the Why-What-How relationship between each category.

4.1.2. Abstraction Means-end Analysis

The means-end analysis is the vertical component of WDA that seeks to explain for each system and subcomponent as Rasumussen in his investigation of nuclear power plant workers determined that workers abstract of the decision making. These means-end categories have undergone many transformation in subsequent research. One of the weaknesses of the WDA and CWA methods is the difficulty in conveying the meaning of these levels to the analyst. (references?) The leftmost column in Figure 4.2 shows my modification of Rasmussen's original relationships, adapted for this research and work domain. The means-end categories define a WHY-WHAT-HOW relationship. Figure 4.1 shows each category can represent a "WHAT" while the category above represents "WHY" the category below represents "HOW" the WHAT can be accomplished.

To help generalize and re-use this method in developing healthcare information systems, I adapted Rasmussen's original categories to be more applicable to health care settings. Table 4.1 shows Rasmussen's original means-end categories and my modified means-end categories as well as brief definition of how I defined each category. I will now describe each means-end category and the descriptions used to fill each category. The full diagrams showing the abstraction decomposition space and the data described in this section can be found in Appendix 1.

Rasmussen's original means-end categories	**Means-ends categories modified for this research**	**How I used this means-end category for this research**
Functional Purposes	Goals, Values, Mission, Policies and Regulations	The specific goals and values of the work domain that the institution that should influence work. The policies and regulations that cannot be affected by the workers?
Abstract Function	Quality Measures and Balances indicating Success	How the institution measures success, often through quality improvement measures developed by the institution or external agencies such as the Department of Health and Human Services (HHS) or the Agency for Healthcare Research and Quality (AHRQ).

		Individual measures that need to be balanced to achieve goals.
General Functions	General Functions	This category describes the general functions (or work) of the work domain using the Physical Functions in the next level. The scope of this category is not necessarily specific and the analyst must use his/her experience to determine the scope of the set of activities in breadth and depth. The General Functions in this research were determined through inductive open-coding of the qualitative data.
Object Related Functions	Physical Functions and Intentional Processes	This category links the physical objects and the general functions through a describing either the physical functions of the objects of the intentional processes of the general functions. This level is both a property of the object (the WHY) and a method to carry out a general activity (HOW).
Physical Objects	Physical Resources	The physical and material resources available in the work environment including physical plant, technology and information resources.

Table 4.1 The original hierarchies of the abstraction space as described by Rasmussen. These definitions are re-defined for this healthcare setting.

4.1.2.1. Goals, Values, Mission, Policies and Regulations

This top category defines the first set of "WHY" data for the work domain. Constraints in this category include concepts and objects in the work environment that the work domain cannot influence. Data included in this domain are the institutional mission, values, goals, policies and regulations. In healthcare settings, these can be determined from mission statements and other corporate documents that explain the purpose of the organization as well as asking participants about values of the institution which I did in my participant interviews. The type of health care organization will also help the researcher orient towards the goals of the institution. Urban teaching hospitals differ from rural community hospitals. Verifying these goals and purposes with the workers will further refine the goals and value or indicate that the institutional values are not reaching workers which may influence system design or uncover inconsistencies.

From the data presented in the previous Chapter, the goals of Seattle Children's Hospital include their core Continuous Performance Improvement measures, Quality Cost, Delivery, Safety. Other values that emerged from the data and include Family-Centered Care, Efficiency and premier pediatric education. The institution and residency education program are governed by regulations, laws and internal policies such as residency work hours, admission and discharge policies.

4.1.2.2. Quality Measures and Balances Indicating Success

This second level in Figure 4.1 asks the question, "HOW does the work domain measure or balance progress towards goals?" It describes the measures in determining if the WHAT of the goals, values, missions and other constraints in the previous category met. Quality measures indicate how the work domain measures success and by extension how workers in the work domain should be able to measure their success as they work towards goals. As there are both institutional and individual goals, there are institutional measurements and individual measurements of success. These measures can become direct interface design objects as I will discuss in Chapter 5.

To determine the quality measures for individuals, I asked participants questions such as, "how do you measure success?," "how do you know you are meeting your goals?" Seattle Children's physicians monitored the number of patients they carried and their overall activities of daily living (sleeping, eating etc.). They were aware of how long each patient was in the hospital because this number is displayed on their patient data sheets.

However, they reported that they were not as aware of the costs of treatment or any financial considerations. Other measures of performance included maintaining low number of action items for the individual or team or the number of calls from pharmacists and nurses asking for clarification on their decisions.

In 3.1.1.2 I describe the CPI program and Table 3.1 shows some of the quantitative and qualitative measures used by the program to determine if the institution is meeting CPI goals. In developing the WDA model, the formulas and measurements are included at this level. I reported that the residents do not feel particularly pressured to make decisions according to these measurements and senior physicians suggested residents should not be aware of the measures in order to focus on medical education. However some residents indicated they would prefer to see the financial and organizational impact of decisions as part of modern healthcare education.

4.1.2.3. General Functions

The General Functions of the work domain serve as the central point in the means-end analysis and the core functionality of the system that will serve this work domain. These activities serve as the "how" for carrying out the measurements and balances which in turn serve as a the "why" for the need for the activities. This category intends to frame the general activity or purpose of work domain. The next level will contain the Physical Functions used to carry out these General Functions so the analyst therefore must be able to develop this level with enough abstraction that it can support multiple Physical Functions without being too broad. For instance, in this medical-based research, a general activity of "medical care" would be too broad and "patient documentation" too specific. It is a subjective process, but by understanding each means-end category and how they relate, the analyst should be able to arrive at appropriately scoped General Functions. In this research, the General Functions were derived from inductive qualitative analysis. The qualitative themes that I defined in the Chapter 3, Patient Project Management, Medical Education, Environmental Education, Team Management and Personal Time Management are the General Functions of this work domain . These categories will also frame the system and software requirements documents that could be generated for this work domain that I will discuss in 4.3.

4.1.2.4. Physical Resources and their Functions and Intentional Processes

The bottom two levels of Figure 4.1 concern the physical resources in the environment including physical plant, technology and information resources. The bottom most category includes the actual resources which are easily found in the observational data. The step above the Physical Resources and Intentional Processes includes the Physical Functions the physical resources serve. While these physical resources could serve many Physical Functions, the physical functions must answer the "How" of the General Functions. Multiple Physical Resources can afford the same Physical Function. For instance, pagers and phones both afford communication. Table 4.2 shows a subset of the physical resources and their Physical Functions. See the Appendix B for the full analysis and diagram.

Physical Functions	Physical Resources
General Medical Information	Guidelines, Order Sets, Resident Handbook, Primary Literature, Formulary, Internet (Google, Wikipedia), Medical reference books, Online medical references
Historical Patient Data	CIS, Email, Patient-provided documents
Communication	CIS, Personal cell phone, senior phone, intern phone, teamroom phones, pager, white board
Hospital Information/Policy	Census, Guidelines, Order Set, CHILD (intranet)
Current Patient Data	CIS, Personal notes, Patient medical binder
Personal Schedule Data	Teamroom white board, amion.com, Personal notes

Table 4.2 Examples of physical resources available in the work environment and their capabilities for the lowest two levels in the means-end analysis.

The Physical functions and Intentional Processes level is particularly challenging in this work domain that as I described in Chapter 2 is both natural and intentional. The natural aspect of this system is reflected in the properties of the various information sources. For instance, the General Medical Information is a physical function of multiple physical objects such as books, internet resources and medical literature, but not their relationship in terms of an "is-a" relationship but in terms of their physical properties that define a "what-how" relationship. For instance, books are physical while internet is online and searchable. Conversely, books may be more trusted than general online resources while more outdated than the most recent published literature.

4.1.2.5. Diagram showing means-end relationships

Combining the means-end data into a single diagram results in a hierarchical model. The model represents how goals are accomplished with physical resources though intermediate functions and measurements. It indicates which measures and balances in the environment constrain the worker for a particular work activity. This hierarchy also allows the analyst to focus on one particular function or measure and follow its related constraints. Again, each level should answer the question WHY for the level below and HOW for the level above. In Figure 4.3, the red lines indicate that High Quality Patient Care is measured through the three functions Family Satisfaction. The full abstraction hierarchy is presented in the Appendix.

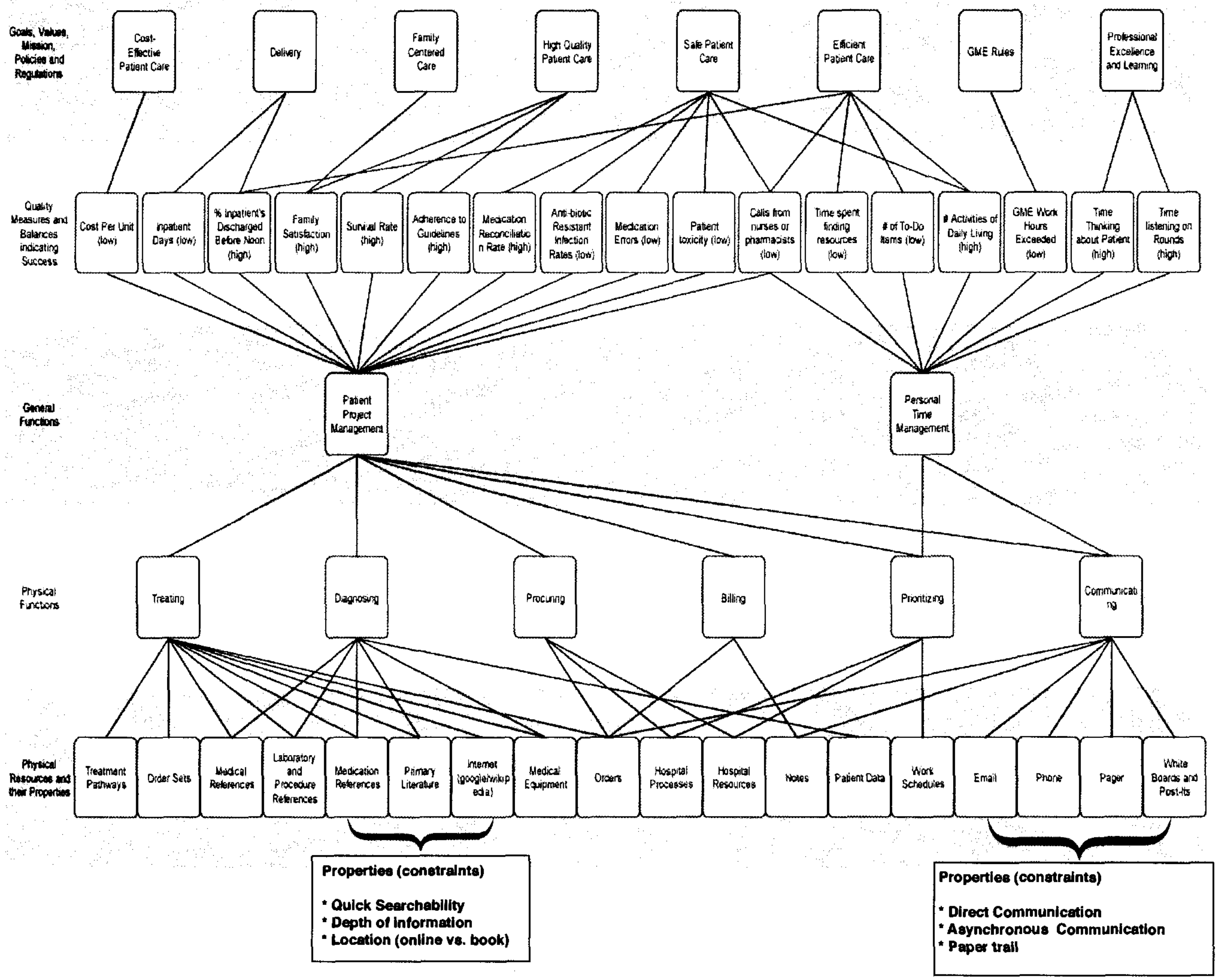

Figure 4.3 Means-end links between the five abstraction hierarchy categories. The yellow box indicate the properties of the physical resources that provide additional constraints in the environment.

4.1.3. Decomposition: Part-Whole Analysis

The goal of this axis is to define the system and subsystems that workers perceive as they make decisions. Lind discusses that the method for choosing what type of part-whole representation remains ambiguous in the descriptions of the ADS and work domain analysis.(Lind 2003) While this aspect may not be as fully explored as it could be, careful understanding and selection of the work domain and the work domain boundaries will guide the analyst towards selecting a relevant part-whole decomposition (if any) using the workers conceptualization of the work domain as a guide.

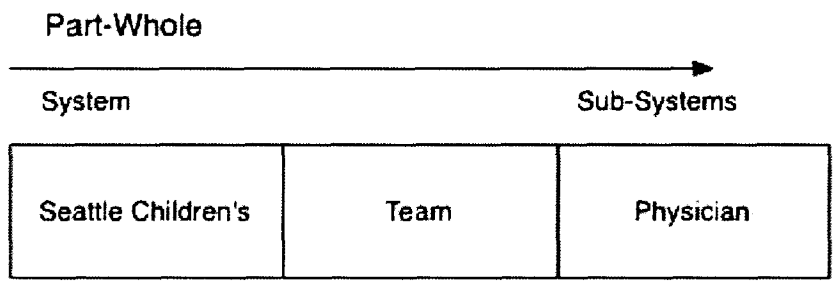

Figure 4.4 The Part-Whole decomposition of the work domain analysis.

I chose to model the work domain of an inpatient medicine team. Based on the qualitative results I described above, my analysis showed that the physician viewed their work in terms of Seattle Children's, their team and themselves. This structure is also reflected formally in the infrastructure of the training program, but also reflected in the physicians perception of their work as well. While, each physician is concerned with their own performance and patients, I observed them helping their teammates, dividing work, covering for each other. The workers also were very conscious of their institution, the regulations, guidelines and their participation in the graduate medical education program. Figure 4.4 shows these categories on the x-axis of the work domain model.

4.1.4. Combining Part-Whole and Means-End Analysis

Combining the analysis from 4.1.2 and 4.1.3, I assembled a model shown in Figure 4.5 illustrating the decomposition of the means-end levels for each of the sub parts of the work domain. This complete model allows the analyst to map the decision processes from activities onto the various objects in the work domain which will aid in the development of design requirements. In addition, this abstraction analysis shows that the majority of physical resources for these two work functions (patient project management, personal time management) are mainly hospital resources. This includes the equipment, computers, information resources. Some of the goals are shared across parts. For instance, the institution has clear measures for efficiency, but physicians also reflected personal efficiency goals. The physical capability of Communication can be achieved through physician resources such as pagers or phones but also through hospital resources such as the CIS. However, it is worth noting that while the institutional has values and measures for high quality, safe patient care and other quality measures, the activity of project managing patient is not a hospital activity, but a Team activity.

Abstraction \ Decomposition	Seattle Children's	Team	Physician
Goals, Values, Mission, Policies and Regulations	Family Centered Care High Quality Patient Care Cost-Effective Patient Care Delivery Safe Patient Care Efficient Patient Care		Professional Excellence and Learning
Quality Measures and Balances indicating Success	Family Satisfaction (high) Survival Rate (high) Adherence to Guidelines (high) Cost Per Unit (low) Inpatient Days (low) % Inpatient's Discharged Before Noon (high) Medication Reconciliation Rate (high) Anti-biotic Resistant Infection Rates (low)	# Patients assigned to Physician (low)	Calls from nurses or pharmacists (low) # Activities of Daily Living (high) Time spent finding resources (low) # of To-Do items (low) Time thinking about patient (high) Time learning about patients on Rounds (high) Time learning at Bedside (high)
General Functions		Patient Project Management	Personal Time Management
Capabilities of the Physical Resources	Hospital Information/Policy General Medical Information Historical Patient Data Current Patient Data		Communication Personal Schedule Data
Physical Resources	Census Guidelines Order Sets Consulting Services Primary Literature Medical Reference Books Patient-Provided Documents CIS Patient Medical Binder amion.com	Teamroom Phone Teamroom White Board	Personal Notes Pager

Figure 4.5 General Abstraction Decomposition space (Part-whole and Means-End Analysis) of physician team work.

Performing a decomposition of the concepts and nouns in the work domain analysis is an important step towards design. The decomposition derives from analyzing worker's perceptions of the environment. Therefore, the design of the information by reflecting the part-whole relationships will reflect worker's true perceptions of the environment.

4.2. Activities Analysis and the Task of Ordering

In 4.2, I focused on the nouns and objects in the work domain to define boundaries and behavior shaping constraints and in this analysis phase I will focus on the verbs. Work domain analysis models the work domain specifically without reference to how goals or functions are achieved, how the physical resources are used and by whom. In this section, I will discuss what activities are required in order to achieve goals with the understanding that the set of actions to achieve goals may be different in different contexts or by any actor (human or computer). The goal according to Vicente is to identify the requirements that must be satisfied if goals are to be reliably and consistently attained.

Hajdukiewicz explains the difference between work domain analysis and activities (or task) analysis as the former are "information requirements that are time and event independent while the latter are time and event dependent."(Hajdukiewicz and Vicente 2004) Work domain analysis provides the structure to support worker adaption to unanticipated situations by representing the work domain accurately in terms of structural means-end relationships. Activities analysis focuses on anticipated and known situations. Work domain analysis permits the representation of current and desired states so that workers can decide actions. However, once actions are decided, task analysis is necessary for systems to support the chosen set of actions.

I performed an activities analysis with the following steps:

1. I identified prototypical work situations and work tasks that segmented physician work (4.3.1-4.3.4)
2. I identified the work tasks that contained the discrete task of ordering and used Rasmussen's decision ladder template to explore this activity (4.3.5)

4.2.1. Contextual Activities Template

Task analysis focuses on *what* needs to be done in a work domain to achieve goals.(Naikar, Moylan et al. 2006) Task analysis is not concerned with how (Strategies Analysis) the work is done or by whom (Social-Organization Analysis) .

Rasmussen suggests decomposing activities into either (a) work situations that are more scheduled or well-defined in time or (b) work functions (I call them work task here to differentiate them from the functions in the work domain analysis) that are better defined by discrete sets of problems to solve independent of time and space.(Rasmussen, Pejtersen et al. 1994) In his example, he suggests that hospitals can be more conveniently decomposed into work situations that are well-defined in time. In this hospital work domain, I chose to decompose activities into both work situations **and** work tasks as I identified that work was performed according to temporally segmented work situations, but also that there were also recurring work tasks. In order to represent both of these decompositions, I have chosen to follow Naiker's Contextual Activities Template (CAT) that creates a matrix with work situations across the horizontal axis and work tasks on the vertical axis. As Jenkins explains, the CAT allows for drawing specific and broader observations about activities.(Jenkins, Stanton et al. 2008) For specific observations, the CAT shows that Documenting, when physicians write their daily assessments and notes on the patient, can take place any time during the work day, but it is unlikely to occur during rounds when the team is discussing patients. Conversely, the CAT permits viewing the key functions for any situation. Formatively, this model also permits the analysis of why certain work tasks only occur in certain work situations. This analysis can be a valuable exercise in redesigning work.

4.2.2. Work Situations

Rasmussen defines work situations as "prototypical task situations… that arise out of scheduled meeting and that are well-defined in time."(Rasmussen, Pejtersen et al. 1994) Although one of the motivations for this work is to support the dynamic work of inpatient medicine teams, it important to identify the prototypical workday for the inpatient medicine teams based on the typical daily schedule as seen in Figures 3.2a and 3.2b. For the activities analysis, I decomposed physician work into critical segments of the day by situation. Figure 4.6 shows five distinct work situations in this analysis horizontally across the x-axis of the

CAT. During the business week (Monday through Friday), the physicians arrive and prepare for rounds. After rounds, they continue with their work for the day, following through with the treatment plan created during rounds or other asynchronous work. Overnight, on-call and weekend are treated differently due to the shift from a full team to a partial team. I will now briefly describe each of these five work situations.

4.2.2.1. Pre-Rounds

The physician team (except the on-call physician who has been working all night) will arrive early in the morning. A key aspect of this work situation is that it is a time for individual work, not team-based work. The interns will assess their patient's situation after the night. They will examine the patient and speak with the families, review medical data and prepare for reporting on the patient during rounds and are supposed have their daily notes completed during this time. The seniors will review the patient list for the team (which now includes patients that were admitted overnight) and go over the day's work for the team. The attending physicians will review the most interesting and critical patients to assess the status of the team's patients.

4.2.2.2. Rounds

For the purposes of this analysis, Rounds includes both "work rounds," a preliminary team meeting conducted in the team room and the "bedside" family-centered rounds that are conducted on the wards often in the patients' room. Both of these scheduled activities are team-based activities. During this time, the team will discuss the patients and plan for treatment and provide teaching on interesting cases. As described in Chapter 3, Seattle Children's conducts bedside rounds where a large team, including the nurses, families, pharmacists and other consultants will discuss the patient. Although this work is confined to the general inpatient (house) service, the seniors and interns also support subspecialities, and similarly round on these patients.

4.2.2.3. Post-Rounds

The work period after rounds is again a period of individual work where the team will return to follow-up on individual patients and execute the treatment plans discussed. The attending will see each patient individually and document their time. During this time, the residents may be scheduled for other training or work outside the hospital so the team composition may fluctuate significantly in the afternoon.

4.2.2.4. Overnight/On-call

The overnight and on-call during the weekday is a period of team work where one intern and a nighttime senior work in tandem focusing on maintaining patients and admitting new patients. The attendings are not available other than for emergencies and in my interviews with residents, there is a reluctance to make changes until the morning. The intern and senior round again late at night and review the patients. Given the stress of nighttime on-call due to the lack of sleep and admission duties, the physicians I interviewed preferred having rule-based strategies (if-then strategies) to maintain stability until the morning when there is a chance to confer with the attending or team. Seattle Children's policy documents support this method as well, requiring each physician to give a list of task items and if-then strategies to the next physician.

4.2.2.5. Weekend

During the weekend, the team consists of one senior and one intern similar to the week nights. However, they are able to review the patients with the attending in the morning over breakfast so this work situation provides more team support than overnight, but less than during the business week when more staff and services are available.

4.2.3. Work Tasks

Rasmussen identified that work activities can also be decomposed by "prototypical task functions (that are) characterized by content independently of temporal characteristics." A challenge for the researchers is deciding the level of granularity when decomposing work into activities. To guide the identification of work tasks, I return to the General Functions identified in the work domain analysis in Chapter 3, Project Managing Patients, Managing Personal Time, Managing the Team and Education. Within these activities, I identified the most common "set of problems" (per Rasmussen) that physicians cope with.

In managing patients, these sets of problems closely follow the trajectory of the patient in the hospital beginning with admission through diagnosis, planning, treatment, daily documentation, hand-off to other physicians and finally discharge. This model therefore is able to represent both the patient path (work tasks) and the physician path (work situations) to understand activity in both contexts.

As I discussed in Chapters 3, efficiency is a key priority for physicians, part of resident evaluations and what more experienced physicians reported as being an important skill for a resident. The hospital culture is highly focused on efficiency. This culture had been embraced by most of the participants I spoke to. Physicians, especially less experienced physicians, develop their organizational skills and find a system that works for them to complete work efficiently and in an uncertain and changing environment. One attending physician remarked that unsuccessful residents, "don't have a system that works for them and so they can't get the work done... (who are) flailing (and) working much harder than the other interns and *still* not getting the work done because for whatever reason, they do not have the organizational skills to make it happen." Managing personal tasks is the primary work task in managing personal time. This function is comprised of managing the work and residency program schedules and tasks and other work tasks including patient care and residency program training.

All the participants agreed that this was a key function of their work and it is a component of the mission statement for Seattle Children's. I observed all physicians regardless of their level teaching their colleagues. Typically, those with more experience teach those with less experience. However, as I addressed in Chapter 3, even attendings that have more overall medical experience are often educated by residents who have more experience with the hospital or with general pediatrics. As I discussed above, the work day is segmented into work situations that alternate between focusing on individual and team work. Following this pattern, education occurs through team-based education in teaching others and self-learning that occurs more often during individual work time, but given the access to the computers-on-wheels during rounds, residents also self-learn using the computer during rounds.

4.2.3.1. Admit Patient

An admission in the hospital is defined as an overnight stay of at least 24hours. The activity element of ordering or related to ordering occurs for all stages of the decision ladder during the admissions functions. Patients are admitted by an intern and senior team who together interview and examine the patient. The intern then will create the documentation using the required forms that according to hospital policy entails “a complete medical history including the reason for visit (chief complaint) and pertinent history of present illness, past history/family history/social history, review of systems, current physical examination and assessment/plan.” These tasks must be completed within twenty-four hours of admission. The assessment and plan may not completed until after the patient is presented to the attending the morning after admission.

The end result of the admissions process is documentation and a set of admission orders. Residents are alerted to patients needing admissions via calls from the charge nurse or in some cases for non-emergency, scheduled admissions, via an ad hoc communication from an attending (i.e. a note on the white board). From Process Improvement documents, the hospital desires to create a pre-admission process that includes writing orders before admission for known or “direct” admissions. However, residents expressed frustration with this method due to the fact there was rarely an accompanying note explaining the reason for the specific set of orders thus leaving them without information and many noted that there wasn’t a good pre-admission process. I observed residents using the list of previous orders or pre-admission orders to determine why a patient was hospitalized.

4.2.3.2. Care for Admitted Patient

Physicians are required each day (including when admitting a patient) to assess patients and determine their chief complaint or reason for needing medical care. As a teaching hospital, the forms for the daily assessment are divided into a resident examination and attending assessment. Ideally, the residents should have completed and written their examination documentation during Pre-Rounds as the attendings make their own visits during the Post-Round period.

Part of assessing the patient and presenting the patient to the team is recording and managing patient data including for example vital signs, procedures, medications and determining whether the discharge criteria has been met. Understanding how to record, summarize and determine what data is relevant is an important part of physician education. Recording this data for presentation occurs during Situation Analysis in Pre-round and the data or order history was called upon on an ad-hoc basis during rounds if there were any immediate questions.

In determining the plan for the patient, orders or ordering occur in all three phases of the decision-making path. Physicians look at what orders have occurred previously and look at the order sets that exist to research what test or medications are appropriate. In evaluating options, physicians reported looking at when existing orders where scheduled, the availability of services and also the cost of different options (though interns also reported cost was not a priority for them) to evaluate their daily plans. In the decision for the plan, the physician will record in the documentation and present to the team their plan which usually involves test, medications or consults that will need to be ordered.

When executing the plan for the patient, order-related activities occur during all phases of the decision process. Before an order can be entered, physicians will look at prior orders to see if a similar medication had been ordered before. They will use the ordering system to review which orders are possible in the system. Often the team will decide a plan, but the intern or resident may not know to what the attending is referring and when it comes time to execute the plan, they do not know what they are ordering. Some orders involve multiple steps including a computer entry as well as a phone call to the service, and this information may or may not be available. Other services are available only during certain hours.

Understanding the consequences of certain orders on the patient's timeline, their preferences and erring on the side of making the patient and family comfortable help determine the specific orders. Physicians may also use the formulary or other medical resources or call a colleague or service to help determine which lab or medication to order or to understand how to enter an order for an unusual plan.

In the final execution phase, I observed physicians calling on a colleague or information resource such as a guidelines or reference book or web page to determine the dose, route or consult process. Even after the order is entered, I observed physicians following-up on orders by calling. Ensuring an order or a plan is fully executed is a complex process that can involve multiple iterations and communications until the physician is assured that the request was carried out.

My analysis focused heavily on this work task because of ordering playing a primary task in the decision ladder template of this work task.

4.2.3.3. *Hand-off Patient*

A handoff or sign-out occurs when care of a patient is transferred to a different physician. At Seattle Children's, since there is always an intern and senior on the team, interns will sign out to interns and seniors will sign out to other seniors. According to Seattle Children's guidelines, the current physicians must communicate the plan in the form of a "to do" list and "if, then" recommendations. In my interviews, participants stressed that a clear list of instructions is key to a successful handoff because usually new physician has no experience or history of the patient and needs some easy instructions to follow – especially given the stress of on-call and relative inexperience of the interns. While ordering was not a direct sub-task of this work task, the product of hand-off, the transfer of information directly feeds the decision ladder for Treating Admitted Patient.

4.2.3.4. *Document*

Each day, the intern and the attending are required to document a new assessment and plan for the patient and adjust discharge criteria. In this documentation, current laboratory results and medication are often listed. In this phase, the order-related activities occur in the execution phase. This work task does not require the complexities of a decision ladder analysis, but nevertheless is included in the analysis for completeness in a description of the work environment.

4.2.3.5. *Discharge Patient*

When a patient is ready for discharge, a set of orders are written that indicate the discharge itself and any orderable items (usually medications or referrals) that will be sent home with the patient or that are part of their post-hospitalization care. These orders may be written well before the patient's discharge as part of the daily plan as seen below in the Asthma Care Guidelines:

> *"You should write your discharge orders by the time the patient is on every 3-4 hour albuterol treatments. This will allow the family to get their medications and sufficient time for the floor RN or RT go over the use of the medicines and nebulizer." – Asthma Care Guidelines*

The physician is required to call the patient's primary care physicians with a report on their stay in the hospital as well as create a discharge summary for the patient. This is a priority for the hospital and tracked carefully. The physician will use the order history as part of the data gathering process for these tasks and evaluating the post-hospitalization care plan. The activity of placing an order is used to create the discharge orders and may be referenced when communicating to the primary care physician.

4.2.3.6. Work Tasks of Managing the Team

In managing the team, the seniors are responsible for ensuring the work of the interns and for the team are completed. The work tasks for managing the team (I am not including emotional support because it is not a task-related function) are to first assess the work of the team, often done by "running the list," that is reviewing all the patients on assigned to their team, multiple times during the day to assess the status of work and tasks. This is represented by the work task "Assess Team Work". As I have discussed in Chapter 3, the schedules of the residents can be very complicated and governed by graduate medical education regulations, personal schedules/illness and residency program requirements. Also, the work load of the interns is not intrinsically evenly distributed as some interns may receive more admissions or complicated patients than others. Thus, another key work task for Managing the Team is to allocate the work amongst the team including re-distributing tasks or re-assigning patients to team members, noted in my model as "Allocate Teamwork." Work can be allocated based on personal schedules, on-call schedules, resident work hour limitations, patient load and the capabilities of individuals. While assessing and allocating work is primarily the role of the seniors as I will discuss in Section 4.4 Social Organization, it is a necessary work task for the team regardless of the actor.

4.2.3.7. Work Tasks Associated with Education

Education is an overarching theme of the general work and can be segmented into teaching others and self-learning through research and reading. I observed two types of teaching: Structured Teaching and ad hoc "In the moment" teaching. Structured teaching occurs during Morning Report, a half hour teaching session run by the Chief Residents and during other scheduled didactic sessions. In addition, I classify rounds as a less formal, yet still structured, form of teaching. The "in the moment" teaching occurs through the natural patterns of getting work done. In the moment teaching typically does not extend beyond completing the task or getting the answer, but often times, there are moments of extended "in the moment" teaching such as interns showing medical students how to write a pediatric note. Since the workers have vastly different background, the composition of the team changes on a regular basis, teaching others is an on-going work task.

Self-learning occurs through the natural course of researching diagnosis, treatments in order to carry out the work of patient care. In my interviews, all physicians performed medical research in order to care for patients. Physicians with less experience tended to general medical guides

4.2.4. Contextual Activities Template (CAT)

The contextual activities template (CAT) combines the work tasks and work situations in a two-dimensional matrix. By creating a matrix, we can examine the complete set of work in terms of functions and domains. This representation illustrates the formative properties of Cognitive Work Analysis by capturing all the combinations of work tasks and work situations that are possible and allowing us to examine ordering in terms of all the work tasks and situations. The complete CAT analysis is shown in Figure 4.6.

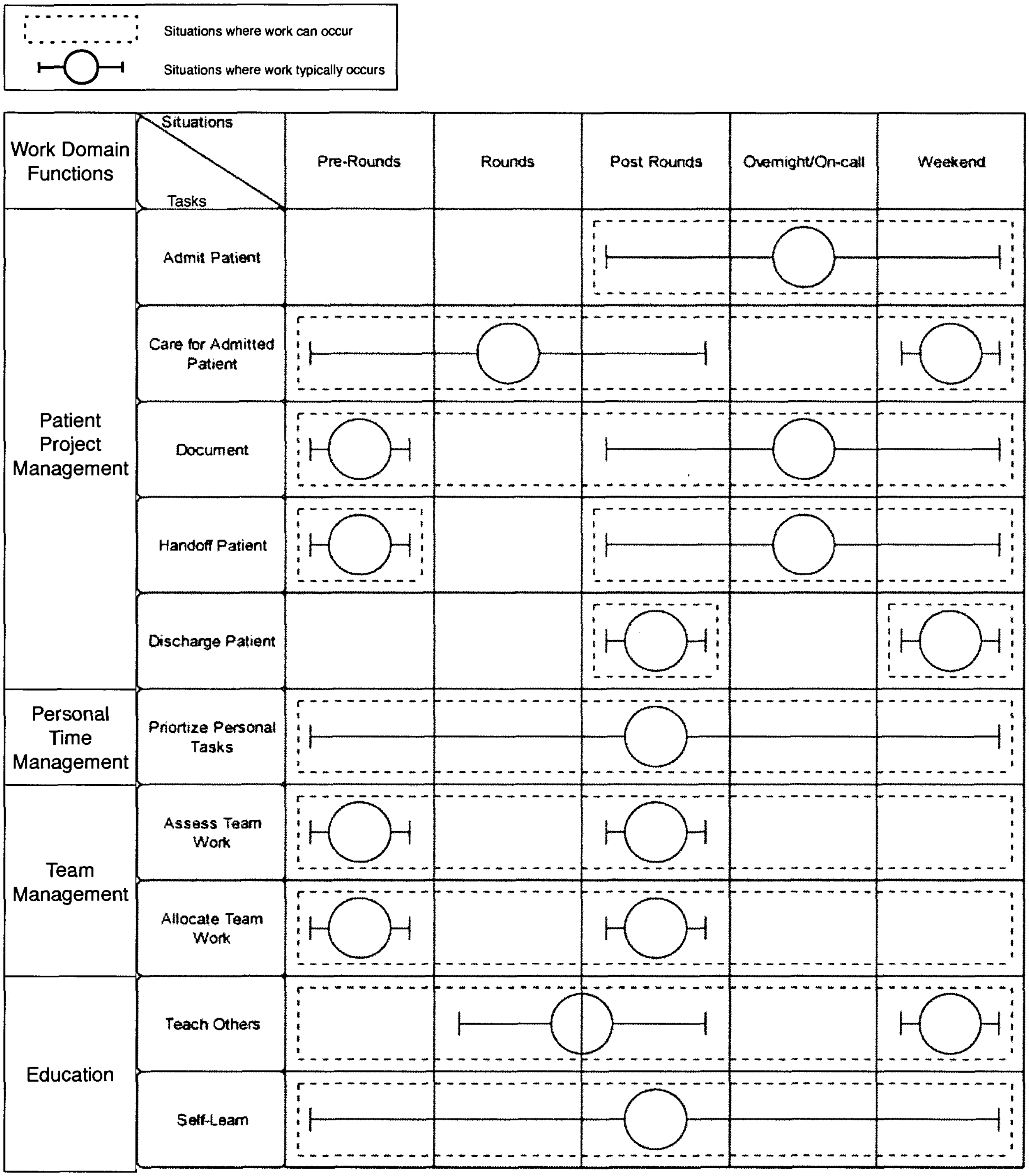

Figure 4.6 Complete Contextual Activities Matrix.

The CAT defines the complete combinations of work situations and work tasks. However, not all functions occur in all situations and some situations may be more likely than others.

Therefore, we can use the model to indicate when work tasks can occur through the dotted boxes and when work tasks typically occur through the circle and lines.

As I will discuss in section 4.8, the system requirements to support this work, these models have implications for design. As Lind explains, "cognitive support tools that assist with execution of specific work (tasks) must be available within the applicable work situation."(Lintern 2009) When considering implications for the design of an ordering system to support this work domain, we must consider the work tasks and situations when ordering occurs and for those work tasks that do not directly influence ordering, we must consider where the outputs of those work tasks enter in the decision process for ordering.

4.2.5. The Sub-Task of Executing A Care Plan

The goal of the dissertation was to closely examine ordering. From my interviews with physicians, the purpose and definition of ordering was much broader than the function of order-entry that fulfills the required software function for future hospital systems. Excerpts from interviews with physicians when asked to explore what ordering is included: "unify what we're doing with the patient," "what am I (the physician) going to do for you (the patient) here," "getting stuff done," "coordinate the provision, space and time of something a kid needs to feel better," "your plan of care," "communication," "history of care," "reflection of your state of thinking." From these descriptions, I summarized these reflections and observations into the sub-task of "Executing Care Plan" that is the primary sub-task of Caring for Admitted Patients and key sub-task of Admitting Patients and Discharging Patients.

Fully decomposing other control tasks such as documenting admission and hand-off identified in the cognitive activities template into complete work activity elements and information resources is beyond this scope of this dissertation would be part of a complete cognitive work analysis of the inpatient team's work.

Rasmussen's decision ladder is a useful tool for analyzing tasks and identifying even smaller activity elements. A decision ladder maps the cognitive states and cognitive processes for a work task, in this case Executing Care Plan. Note that the decision ladder, unlike the abstraction-decomposition space is not a model. It is not meant to be a model of a cognitive activity.(Vicente 1999) Rather it is a template noting general states of knowledge and data processing activities arranged in sequence abstracted from studying decision-making in multiple work domains.(Rasmussen, Pejtersen et al. 1994) As seen in Figure 4.7, there are three main sections of the decision ladder, Situation Analysis, Solutions Evaluation, Solutions Execution based on the five generic classes of Decision Subtasks identified by Rasmussen and from further work by Lintern.(Rasmussen, Pejtersen et al. 1990; Lintern 2009) Entry and exit points (grey arrows) can occur at multiple steps along the ladder and I give examples to illustrate entry and exit along the decision ladder. While the solid arrows represent a full traversal of the decision ladder Dotted lines represent common short cuts across the ladder from states of knowledge to other states of knowledge (D, E, G, I) using direct association without any additional data processing steps or from data processing steps to states of knowledge in other parts of the ladder (C) or from states of knowledge to alternate data processing steps (B, F, H) or in the more rare case of data processing leading to additional data processing of the results of those actions in the case of laboratory tests (A). In order to explain the complexities of the decision ladder, I will next describe the major sections of the decision ladder using examples of the type of data processing or data state of knowledge from the qualitative data.

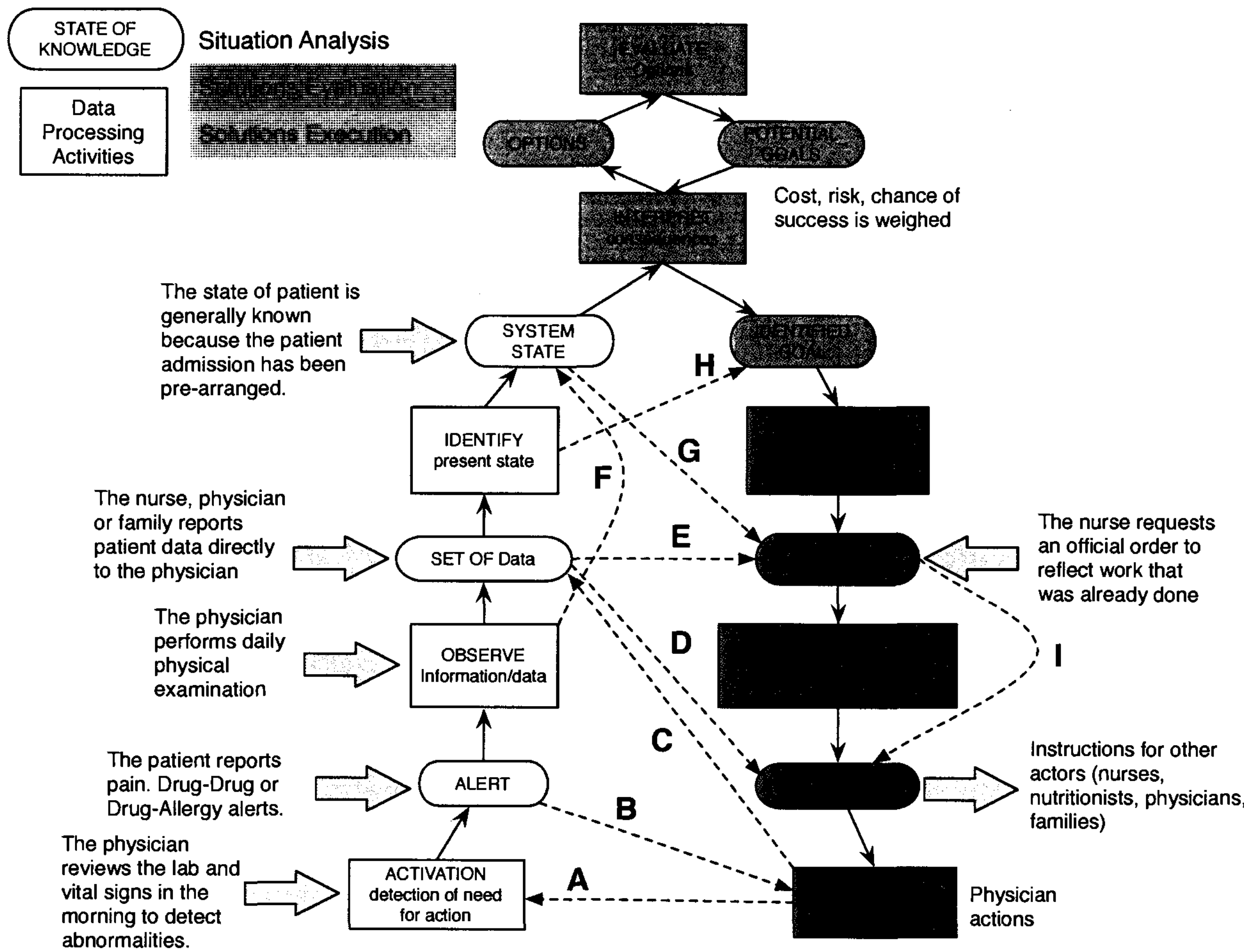

Figure 4.7 Rasmussen's Decision Ladder for the task Executing Care Plan. The decision ladder is a flexible tool for modeling decision-making processes. Short cuts are noted by dotted lines and given letter names for reference in the text.

4.2.5.1. Activation and Alert

This stage of the decision ladder represents detecting whether executing a plan of care is necessary and the state of knowledge of being alert to the need for action. As described in Chapter 3, the standard, prototypical routine is to enter the decision ladder at this point by reviewing any data or changes to determine which patients have priority needs and need to be seen during rounds. An example is this quote from an attending:

> *In the mornings I come in an hour and a half early, I go on the computers, I look at the labs. I see which patients have been admitted, what tests were done, and try to figure out why these things were done and if I chance I'll look at the patient beforehand, but I usually don't have a chance.*

Examples of alert states are medication error alerts or calls from pharmacists or nurses that indicate problems with orders or with patients. All the participants indicated that calls from pharmacists or nurses were the primary method for being alert to a problem with their order. Shortcut B indicates a path from Alert to Execute. This path can occur if after an alert an action is taken without any intermediate data processing such as if patient reports discomfort and the physician immediately prescribes a standard pain medication.

4.2.5.2. Observe Info/Data and Set of Observations

This stage in the decision ladder represents the gathering of relevant data and observations. The qualitative data indicates patient-relevant data in multiple sources (as I analyzed in the work domain analysis) including notes and orders in CIS, vital signs in the patient binder and conversations with consultants and discussions with the patient and families. Physicians can also observe directly by performing a physical examination of the patient. Bedside examinations typically occur before rounds, during the admissions process and in the afternoon, but can occur anytime with emergencies. The set of observations is both saved in the CIS but physicians also copy their set of observations into their personal notes and transfer these to each other verbally.

This stage relates back to the work tasks and work situations discussed in sections 4.3.2 and 4.3.3 and adds further depth to the contextual activities template as seen in Figure 4.6. The work task Hand-off Patient can provide the set of rules (if-then statements) that permit the short cut E from Observations to Tasks. A similar short cut D from Observations to Procedures occurs if the how the tasks should be executed is already known.

4.2.5.3. Identify State and System State

In the medical context, identifying the state and knowing the system state are medical diagnostic processes to use data and determine the current state of the patient in order to determine the plan. Examples of disease specific data processing steps can be found in the Seattle Children's Survival Guide that provides residents with flow charts and decision trees to rule out diseases or confirm diseases or in primary literature for more unusual cases. The shortcut F in Figure 4.7 represents the short cut from observations directly to knowledge of the system state. This short cut is exemplified by expert behavior medical diagnosis. One attending summarized, “Common diseases are common. Rare diseases are rare. So most of what you see is common and it's not very complicated and you sort of know how you're supposed to take care of it.” This attending’s statement reflects that for most diseases they are able to proceed directly from the data processing activity of data gathering to the knowledge of knowing the system state. The system state can be stored currently as a set of problem lists or the “chief complaint” in a note or a daily progress summary.

Knowing the system state does not necessarily equate to knowing the exact problem(s) of the patient, but this state is sufficient to determine the next set of actions even if that set of actions are to order more diagnostic testing or consults. The G short-cut indicates a path from knowing the system state to knowing a set of appropriate tasks. This short cut occurs when typical cases occur and the plan is known either from experience or from known treatment pathways. The H short cut represents an important relationship of this decision ladder and work domain analysis. WDA identifies measurements and balances that lead to goal states. The H represents traversing from current state directly to the goal state by analyzing the balances such as medical errors or cost or length of stay. The goal state is to return the system to a safe state with no errors.

4.2.5.4. Options evaluation and Interpret consequences

This stage at the top of the decision ladder represents the data processing needed to evaluate unusual situations or risky procedures or to determine if the system state requires action or a change in goal state. Novice physicians enter these processes more frequently then expert physicians as more situations are unusual to them. However, even expert physicians describe research and complex collaborations between specialties. The state of knowledge at the end of this process is a defined goal state whether biological or a goal to obtain more information.

4.2.5.5. Evaluate Tasks and Set of Tasks

This stage of the decision ladders determines the set of tasks for the patient, equating to the “plan” for the patient in this work setting. Evaluating the tasks is the data processing step that requires formulating a plan to reach the goal state. I observed medical research, consultations, reviewing previous treatments and medical references as examples of this type of data processing. In some cases, the set of tasks may be complex including consultations, medications and procedures. In other cases, the plan may be very simple. The short cut H represents the path from a set of tasks directly to a set of procedures to execute those tasks. For instance, for a medication dose, the procedure may be simple: enter an order for a medication. However, other sets of tasks may be more complicated and require additional formulation of an execution procedure.

4.2.5.6. Formulate Procedure and Procedure

This stage of the decision ladder is formulating the procedure (not medical procedure) to execute the tasks. Common procedures for executing tasks from the data include calling consults before entering the order, calling consults after entering the order, obtaining patient consent, ordering an interpreter to obtain consent. In terms of medication orderings this step includes calculating the correct dosage and delivery or looking up previous given medications. If procedures or dosage are known immediately then no data processing is necessary, however, as I described in Chapter 3, environmental knowledge is often unknown, especially if the physician is new to the hospital and significant data processing occurs either through asking/calling others or reading posters and hospital documentation to determine procedures for executing tasks. My qualitative data contained many instances of formulating procedures and below are a few examples:

> *"Like someone will say, get that PICC line placed on their IR. Like do I call Fluoro or do I call IR (Interventional Radiology). Because every hospital is different in terms of who will do that. So you end up thinking to yourself, hmm.... who should I call first? Then you kind of like ask your fellow intern."*

> *"There are things like consults that you can't just put in the order for the consult, you have to call the team and explain the patient."*

> *"The neuro attending wants video of the patient and [senior] said she spent all day trying to figure out how to order that and get it and finally she figured it out."*

> *One example of a place where we can't do that is if you want a scan under sedation, the process at 4pm is completely different than the process at 6 o'clock, completely different and people get really frustrated 'cause they spent all this time learning how to this process at 4 o'clock and they try to do it at 6 o'clock and it's saying well you*

can't do that. And they say, what do you mean I can't do that? I just did that 2 hours ago. Drives people crazy.

Each physician has their own method for recording their list of action items that need to be executed. Typically this is on a patient list printed from CIS, but I observed one intern had made her own custom form and others use blank sheets or index cards. In the current system, each physician has their own method for storing the Procedure state of knowledge.

4.2.5.7. Execute

The execution of the plan is the use of the physical resources identified in the work domain analysis includes the order-entry system, the communication resources, the order sets and treatment pathways. The short cut A and C from Execute to Observation and Activation represents the detecting whether the treatment or plan was in executed either by observing patient data reflecting execution or by detecting that the tasks were not processed such as if procedures are cancelled by other departments.

4.2.5.8. Entering the decision ladder from other activities

The decision ladder is a flexible template. It does not prescribe any specific set of actions or tasks. Just as the short cuts enable jumping from one part of the decision ladder to another apart further down the linear path, the decision ladder also support entry and exit points along the ladder. Figure 4.7 shows multiple entry points into the decision ladder. Each day the intern performs a physical examination and review of their patient's data. These actions are done routinely and not as a response to an alert or problem and therefore, the decision ladder is entered at the Observe data/information stage. In other situations, the physician does not perform any data processing activities to gather or observe data because other physicians, nurses or patient/families directly communicate the needed data such as during hand-off or during rounds. The decision ladder is entered from the state of knowledge having already gathered data. I observed nurses spontaneously asking physicians for orders, such as adding a heparin lock on an IV that was already done or to order meals. This situation is represented by an arrow directly entering into the Tasks state of knowledge. The Procedure state of knowledge can result in instruction or actions for other workers. This situation is an exit point from this decision ladder and a potential entry point for another decision ladder for another actor.

4.2.5.9. Segmenting the decision ladder by work task and situation

The contextual activity template can integrate the various elements of activities analysis by highlighting the contextual relationships between work situations, work tasks and sub-tasks.(Naikar, Moylan et al. 2006) As seen in Figure 4.8, various stages of the decision ladder in Figure 4.7 are more likely to occur in certain work tasks or work situations and those are filled in. This does not imply that those other processes cannot occur, but provides a context for prototypical or likely behavior. Most notably, the data gathering and processes when the patient is admitted occur typically during pre-rounds and then again during post rounds. During pre-rounds the execution of plans does not typically occur. In Figure 4.8, the Care for Admitted Patient/Pre-Rounds box the situation analysis and solutions evaluation sections of the decision ladder are filled in while the solutions execution processes are unfilled. During rounds, the team may look at additional data and tasks that can be determined and executed immediately without more elaborate information processes are completed. Thus in the Care for Admitted Patient/Rounds box, most of the processes can occur. The information processes associated with determining alert states is left unfilled because the intern is presenting the patient having already reviewed the data during pre-rounds. It is worth noting that only order-entry is explicitly supported during rounds and any other procedures needed to execute the plan are left until post-rounds. Typically for discharging the patient, the system state of the patient is well-known because the patient has met the discharge criteria. Therefore processes for situation analysis are not typical during discharge.

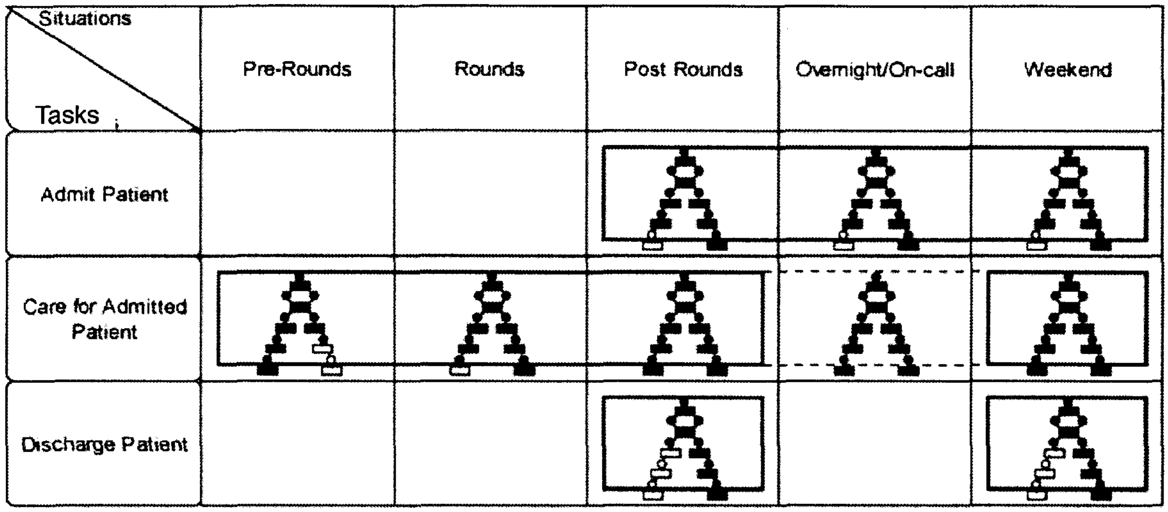

Figure 4.8 The Execute Care Plan task segmented by relevant work task and work situations. Filled in data processing activities and states of knowledge are more likely to occur.

Both the activities analysis products in Figure 4.6, 4.7 and 4.8 describe current work practices. However, because these representations include all work situations crossed with work tasks, it is possible to examine each box in the CAT and analyze why certain combinations do not occur. Similarly, we can analyze why certain data processing activities do not occur during certain work tasks or work functions. Why are orders not entered during pre-rounds? Why are does hand-off not occur during rounds. The answer may be readily apparent, but these representations can help organizations determine both wanted and unwanted constraints, influencing future work. This is an example of the formative properties of CWA.

4.3. Strategies Analysis of Executing Plan of Care

Strategies analysis is the third phase of CWA. Work Domain Analysis determines the constraints and affordances in the domain, characterized by a structural-based (noun-based) means-end analysis. Activities Analysis determines what needs to be done in an action-based analysis in terms of work tasks and work situations. This section, Strategies Analysis, focuses on how tasks could be done but does not include by *whom* which is left for Social-Organization Analysis, the fourth CWA phase in 4.5. Per Vicente and Rasmussen, the CWA definition of a strategy is "a category of cognitive task procedures that transforms an initial state of knowledge into a final state of knowledge"(Vicente 1999) The important deviation from other definitions is the notion that CWA strategies are a category of procedures rather than any specific procedure.

CWA allows for the identification of strategies through formative or empirical analysis. Formative analysis uses a complete work domain analysis to develop a complete list of possible strategies, regardless whether they are in current use by workers.(Roth 2009) An example in this work domain are treatment pathways that in my qualitative data were not used often, but through work domain analysis, it is an equal part of the space of *possible* strategies that could be used. Formative analysis using the abstraction decomposition is a useful method for identifying multiple information sources or physical resources such as pagers, phones and email that provide the same physical function but are employed in different contexts. For instance, some physicians preferred direct conversation or a phone call for immediate attention. Others preferred paging for asynchronous communication to give the other party more freedom.

Empirical approaches to strategies analysis study strategies in-situ and can complement formative strategies by revealing the knowledge and skills required for expert performance. Using the example of the treatment pathways, empirical analysis reveals that ignorance of the pathways or the inability to find them due to the relative institutional inexperience of many physicians may be a reason that treatment pathways are under-utilized. In addition, empirical strategies analysis can determine which strategies are sub-optimal work-arounds, which are expert behaviors and novice behaviors. Our goal is to encourage expert behavior and to design displays and systems that reduce cognitive burden but also support multiple effective strategies.

My empirical strategies analysis is focused on data gathered from observations and interviews. I explored strategies in interviews by asking open-ended questions such as, "What do you do before and after you order?" "How do you know your order has succeeded or failed." Strategies analysis is less mature phase of CWA.(Kilgore, St-Cyr et al. 2009) I have decided to present two broad strategies that I identified from the qualitative data.

4.3.1. Prioritizing by Patient

One strategy for executing a treatment plan is to prioritize based on the patient, their needs and level of illness. Patients are assigned to individual physicians and allocated and re-allocated to multiple team members. Physician reported the desire to be able to holistically think about the patient, their history and treatment, and to listen in during rounds, but time constraints often do not make this possible on the general inpatient service where there are often too many patients to allocate enough time for all them. Participants did report that with low to moderate work loads, they are able to work on a patient-by-patient basis. For patients that are seriously ill, physicians, especially attendings, will focus on their care as it is more likely to involve coordinating multiple subspecialities and consultants. Each day, the more serious or new patients take priority during rounds over stable and more routine patients. To determine who the team is going to see on rounds, prioritizing by patient is the only strategy employed.

4.3.2. Prioritizing by Task

The second strategy for allocating work and prioritizing work is by the complexity of the work itself or the priority of the work across patients. Participants reported that they prioritized tasks require more time or require other parts of the hospital to act such as ordering imaging studies. The seniors and team leaders are required to take a team-view of the work and ensure that all the work is accomplished across all the interns. While ideally the focus is on "ownership of patients" as one senior reported, this may not always be possible, and I observed team members asking each other to do specific tasks without transferring the ownership of patients.

4.4. Social Organization

The social organization phase of CWA addresses finally *how* work is done or could be done. This phase of analysis is accomplished by overlaying the roles and the team members on top of the work products from the previous phases of CWA. I will present two types of social organization analysis. The first focuses on individual versus team work through an analysis of current role allocation of work tasks and work situations. The second focuses on human versus computer roles in the specific data processing activities of execute care plan task by treating the computer as a potential actor.

4.4.1. Work by Role

Figure 4.9 shows a social-organization analysis of the contextual activities template. The different colors indicate the different physician roles as discussed in the Social-Organization section 3.3 of the qualitative data results. Interns are first year residents, seniors and second and third year residents and attending physicians are physicians who have finished their training. For design, we need to ensure that we can support not only a specific work task in a specific work situation, but also that we account for the abilities, level of training and goals of the worker assigned to the task. Figure 4.9 shows current allocation of roles, but this CWA analysis tool can be used to examine formatively why certain roles are constrained from performing work.

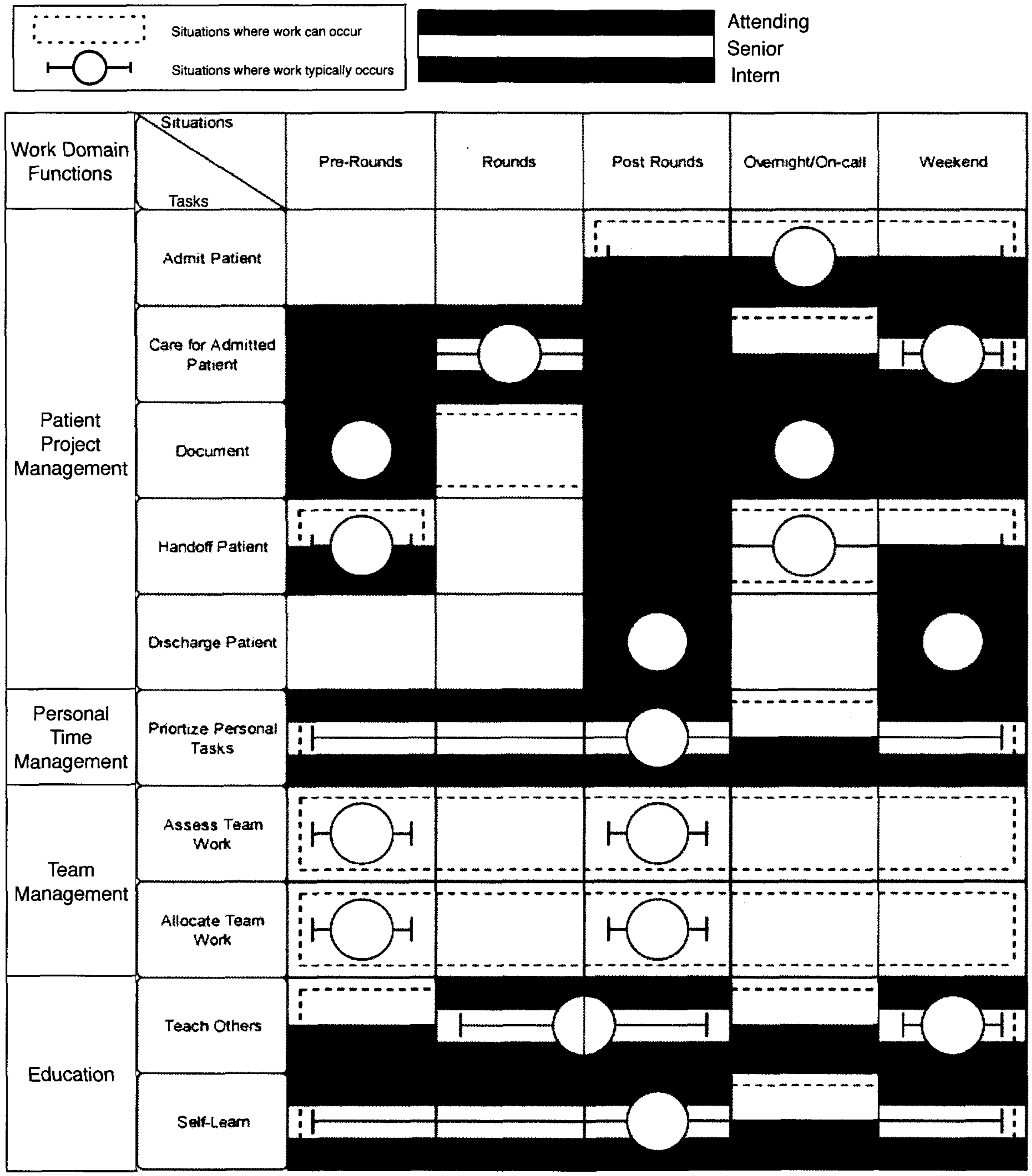

Figure 4.9The contextual activities template including social organization analysis. Blue indicates intern, Red- attending and Yellow –senior.

The goal of the residency training program is support physician education and provide experience and learning opportunities so that novice physicians can become more experienced physicians i.e. interns become seniors, seniors become attendings. Therefore, a clear delineation between roles was less useful than in other work domains that contain a mix of professional skills such as teams of physicians and nurses or surgeons and anesthesiologists. While certain actions are more likely executed by certain types of physician, it was more useful to observe the patterns of work for each work situation functions in terms of team or individual work. During pre-rounds, physicians work more independently as they prepare for rounds. Rounds is by definition a time for group work and discussion. Post-rounds is again a time for team work with the attending working more independently. Overnight and on-call is the work situation where one senior and one intern work together without the attending. The weekend is again a time for team work in smaller teams with the attending and one senior and one intern.

Another interesting pattern is to recognize when the team is staffed only with residents with limited attending support. These work situations that are resident focuses are pre-rounds and overnight/oncall and work tasks that are executed primarily by residents are admitting, and daily hand-off. Attending physicians do hand-off their patients to the next attending, but only after their two week service.

4.4.2. Human vs. Computer

CWA does not specify until the social organization phase *who* will execute tasks and activities. One method of using social-organization analysis is to determine which tasks and sub tasks can be automated to take advantage of computing capabilities and which are better suited for human cognitive abilities.

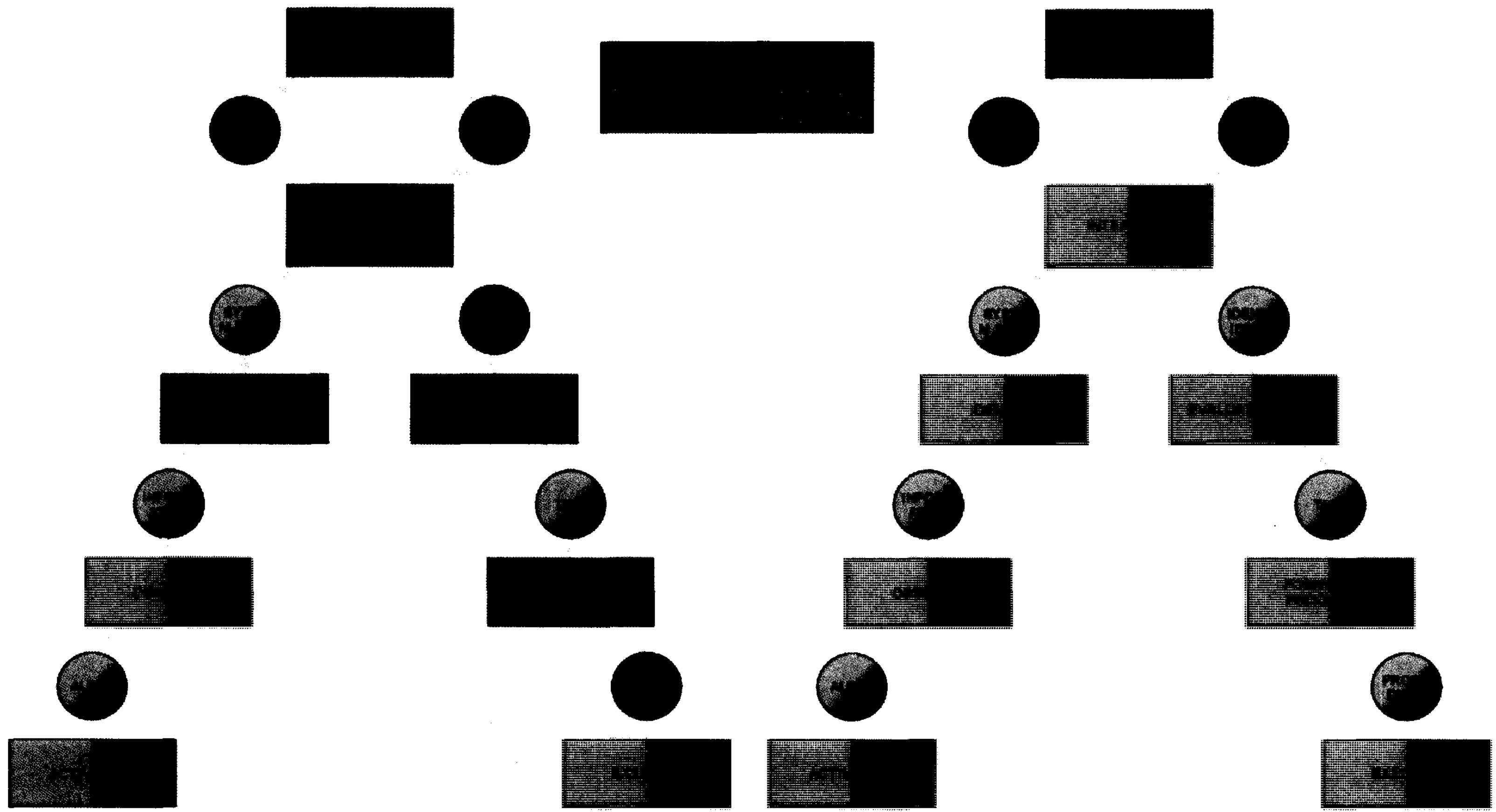

Figure 4.10a Current System **Figure 4.10b Future System**

Figure 4.10a and 4.10b The decision ladder template for executing care plan overlayed with a human or computer role. Figure 4.10a shows the parts of the decision ladder that currently contain computer automation.

Figure 4.10a shows the data processing activities that are currently automated in the Seattle Children's work environment. Because Seattle Children's employs a CPOE system that has medication alerting, the system is capable of processing alert rules and indicating the system is in a state of alert as well as automatically executing care plans via order-entry. Furthermore, the majority of patient data is kept in the electronic medical record so the Observe data processing activities that gather data are also automated. These processes are automated in some respects but there is still a human element to many Activation and Observe information processes such as physical examination or verbal cues for alerting. Therefore in Figure 4.10a, the boxes and circles are both orange and green indicating both human and computer roles. The System State circle is both orange and green due to the use of problem lists. The Task circle in 4.11a is also automated through the use of order sets that pre-determine a set of tasks that the workers can choose.

Figure 4.10b shows a potential future system that includes potential areas for additional automation. The proposed addition of automation will be reflected in the design implications of Chapter 5. I have left the solutions evaluation processes un-automated because they are out of scope of this research. These processes would require clinical domain knowledge and bio-simulation to develop decision support systems that helped workers interpret and analyze the effectiveness of solutions. These processes require higher levels of cognitive skill that should be human focused. My focus is to add automation to aid in data processing skills and also add automation to the storing of states of knowledge.

For instance, with an accurate work domain analysis, an automated system should be able to aid in the processes for identifying the state of the patient that currently by and large is left up to human processing of the observed data. The display of balances and quality measures will aid in identifying error states in the execution of their plan and help guide the worker to determine the desired goal state which should be to bring the plan back within safe or desired operating procedures. Encoding if-then rules or clinical guidelines into data processing functions (not just as data sources) will help workers evaluate which tasks will lead to the desired goal state. Adding automated support for determining the procedures (i.e who to call, when services are available) for carrying out tasks will support workers. I also propose that the states of knowledge for tasks and procedures can benefit from automation by saving those states – that is saving the tasks indicating the plan and the procedures indicating a list of "action" items to aid workers. I will discuss these ideas in Chapter 5.

4.5. Worker Competencies

The purpose of this final phase of CWA is to determine the competencies required by team members in order to execute the tasks, including ordering. This phase inherits all the constraints from the previous four levels and introduces three psychological processes, skills, rule and knowledge based behavior, each requiring a successively higher level of cognition. The goal is to support all three types of processes but not to force a higher level of cognition on a task that requires a lower level of cognition.

4.5.1. Skill-Based Behavior

Skill-based behaviors include direct action-perception behaviors. Skill-based behaviors are usually defined as motor-skills based on tacit knowledge that cannot be verbalized by the worker. Clinical skills such as performing physical examinations would fall into this category but are outside this work domain (but not outside other medical work domains such as medical devices with computer interfaces). Accessing the physical properties of the environment (seen in properties of the physical resources level of the WDA in 4.2) such as phone numbers, location of rooms, availability of subspecialties, specific names of tests are the skill-based behaviors in this work domain. Physicians must be able to directly perceive collisions or mismatches in resource availability and desired orders, staff availability and potential medical errors.

4.5.2. Rule-Based Behavior

Rule-based behavior is defined as planning by recalling the past, predicted scenarios, recognizing cues, patterns and historical behavior. Rule-based behavior is action based on familiar cues and heuristics without higher reasoning. Workers should be aware of the cognitive processes and be able to verbalize their thoughts. Rules based behavior is highly encouraged in this work environment. Policies and interviews suggest if-then rules for physician hand-off are highly desirable. This is likely because there without proper knowledge of the patient, knowledge-based behavior is more difficult. Physicians engage in rule-based behaviors when they review past orders to copy the same dosage and delivery method for future orders. Hospital policies define procedures to obtain services or admit patients and knowledge bases contain heuristics for medication error detection. These rules can be computationally integrated into a system and visualized in an interface, thus alerting the physician to patterns and suggested behaviors without the need to have a mental model of the work domain.

4.5.3. Knowledge-Based Behavior

Knowledge based behavior requires the worker to actively problem solve. The worker cannot rely on rules or action-perception cues and therefore must have an accurate mental model of the work domain and the means-end relationships between the structures within the work domain in order to reason effectively. In other words, if the worker understands how the system functions, then they will be able to adjust to unforeseen and unpredictable events. An example of knowledge based behavior includes a situation if the team is short staffed or if rounds end much later than normal or any unforeseen situation occurs for which there is no rule (or even if there is), only with a complete understanding of the work domain of the team, that is the schedules, the tasks and the constraints, can the workers adjust and continue to function effectively. Coordinating complex care and project managing a complex patient exceeds the ability of rule-based behavior and the physician must engage in higher order of cognitive processes in order to work safely and efficiently.

4.6. Information System Requirements

Now that I have described how I analyzed the work of inpatient medicine teams and ordering using CWA, I will turn to the practicalities of software development by discussing how these results can be used to develop information system and design requirements. The purpose of work analysis is to ensure that there is a good fit between the support provided by the information system and the work demands.(Vicente 1999) Information systems development, especially systems of the scope of a hospital system, often involves the process of *requirements engineering* which includes system requirements that define the problem that the software is supposed to solve and software requirements that define what the software is supposed to do.(Nuseibeh and Easterbrook 2000; Cheng and Atlee 2007) In this section, I will discuss some of the system requirements that I have generated from the analysis in the previous sections. I will show which parts of the analysis correspond to which type of requirements by using the IEEE guidelines for systems(IEEE 1998) and software(IEEE 1998) requirements as representatives of industry standards for these types of documents although how the analyst structures the requirements documents certainly depends on the project. This section is not meant to be an exhaustive or full set of requirements that would be used in a major software development project. The system suggested by this research is part of a larger health information system that includes administrative and other clinical services that are out of scope for this project as well as legal, security, privacy and other regulatory provisions. My goal is to illustrate how through using CWA, the analyst can partition the results of the analysis into software and system requirements. This section will lead into Chapter 5 where I will illustrate specific design results of these requirements.

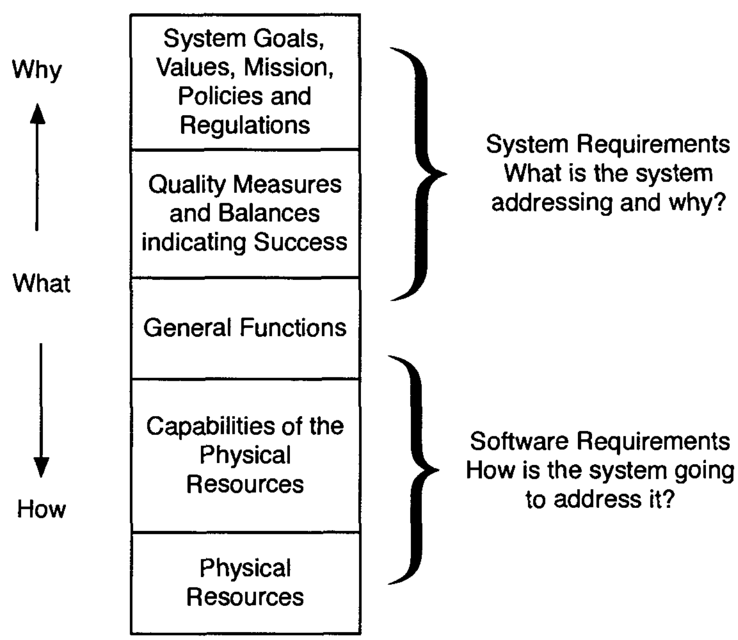

Figure 4.11 The 5 levels of work domain analysis broadly divided into system and software requirements.

4.6.1. System Requirements

System requirements define the problem that information system will address. From the IEEE Guide for Developing System Requirements Specifications (IEEE 1998), I have adapted a set of system requirement categories in the standard to discuss here in the context of the CWA analysis and Chapter 3 qualitative results. Rather than repeat data already presented, I will briefly summarize the information that would go into the major sections of a requirements document.

4.6.1.1. System Purpose and Scope

The system's purpose and scope can be described using a combination of the definition of the work domain 2.1.2 and the Goals and Values dimensions of the work domain analysis described in 4.1.3 and seen in Figure 4.12. The boundaries of the of the work domain as I have discussed is a critical step in determining the study design or requirements gathering methods and therefore the requirements data is bounded by this initial definition. A description of the Goals and Values dimension of WDA will give engineers a brief synopsis of the culture and broad context for the clinical work and users. For this study and work domain, an information system must serve the work of team of physicians comprised mainly of residents enrolled in a training program at a major academic pediatric hospital in Seattle, Washington. The team of physicians care for patients who have been admitted into the hospital and are cared for 24-hours a day necessitating the system to be available 24/7. The work of this team is part of a larger hospital system that includes ambulatory clinics, medical research, other medical subspecialities and administrative staff. Seattle Children's institutionally emphasizes their "four pillars" that are Quality, Cost, Delivery, Safety. Their culture encourages collaboration, family centered care and learning, but their core business measurements focus on improving in four pillar areas.

4.6.1.2. Policy and Regulation

All external policies and regulations as well as internal hospital policies that the work domain (i.e. physician team) cannot influence should be identified as top level constraints both in the overall CWA onion at the Work Environment level and in the Goals and Values level of the WDA. For this hypothetical system for Seattle Children's, policies and regulations include medical legislation, billing policies, graduate medical education rules and internal rules such treatment guidelines, admission and discharge procedures and physician handoff procedures.

4.6.1.3. Major system capabilities

The major system capabilities should be derived from the General Functions of the work domain. For this work domain, I return to my General Functions, patient project management, personal time management, team management, medical education. The information system that will support the work of this work domain needs to support these activities whether or not there are individual modules or applications. An evaluation of the final system should indicate that these activities are fully supported. A method for determining the level of support for the General Functions is analyzing if the work tasks from the activities analysis and physical resource capabilities from the work domain analysis are supported and interfaced.

4.6.1.4. User characteristics

This section of a systems requirement document corresponds to a discussion of the social-organization dimension of the CWA onion. The users of this system are physicians who work in teams with a relatively hierarchy of responsibility and experience. This section should include qualitative descriptions of backgrounds and motivations of the physicians and roles as described in section 3.3 as well as descriptions of team versus individual work. An important characteristic of the users of this system is the dynamic team composition. Some users will be able to gain experience with the systems through long-term exposure. Others must learn how to be expert users without any training, but are still required to perform as effectively. While the workers have team rooms and some have offices, all workstations are shared in work environment and should be treated as terminals.

4.6.2. Software (Functional) Requirements

Software requirements define what the system is supposed to do from a functional perspective. These requirements specify modules and sections of systems to support specific tasks.

4.6.2.1. Product functions

The system shall have three displays corresponding to the three work domain general functions, patient project management, team management and personal time management. Each of these displays is associated with certain measures of success and balances. The system shall graphically display those measures and show how those measures are affected by user action before the final set of actions is determined to support trial and error. Individual and team views will support the results of the socio-organization analysis that shows work situations and functions segmented into individual and team work.

The system should support developing care plans and formulating procedures for executing those plans based on multiple strategies. The system should aid in determining for executing plans such as hospital policies and scheduling. The system should also record the plans and task lists since workers spend significant resources organizing and recording plans as well as carrying over work between work situations.

The system shall support the following features in Table 4.3 based on the data processing and states of knowledge of the execute care plan task.

Decision Ladder Step	**Function**
Activation	The design should highlight new results, notes or status changes of orders.
Alert	The system shall show alerts such as medication errors that indicate the physician needs to take action. The system could allow nurses or pharmacists to flag or hold orders with questions while they contact physicians.
Observe	The system will interface and integrate with multiple data sources that contain patient data and allow multiple views such as more current versus historical.
Set of Observations	The system will permit easy (drag and drop) collection of clinical data elements from into a patient summary that can be displayed or printed.
Identify	The system should integrate with multiple types of information sources including guidelines, primary literature and general medical literature and allow user to choose the type of information source they need. If the general complaint and diagnosis is known, then the system should integrate in a disease specific method.
System State	The system shall support creating of a patient summary and patient status report including dragging and dropping relevant

	clinical information or notes.
Interpret	The system shall display relevant quality measures for meeting goals.
Goal State	The system shall support recording and codifying milestones and discharge criteria.
Define Task	The system shall support the recording and codifying of if-then rules from hospital guidelines or manual entry.
Task	The system shall support saving a task list representing the plan.
Formulate Procedure	The system shall automatically encode and alert the user to hospital procedures and can add them to the task list. The system shall integrate with clinical decision support and highlight previous, similar orders.
Procedure	The system shall store the set of steps for executing the plan as defined in Define Task
Execute	The system shall permit the execution of the plan through multiple methods from the various states of knowledge

Table 4.3 The steps in the decision ladder and the software features that support executing care plan.

The system shall support three types of worker competencies, skills, rules and knowledge based behaviors. The latter is supported by an accurate work domain representation and means-end relationships. Skills-based behavior such as automatic access to data such as the location of rooms, phone number should be supported. For rule-based support, the system should support the creation of if-then rules that can be transferred during hand-off as well as codify institutional if-then rules.

The system should support education, both teaching and self-learning in all the displays and functions. Educational data sources should be available for self-learning. All displays should have a teaching mode that can support didactic functions such as highlighting patterns or perform hypothetical actions.

4.6.2.2. *Data sources*

The data sources that this software needs to interface with can be determined from examination of the physical resources of the work environment. As seen in the bottom part of Figure 4.11, the WDA contains the physical resources in the work domain. While all of these resources may not interface with the systems, by using the social-organization analysis, we can see where automation is desired and the data sources needed for automating those processes should be supported.

4.7. Concluding Remarks for Chapter 4

In this chapter, I have presented a work domain analysis of the inpatient medical service at Seattle Children's hospital. As I explained in the introduction, this is the "map" of this work domain that will help develop a system that can respond to novelty. The pieces of the work domain analysis are derived directly form the qualitative field descriptions from Chapter 3. I have shown that ordering can be decomposed into work situations and work tasks, following Naiker's contextual activities template based on Rasmussen and Vicente's work. Because I used work situations and functions, my model reflects both the patient-focused and physician-focused work flows and trajectories. A situation-function matrix using physician-focused work situations crossed with patient-focused work tasks permits a formative analysis of tasks. We can systematically analyze all functions in all situations. This does not necessarily imply that all functions occur in all situations nor that every situation-function combination requires specialized support, but the holistic quality of this method departs from descriptive methods that are limited to what is known currently or normalized methods that prescribe situations and functions.

I employed the decision ladder template to decompose a specific task related to a broader definition of ordering, executing care plan, that is a sub-task of the work tasks admit patient, care for an admitted patient and discharge patient. I also discussed multiple strategies employed by physicians both from a formative analysis of the work domain to that reveals multiple physical resources that can be used to accomplish goals as well as an empirical study of strategies that identified two key strategies, prioritizing by patient and prioritizing by task that should be supported by the system. I also analyzed team versus individual work to identify that both team and personal views of the system should be supported and also analyzed current human vs. computer roles in executing a care plan. Analyzing human vs. computer roles in the current system led to a proposed social organization analysis suggesting new roles for automation that I will use in my design suggestions for Chapter 6. Finally, I analyzed worker competencies to identify specific types of skills-based, rule-based and knowledge-based behavior that exists currently in the work domain and that should be supported in the system.

I summarized the findings of these CWA products in a set of system and software requirements. These requirements are not exhaustive but highlight how CWA work products can be re-shaped and used for requirements engineering. I will use these requirements in Chapter 5, Design Implications.

Chapter 5: Visualizations and Design Implications of an Ecological Approach to Physicians' Work

What can a constraint-based approach look like based on the results presented thus far in this dissertation? In this chapter, I present three computer display examples based on o the systems requirements and analysis results presented in Chapter 4 using cognitive work analysis. The results and figures I present are visualizations of design implications to show specifically how the concepts in the CWA work products could be used to create an ecological design and visualize constraints. These are neither working systems nor recommendations for optimal designs. In Chapter 1, I explained that I set out to study the work-technology disconnect between clinical work and clinical computing systems. Thus, this result of this chapter explores the bridge between the cognitive work analysis and technology while stopping short of technical specifications that could be immediately implementable. In 6.4.4, I discuss how this work could be extended with the aid of other design methods to develop designs specifications.

I used principles of ecological interface design (EID), a graphical design technique developed by Vincente and Rasmussen as an outgrowth of their work in cognitive engineering and based on principles of ecological psychology. EID focuses on use of the abstraction hierarchy (means-end) and the Skills-Rules-Knowledge (SRK) framework that I also used in my CWA analysis.(Vicente 1996) However, the illustrations I will present also rely heavily on the data processing activities and knowledge states of the decision ladder template.

The majority of interfaces designed using ecological interface design or modeled on abstraction hierarchies and cognitive work analysis have been in work domains where the effect of decisions on the environment is temporarily more immediate and the variables more measurable. In transportation, power plant, intensive-care-unit monitoring, the variables measured are based on physical principles (physics, biology etc.) and changes and effectives are more easily shown.(Sharp and Helmicki 1998; Burns and Hajdukiewicz 2004; Drivalou 2005) In the social systems that have been described in the literature including library systems and gambling systems, the effects of tasks and strategies can be shown to have an immediate effect on the system such as the flow of money or odds in the case of gambling and the document classification in library search systems.(Pejtersen 1992; Burns and Hajdukiewicz 2004)

In Chapter 4, I presented the emerging work themes from the result of my analysis: Project Managing Patients, Team Management, Personal Time Management and Education. In this chapter, I will now illustrate a potential design for the first three themes and general functions. Education is a work theme and a general function of the inpatient medicine team as seen in the work domain analysis in Chapter 4. For design implications, Education is best supported as a goal in the work domain analysis of personal time management (section 5.2) and team management (section 5.3) so that these modules can be used for in situ education.

From the task analysis and the system goals of the work domain, I focused on the sub task of Executing Care Plan in section 4.2.5. Using the decision ladder template, I coded the qualitative data using to explore the various data processing and knowledge states required for this sub task. I will present how I used this phase of CWA analysis and the decision ladder to explore specific design implications for a Patient Project Management module in section 5.1. In sections 5.2, 5.3 and 5.4 discuss how the other general activities of the work domain are also reflected in the core module.

The first phase of cognitive work analysis is work domain analysis and WDA is the core modeling tool of ecological interface design.(Burns and Hajdukiewicz 2004) In Chapter 4, I presented a work domain analysis for the inpatient medicine that was a high level view of the environment in which the physicians I studied operate. Here, I will present derivative work domain analyses specifically for design of the systems that these physicians control. The system boundaries should include objects the users will control and information that will influence actions and lead to goals. Education is not a system of control. It is a goal of the other systems of control (Patient Project Management, Team Management and Personal Time Management) therefore Education is included in as a goal in those work domain analyses.

I chose to implement graphical displays to show data and constraints of the system. Previous work such as that of Alonso et. al show that using a graphical display of temporal medical history with the addition of detailed information via mouse-over or balloons can improve time interval comparisons, combining data from multiple source types and recall of data.(Alonso, Rose et al. 1998; Plaisant, Mushlin et al. 1998) Considering these prior results, I used a temporal graphical display for the central design aspect of the three abstract graphical displays. Figure 5.2 shows the first of these displays, the patient project management display screen. The screen visually integrates patient data across a timeline.

For each of the three design implications I will present, I will first describe how the result of the CWA analysis influenced the design decisions. Because my dissertation focuses on ordering and order entry, I explored project managing patients and executing the care plan in the greatest depth. Therefore, the Patient Project Management module in 5.1 is similarly the most well-developed and explored. The Team Management and Personal Time Management modules are important results of this dissertation, and I developed work domain analysis and initial design implications for both modules. I leave exploring the next phases of CWA for these work functions to further refine and develop these models as future work. I will discuss this future work in Section 6.3.1.

5.1. Patient Project Management Module

The patient project management module is the core functionality of the three displays I will discuss in this chapter. The initial step for developing a patient project management display is a work domain (means-end) analysis of the system the user will control which in this case is the patient. Other researchers have developed patient work domains that are physiological or biological to simulate the human body for the work domains they support such as anesthesiology monitoring. In this research, the patient is a "project" with tasks, timelines and associated clinical and business rules to meet a complex set of goals. The interface I suggest is an ecological representation of the patient as a project showing the relationships between these factors. I will introduce a new work domain analysis, specifically for the Patient Project Management work function in section 5.1.1. In section 5.1.2, I will discuss the design implications of the activities analysis and decision ladder from 4.2.5 and the social-organization analysis in 4.4.2. In section 5.1.3, I will show the design implications of the worker competencies analysis I introduced in 4.5. This section will illustrate the integration kills, rules and knowledge-based behaviors.

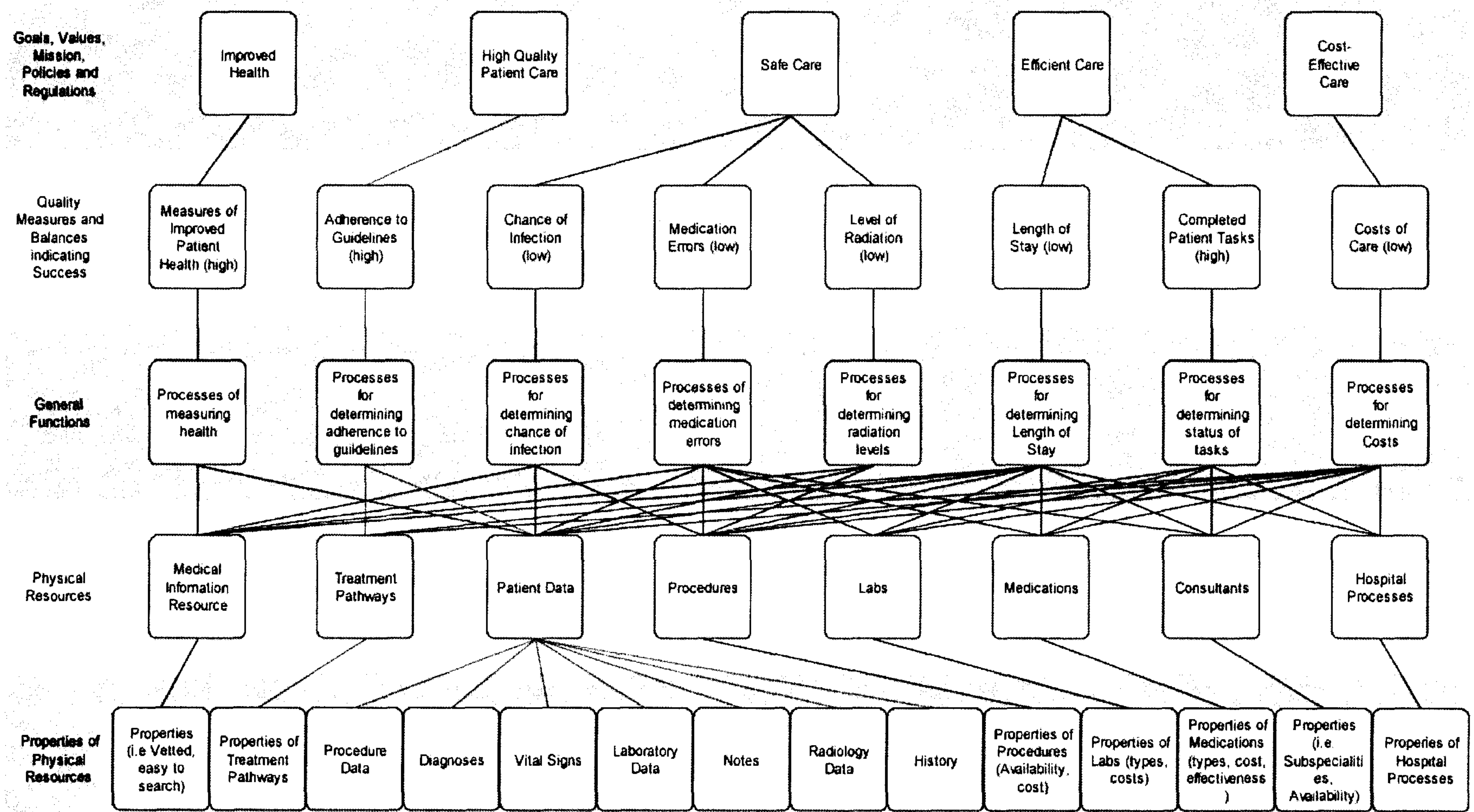

Figure 5.1 Patient "Project" Work Domain Analysis (Means-end dimension)

5.1.1. Patient Work Domain Analysis: Means-End Relationships

Figure 5.1 shows a means-end analysis of the patient in terms of resources. The goal of this means-end analysis is to model the relationships between the goals of the work domain at the top and the physical resources toward the bottom. The objects in the means-end analysis obey the WHY-WHAT-HOW paradigm discussed in Chapter 4. The high level goals of the patient domain such as improved health are supported by measures of patient health that are determined (HOW) by processes to measure health. The specific equations and formulas are left deliberately general here, and to build a fully functional system, they would need to be defined by experts. However, Figure 5.1 does show the framework that models the relationships between the entities in the work domain. The goal is to accurately represent the work domain environment by encoding the relationship between the physical resources and process to the quality measures. With these relationships established, when the user manipulates those resources, the interface should be able to show the effect of their actions on the work domain goals. Seeing this relationships will aid in decision making by providing accurate mental models of the work domain for knowledge based behaviors. The interface should show when the quality measures and balances are in an error state that is not achieving goals and when those measures have returned to an acceptable state. It is important to note that information processing functions such as order-entry or data entry are not included in the means-end analysis because they are actions taken by the actors on the work domain and do not model the actual patient work domain. This section will describe how the proposed interface of a patient project management accurately represents the work domain through the functions and are modeled through a means-end hierarchy.

Several of the goals of the work domain such as "Improved Health" appear in Figure 5.1 at the top most level of the work domain analysis. Now I will show how I represented these goals in the corresponding Patient Project Management design illustration in Figure 5.2. Each of the design illustrations, such Figure 5.2, is divided into design areas delineated with a circled number. I will refer to these areas in the following manner: Figure Number (Design Area Number). For instance, I will now discuss how the work domain goals are seen in Figure 5.2, area 1, abbreviated 5.2 (1).

A goal of the patient work domain is "improved health." Abstract measures of improved health (shown as a link from improved health in Figure 5.1 in the Quality Measures and Balances level) could be measured by improvements in laboratory results or vital signs. Thus, I illustrate Lab X/Vital Sign Y in Figure 5.2 (1) under Improved Health. Similarly, Safety is also a work domain goal and these are measured by medication errors, chance of infection and level of radiation as show beneath the heading and seen in the Quality Measures level of Figure 5.2. Because we have outlined the relationship between goal states and measures of those goal states, the display should indicate to the user if they have satisfied their goals. If a goal of the work domain is efficient care and one measure of is the number of tasks that have been completed, then the display will show this to the user as seen in 5.2 (1) and 5.2 (7).

The display needs to ensure that the current actions or processes are behaving correctly and not causing errors. (Elm, Potter et al. 2003) In addition to constraint violations of the quality measures, the display should indicate and draw attention to abnormal states or constraint violations of the physical properties such as overdue consults or conflicting medication orders. For example, Figure 5.2 (2) shows an example of a nutrition consult that was ordered but was not completed. In terms of the means-end analysis, General Function "Processes for determining status of tasks" represents this calculation.

One goal of the interface is to indicate abnormal states, but the subsequent goal is to aid the user in returning the work domain back to a normal state. Since the work domain here is

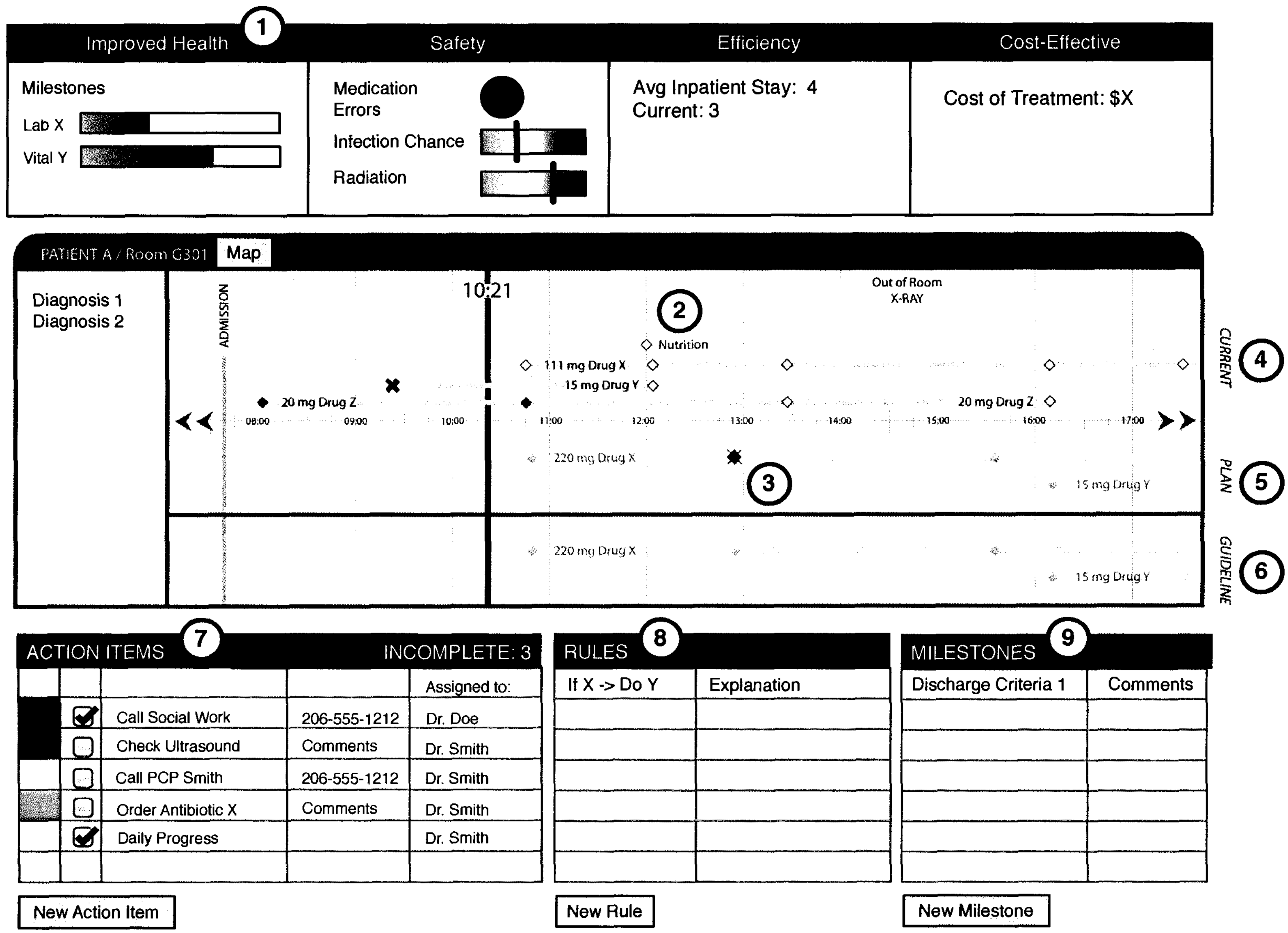

Figure 5.2 Visulations of Patient Project Management module interface. This display is an illustrative and hypothetical result of integrating the CWA results into a design interface.

the intentional work of physicians, the definition of "normal" is not a health state, but a work state based on the constraints of the environment with regard to the constraints and availability of human and information resources, legal, policy and guidelines and work goals. Rasmussen's recommends of showing the "intermediate results" of strategy choices so workers can shift their strategies and level of abstraction to adjust to new situations.(Rasmussen, Pejtersen et al. 1994) Thus within the constraints of the work domain, this interface should allow the physician to explore methods of returning their work to a normal state by trying different orders or guidelines. This is indicated in Figure 5.2 (5) where a proposed plan can be viewed and compared against the current plan in Figure 5.2 (4) and the effects of the plan on the goals can be reviewed as well as any potential constraints violations of the physical resources seen in Figure 5.2 (3).

5.1.2. Activities Analysis and Social Organization

The patient project management module should support the executing a plan of care task that I discussed in the activities analysis in 4.3. From the analysis of human and computer actors in 4.4.2. the design should support the data processing activities and knowledge states of the decision ladders (4.6.2.1). Because this phase of CWA relates to how workers act on the interface and the information processing abilities of the system, not all of the stages in the decision ladder can accurately be reflected in a static interface, but I will briefly give examples of how some nodes the decision ladder are represented. In particular, it is more difficult to illustrate the data processing nodes in the decision ladder, but easier to show the resultant states of knowledge. Given the team-oriented and distributed nature of work, the ability to save knowledge states is particularly important to this work domain. In addition, the highly interruptive nature of physician work and the need to support physician hand-offs also suggests saving states of knowledge is important in this work domain.(Harvey, Jarrett et al. 1994)

Referring back to Figure 4.7 that shows the decision ladder template, Figure 5.2 (5) shows the plan for the patient that corresponds to the "Task" state of knowledge. Figure 5.2 (7) shows a list of action items that supports the state of knowledge "Procedure". Not shown is the automatic population of hospital procedures such as phone calls or forms into the Action Items supporting the Formulate Procedure data processing activity. Figure 5.2 (9) supports the "Goal State" knowledge state by supporting the milestones that can be user-created or automatically through guidelines. The error indication (red diamond) shown in Figure 5.2 (3) and the Medication Error indication in Figure 5.2 (1) support the Activation data processing activity. The interface also shows examples of short cuts through the decision ladder that I discussed in 4.2.5. Figure 5.2 (8) shows how the interface supports the short cut from the knowledge state System to Task by allowing users to create if-then rules that can be used computationally during the Activation data processing activity.

The "Rules" and "Milestones" areas in Figure 5.2 (7) and 5.2 (9) respectively are examples of what Vicente calls "users finishing the design" for flexibility in design. (Vicente 1999) That is, because not all work situations and disturbances can be anticipated at the time of design, Vicente advocates for an approach that allows workers to modify the design based on local information, knowledge and expertise in partnership with the computer that can provide constraint information and other helpful domain state information. This perspective provides flexibility and adaptability to new situations that the designer could not have foreseen. It is not desirable for workers to "finish the design" in ways that are not safe yet the more degrees of freedom in a system, the more likely this may occur. Therefore as Vicente suggests, the level of freedom for any given task should be based on the CWA analysis. Some tasks may need to be fully automated. Other tasks should allow users freedom to adapt and set their own constraints.

5.1.3. Worker Competencies (SRK Framework)

Worker competencies analysis allows design to support work at the appropriate level of cognitive control of the worker. Therefore work requiring low levels of cognitive control such as finding where a patient's room is left unsupported will instead require the worker to use high levels of cognitive control. Specifically, using Vicente and Rasmussen taxonomy, I examined skills, rules and knowledge (SRK) based behavior with in patient project management.(Rasmussen, Pejtersen et al. 1994; Vicente 1999) Vicente in (Vicente 1996) describes the design implications of the SRK framework as follows:

1. Skill-based behavior—support interaction via time-space signals; the operator should be able to act directly on the display.

2. Rule-based behavior—provide a consistent one-to-one mapping between the work domain constraints and the cues provided by the interface.

3. Knowledge-based behavior—represent the work domain in the form of an abstraction hierarchy (means-end analysis) to serve as an externalized mental model that will support analytical problem solving, especially for unknown and unfamiliar situations.

In the interface in Figure 5.2 skill-based features are seen in the availability of important data such as room numbers, maps and phone numbers. Users will be able to act directly on the display in the "Plan" area to move appointments or medication schedules at the lowest level or at higher levels by manipulating entire guidelines or plans. Support of rules based behavior is seen in the if-then box (Figure 5.2 (10)) Physicians may add rules (workers finish the design) or rules may be generated by the treatment pathways or quality measures. The interface will show these if-then statements in addition conflicts or errors via the rules of the work domain that detect scheduling conflicts or medication errors. Physicians will respond to those visual cues with rules or patterned behavior.

Representing the patient means-end analysis accurately in the interface in terms of quality measures, processes, physical resources and properties supports knowledge-based behaviors by giving workers accurate mental models with which to adapt to unexpected circumstances. The patient project management module needs to supporting knowledge-based behavior considering that unanticipated events and unexpected interactions of the system will occur, and by definition cannot be pre-determined and engineered for a priori.(Perrow 1999)

The interface must support all three types of decision making behavior because most situations do not require high levels of reasoning, and therefore to force high level cognitive burden on lower level tasks will not result in a successful design.

5.2. Personal Time Management

The personal time management module helps physicians prioritize and manage their list of patients and daily tasks. Figure 5.3 shows a work domain analysis using the mean-end dimension for a work domain defined as "personal time." The high level goals share similarities to the patient work domain analysis discussed in 5.1. However, in the personal time management domain, safe patient care is measured by the participants in terms of patient safety measures discussed in the patient work domain, but also in terms of the number of calls from the nurses or pharmacists questioning their decisions.

While not all of these quality measures and balances are obviously translatable into an interface because of lack existing processes to measure (for instance) Time Thinking about Patient, nevertheless including these measures in the work domain analysis provides a placeholder for the development of such processes as well as provides an accurate model of the work domain. In this work domain analysis as with the team management analysis in 5.3, the patient is treated as a physical resource and constraint.

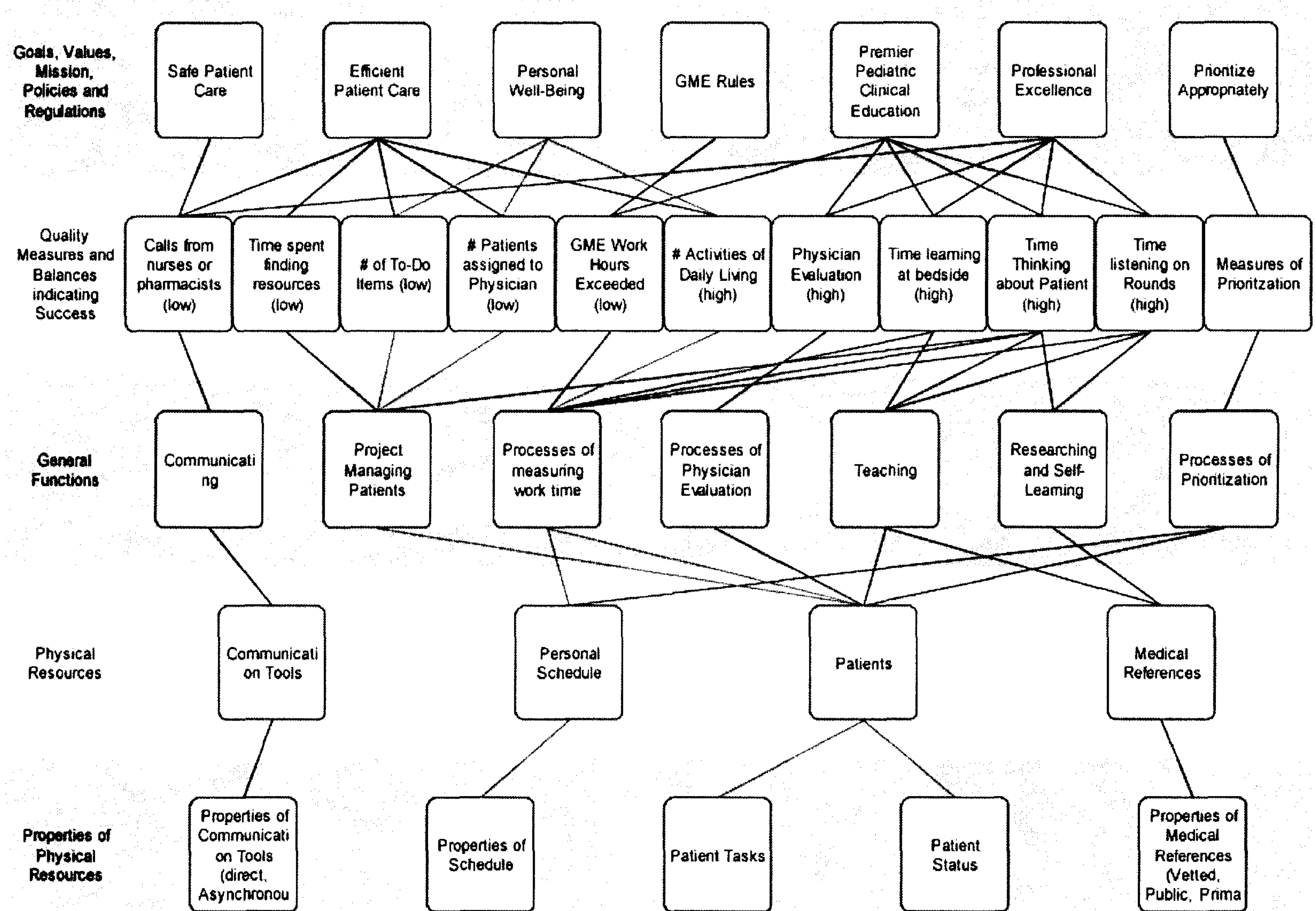

Figure 5.3 Personal Time Management work domain analysis (Means-end dimension)

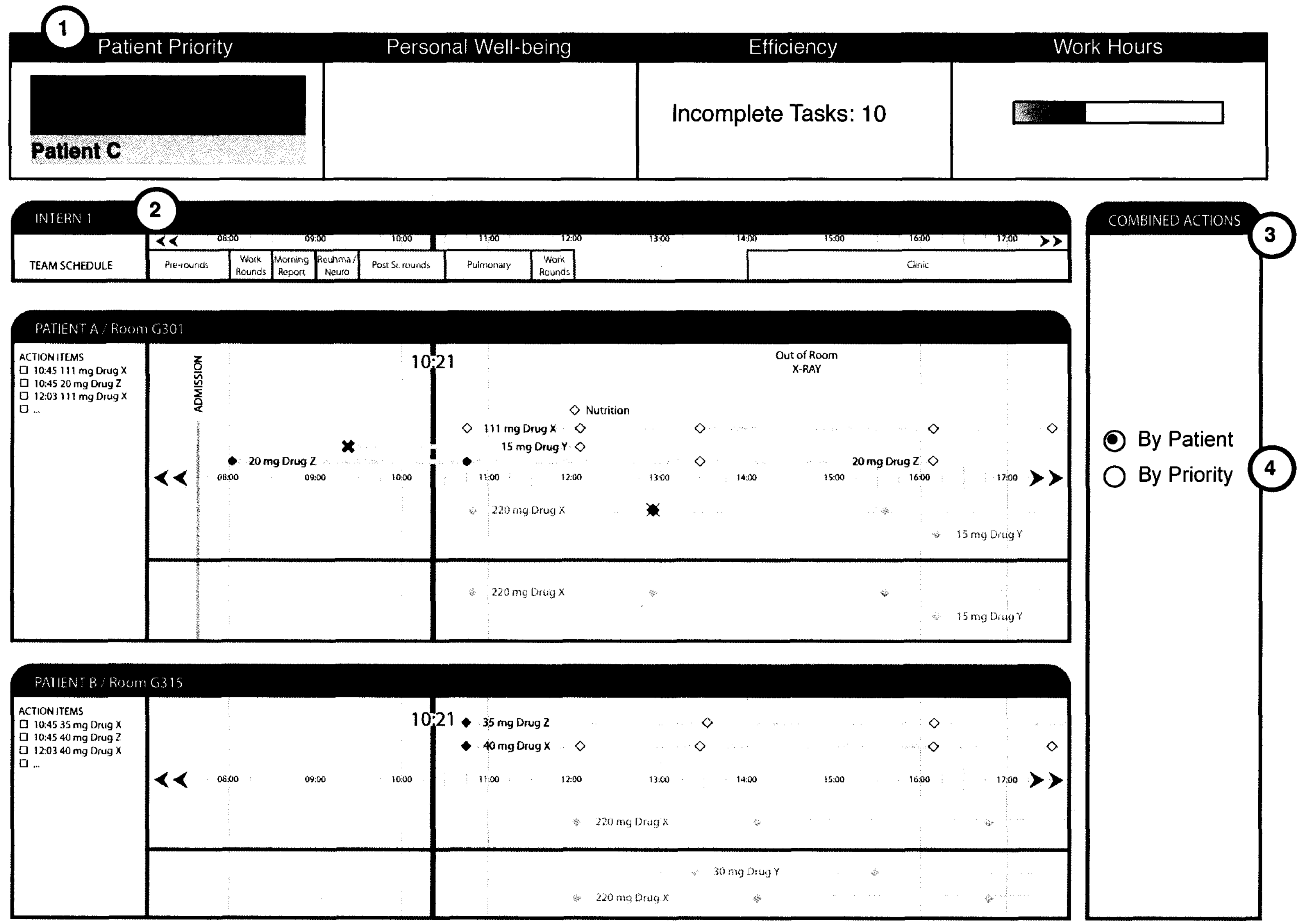

Figure 5.4 Personal Time Management design visualization

The example design for personal time management is shown in Figure 5.4. The goal of this interface is to unify the physician's work together in one interface. The key physical resources, a personal schedule, a list of patients and their tasks and priorities are shown Figure 5.4 (2) and (3). In addition, similar to patient project management, the quality measures that can be displayed are show in Figure 5.4 (1). The goal is for the physician to prioritize their patients and manage their tasks in relation to their personal work schedule and other constraints of work such as the number of work hours and on-call schedule. Figure 5.4 (4) shows support for the two types of prioritization strategies I identified – prioritizing by task status and prioritizing by patient.

5.3. Team Management

The team view supports management of all the patients and their tasks to help the team leaders assess and redistribute work. Similar to the patient time management module, the patient is a physical constraint in the work domain analysis of team management. As seen in Figure 5.5, the general functions of team management are assessing team work, allocation team resources and teaching. These functions are HOW (in the means-end paradigm) the higher goals such as high quality patient care, efficient patient care, high quality education and obeying the rules and regulation that govern work are achieved and measured. The team leader must anticipate and adjust for resource contention, mentor interns as well as ensure that the work is done.

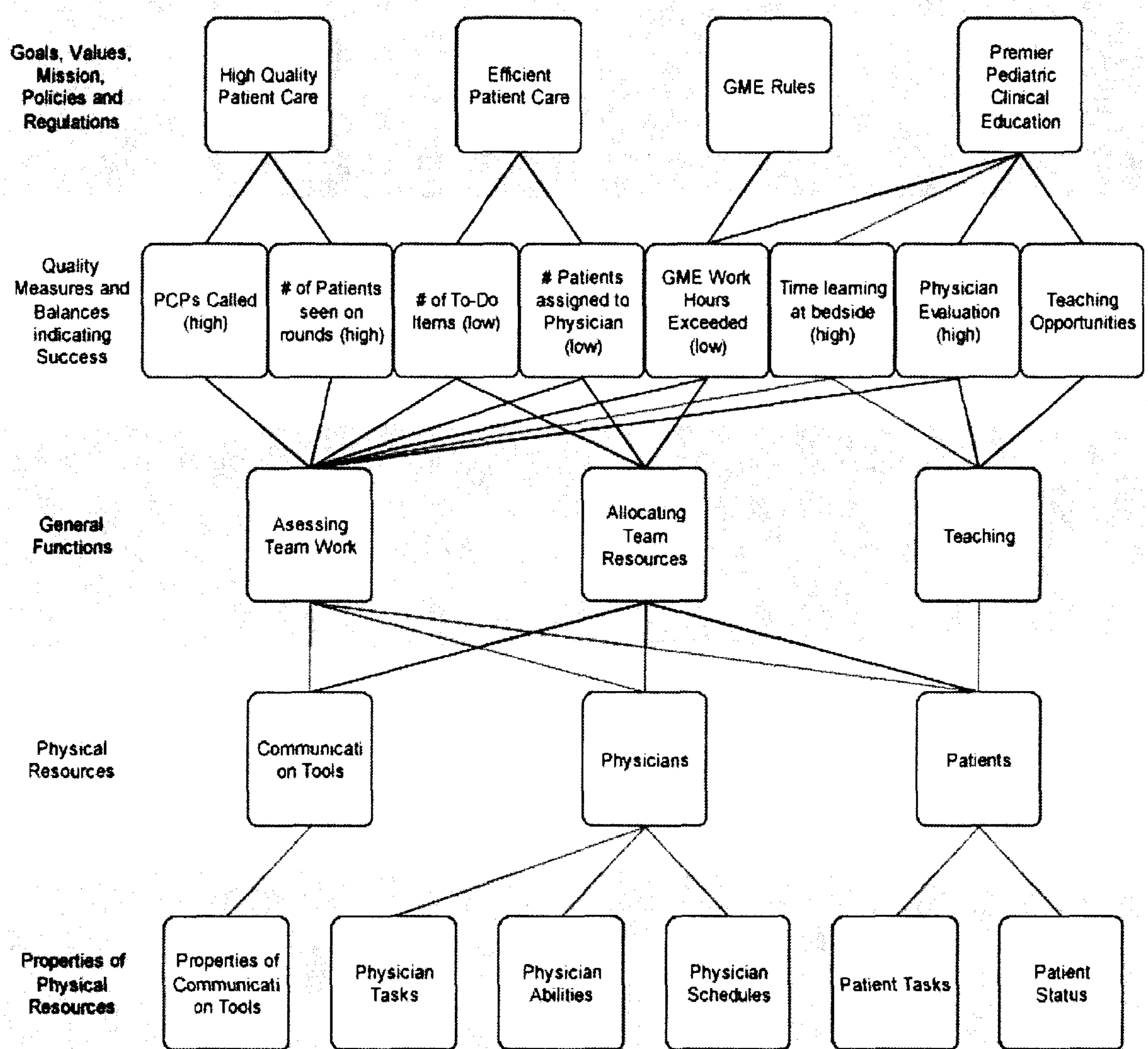

Figure 5.5 Team Management Work Domain Analysis (Means-end dimension)

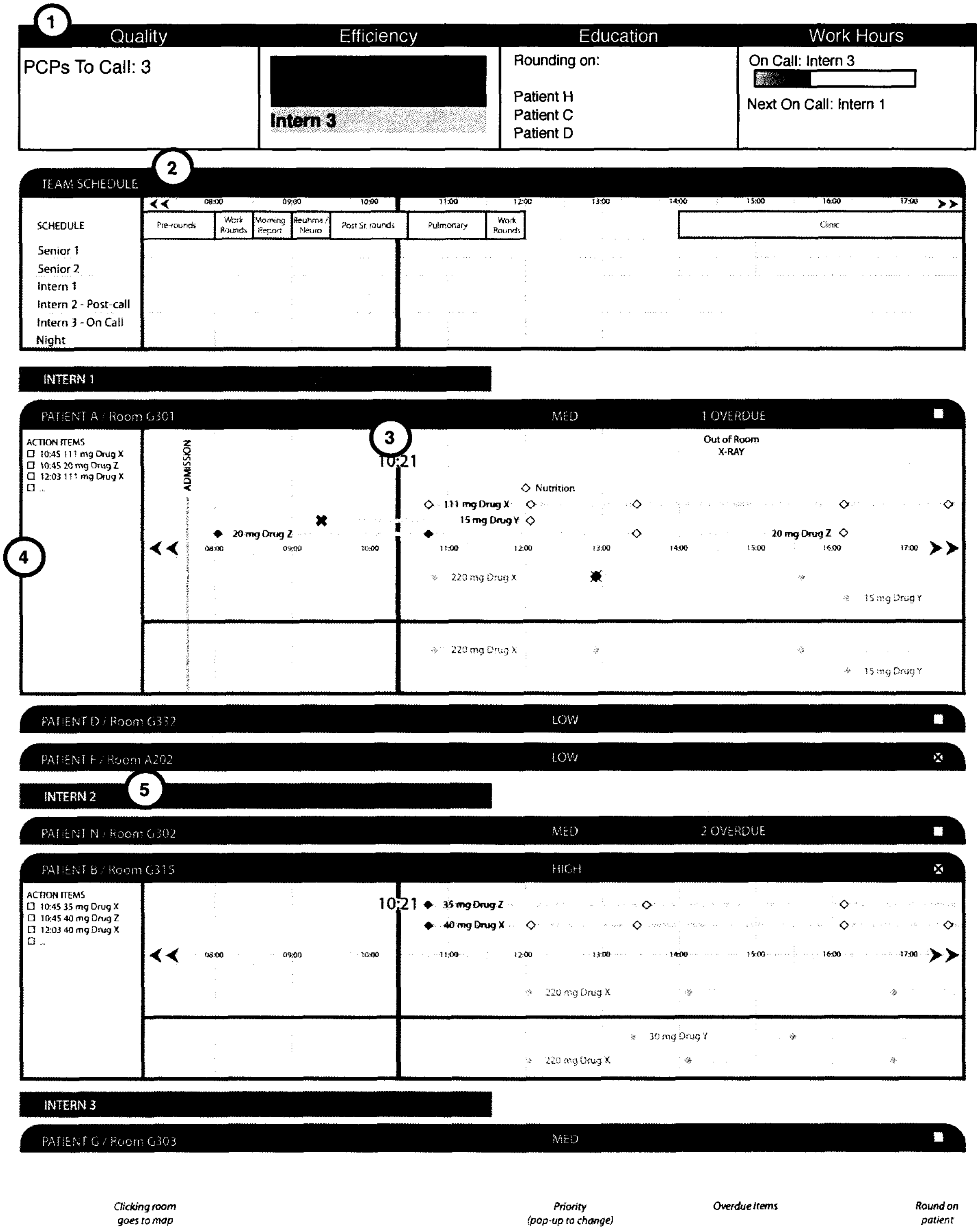

Figure 5.6 Team management design visualization

The quality measures of the work domain are shown in Figure 5.6 (1). These measure include ensuring that the on-call intern does not exceed GME work hours, that interns with high numbers of overdue tasks are flagged and that seniors have selected good cases for education. The physical resources such as the team schedule, Figure 5.6 (2) and the patients are shown in the interface. Constraints such as the unavailability of physicians due to scheduling conflicts are also shown in Figure 5.6 (4) where Intern 3 is not available for work and their patients need to be re-assigned.

5.4. Education and Teaching

Teaching is a very important part of the inpatient medicine team. Studies show that residents only spend 16% of their efforts in organized educational activities that include rounds, teaching, conferences and consultant education and planning.(Boex and Leahy 2003) As an overarching theme to this work that may be specific to teaching hospitals, a strong educational element should be included in the design of any system to support this environment. Future work may be able to integrate measures of education into modules to support education goals in team and personal time management work domains.

I have discussed in 5.1.6, designs based on CWA should support skills, rules and knowledge-based worker competencies. If worker competencies are adequately supported in terms of the SRK framework, then the interface to work domain should be able to support knowledge based reasoning and solving unanticipated situations while still supporting rule-based policies, guidelines and procedures as well as other expert rules. If workers can use an accurate representation of the means-ends relationships in the work domain to problems solve, they can reduce the learning curve to becoming experts in their work.(Burns and Hajdukiewicz 2004) Straight information access to medical resources, basic medical knowledge for novices and primary literature for experienced physicians as well as providing explanations of guidelines will support clinical education. However, these ecological interfaces can also aid in prioritizing and efficiency that are thought of as properties of expert and successful physicians.

5.5. Concluding Remarks for Chapter 5

I have presented three graphical illustrations for technology interfaces that support the three of the themes I identified in Chapter 3 and illustrate a constraint-based, ecological approach. I do not suggest these representations are optimal. The fourth theme, education, is integrated into the work domain analysis of the personal time and team management. These interfaces demonstrate an ecological approach to interface design primarily using the CWA phases work domain analysis, activities analysis and worker competencies. Designing from the results of work domain analysis to represent constraints in the environment shows how manipulating the physical resources influences goals and also detects constraint violations. Activities analysis shows us what types of knowledge states and information processing activities could be displayed. Support of skills, rules and knowledge based behavior will encourage expert behavior and reasoning in unanticipated situations by showing physicians the relationship between their decisions and the larger environment. Accurate work domain representation has been show in other fields to aid performance and learning from unanticipated situations and may also serve the same in medical domains.

Chapter 6: Summary, Discussion, Limitations and Future Work

In this chapter I will explore the results of my dissertation and the broader meaning these results have for informatics and hospital information systems. I will discuss the contributions of this work to biomedical informatics and Cognitive Work Analysis (6.1). I will also discuss the limitations of my study (6.2). I will conclude with recommendations for future research extending this work (6.3).

6.1. Summary

In this work, I conducted a field study at Seattle Children's, an academic pediatric teaching hospital and presented an ecological perspective on ordering and order-entry systems. I performed observations of work in situ over extended periods of time in order to immerse myself rather than observing a few hours here and there. I interviewed physicians regarding their work, roles and ordering processes and collected hospital documents. I analyzed the resulting body of data both inductively to generate themes and deductively to apply the CWA framework. In Chapter 3, I inductively identified four themes: patient project management, team management, personal time management and education. The first was a result of matching open codes to standard definitions of project management concepts from the industry literature. The latter three were general functions that were more overtly defined role definitions and institutional goals. I deductively coded my data using the CWA framework and the decision ladder template used in the second phase of CWA, activities analysis.

In Chapter 4 I used the four themes to develop my first CWA work domain analysis, which describes the overall "gestalt" of the work of inpatient medicine teams, taking a high level view of goals and physical resources. The themes are the functions that link the high level goals and measures of success to the physical sources in a means-end hierarchy. I redefined ordering as executing a care plan based on the qualitative data and performed an activities analysis identifying work situations and work processes in which ordering can occur. I mapped the qualitative data onto the decision ladder template to identify different data processing activities leading up to order-entry as well as short cuts across the decision ladder. Order-entry itself is a data processing activity in the last step of the decision ladder. Thus, one off the key results and contributions of this work was the systematic analysis of the work of inpatient medicine teams using the multiple dimensions of CWA. I used CWA models such as the abstraction hierarchy and the decision ladder, adjusting the use of these tools to suit both the inpatient medicine team work domain, the patient, the team and the physician. The result of this analysis showed the limitations of focusing on order-entry as a functional software requirement in the larger context the work environment. The demonstrated use of CWA and the subsequent work products from the five phases of analysis are an additional research contributions.

Finally, I showed how CWA can directly lead to design artifacts. The first (gestalt) work domain analysis framed the types of computerized modules and informed system and software requirements. From those requirements, I described three modules and hypothetical interfaces for those modules. These modules are the Patient Project Management module, Team Management Module and a Personal Time Management Module. I developed new work domain analyses specific to these new work domains or systems of control. From these new work domain models and CWA results from Chapter 4, I illustrated specific design choices that represent and ecological view of the system of control. The worker is able to see how their actions affect the work domain and detect abnormalities so they can bring them back to a normal state.

6.2. Discussion

In this section I will briefly discuss how these results relate to CWA work done in medical domains (6.2.1) and studies of physician work using other methods (6.2.2) I will then discuss this work's academic contributions to Biomedical Informatics (6.2.3), Cognitive Work Analysis and Systems Engineering (6.2.4).

6.2.1. Relation to other cognitive work analysis studies in medical domains

There have been relatively few application of CWA in medical domains and none specifically studying pediatric inpatient physicians or ordering. Effken and Hajdukiewicz employed work domain analysis and ecological interface design to build displays for oxygen management in ICU settings (Effken 2006), anesthesiology interfaces.(Hajdukiewicz, Vicente et al. 2001) and neonatal ICU monitoring.(Sharp and Helmicki 1998) In all these cases, the researchers developed their abstraction decomposition heirarchies based on biosimulation categorizations starting with the premise of the patient as a biological organism in contrast to my work that casts the patient as a managed project. More recently, Lopez et. al used CWA to characterize inpatient falls in terms of constraints to develop new methods to improve fall rates. (Lopez, Gerling et al. 2010) The "gestalt" view of the general inpatient teams in Section 4.1 is a related to her results by framing a work domain without leading specifically to technology implications.

My work is most closely related to the work done by Burns et. al who studied Cardiac Care Nurses.(Burns, Enomoto et al. 2009) They developed several abstraction decomposition spaces including matching the patient to available healthcare resources and several decision ladders related to clinician decision making. These results are similar to my abstraction hierarchy of patient project management and my decision ladder analysis for executing care plan. Effken also explored work in ICU settings and used the decision ladder for similar clinical decision making tasks.(Effken 2002) These studies show that CWA methods, the abstraction decomposition hierarchy and decision ladder have been applied similarly in different clinical settings and have proven to be useful tools.

6.2.2. Comparisons to other studies of physician work and systems

Many studies of physician work and ordering are related to task and workflow analysis using various qualitative methods. These studies do examine the individual dimensions of cognitive work analysis such as organizational factors (Ash 1997; Berg 1999; Kuperman and Gibson 2003), tasks and decision making (Gabow, Karkhanis et al. 2006; Weir, Nebeker et al. 2007), social-organization (Horsky, Gutnik et al. 2006; Laxmisan, Hakimzada et al. 2006), and ordering strategies (Horsky, Kaufman et al. 2005). While these studies do not employ constraint-based approaches, their results are valuable can be used to further inform a Cognitive Work Analysis. The closer to the center of the CWA onion, the more cognitive and less ecological CWA framework becomes. Therefore, other work identifying ordering strategies or resident tasks could be used to guide analysis at the appropriate CWA dimension using methods of validation for individual settings.

6.2.3. Contributions to Biomedical Informatics

This research explored the work of inpatient medicine teams, and by extension, how to build information tools (presumably computer systems) to support work. I showed the distinction between supporting functions versus supporting work itself, as I believe supporting order-entry without other system contexts is inadequate and will result in failed systems that will not incent users. By limiting order-entry systems to data entry and data displays without any supporting other data processing activities or states of knowledge is inadequate to support decision making and collaborative, interrupted work. By supporting an ecological display, physicians can proactively react to unanticipated situations rather than wait for the consequences of decisions to inform their next actions.

Through this research, I intended to apply a systems approach through Cognitive Work Analysis for the development of order-entry tools as a response to the poor acceptance of CPOE. My approach differs from more common user-centered design approaches such as scenario-based design or user-based needs assessments or expert panels.(Vredenburg, Mao et al. 2002) I note that the qualitative data I gathered could very well have provided the basis for a user-centered approach to systems requirements and design, but by using systematic analysis with the CWA framework and building CWA artifacts, I employed an ecological approach. There is scant literature on the use of the CWA phases other than work domain analysis, and even fewer in clinical domains.(Bisantz and Burns 2009) My work is part of larger class of human factors research methods that are not yet widely used in medical settings to develop systems or understand work and errors.(Donchin, Gopher et al. 2003) Thus this research represents the novel application of an ecological systems analysis method to order entry in an inpatient pediatric setting.

6.2.3.1. Workflow and Unanticipated Consequences

Churchman asked the question in his book, A Challenge to Reason, "How can we design improvement in large systems without understanding the whole system, and if the answer is that we cannot, how is it possible to understand the whole system?"(Churchman 1968) As Ulrich summarizes, the crucial issue for Churchman was not "What do we know?" but rather "How do we deal with the fact that we don't know enough?"(Ulrich 2002) Certainly CWA rejects the notion of designing towards a larger and larger prescribed set of instructions for work as a solution for unanticipated consequences. Modeling the workflow of a certain set of users does not necessarily mean the results are applicable to other users nor does it support the ability for workers to cope with the unanticipated situations, a common source of serious errors. It goes without saying that blaming users for not being enlightened enough to change their work for a system is unproductive if not unjust.(Forsythe 2001) The only recourse therefore is to understand work well enough to model constraints accurately. Niazkhani et al.'s systematic review of the impact of CPOE on workflow concluded that workflow is contingent, collaborative, and subject to rearranging and redelegating.(Niazkhani, Pirnejad et al. 2009) These results support this research and they continue, "When put in practice, the formal, predefined, stepwise, and role-based models of workflow underlying CPOE systems may show a fragile compatibility with the contingent, pragmatic, and co-constructive nature of workflow." Similarly, Ash her and colleagues report a major unintended consequence of CPOE installations as the misrepresent(ation) of collective, interactive work as a linear, clearcut, and predictable". (Ash, Berg et al. 2004) Both of these results support a constraint-based approach or at least reject continuous refining of an instruction-based approach.

6.2.3.2. Supporting workers and knowledge management

Systems should provide computer support for areas where computing is best suited, such as execution of rules-based procedures, data management and data processing activities, thereby leaving human-suited data processing activities and non-computable reasoning activities to the workers. An ecological approach will provide support for physician work by allowing them the freedom to reason and make decisions within safe boundaries. Proactively allowing the physician to see the effects of decisions before committing to them by creating a model of the work domain is one method of avoiding the problems where physicians feel supervised, treated as ''stupid'' and distrusted, which causes them to disregard warnings, turn them off and resent them.(Ash, Berg et al. 2004) Supporting processes well-suited to computation that are not available through current designs (including pen and paper) may incent workers if the system is not meant to replicate antiquated systems but offer new possibilities.

The Institute of Medicine describes five essential competencies for clinicians in their report, *Health professions education: a bridge to quality*: provide patient-centered care; work in interdisciplinary teams, employ evidence-based practice, apply quality improvement and utilize informatics.(Greiner, Knebel et al. 2003) The approaches I have discussed in this work can help each of these competencies. Patient-centered care can be improved if the patient work domain is better modeled and physicians can communicate the status of schedule procedures or consults. A flexible system permits respect for diverse patient needs, values and preferences, i.e. "sweeping in" new patient-centric contexts. Evidence-based practice and quality improvement are supported by directly correlating goals and measures of those goals into the patient work domain and display. Storing states of knowledge and designing and testing for team-based case will aid in interdisciplinary work.

Finally, a challenge of modern team-based, interdiscplinary care and modern health care organizations is managing cohesively the growing volume of health-related data and knowledge.(Blue Ridge Academic Health Group 2000) As health care organizations transition increase their capacity as knowledge organizations, they must create, transfer and retain knowledge – as well as transform that knowledge into improved performance, yet institutional knowledge is largely tacit rather than explicit.(Bock 1998) This rich source of data that could additionally be used for educational or quality improvement purposes is lost if knowledge states and decision making processes are not recorded and remain forever on disposable pieces of paper.

6.2.4. Contributions to Cognitive Work Analysis and Systems Engineering

One of the major challenges in employing CWA is the translation of the existing literature and examples to the work domain in question. In fact, scoping and defining the work domain is extremely challenging because the CWA method departs from intuitive notions of software engineering that aim to describe what people do and to build applications that match. For instance, it is very easy to mistake work domain processes for tasks and actions done to the work domain. The seemingly interchangeable language of "processes," "functions" and "tasks" is confusing. Descriptors such as "abstract" versus "general" are not intuitive to untrained CWA practitioners. The majority of work domain analysis examples in the literature primarily describe military or process control domains. It may be challenging to reapply examples to other domains, especially those of a different work domain type as I discussed in 2.1.2. My dissertation research is an application of CWA to a new domain, inpatient pediatric medicine and ordering. Furthermore, where applicable, I have mapped the CWA concepts of the abstraction hierarchy and the decision ladder to familiar clinical domain concepts. I hope my research will facilitate re-application of these methods in other settings as CWA remains an immature engineering method that needs more research and application, especially in medical domains. Even user-centered methods that have been touted for 30 years as superior to normative methods are still subject to cost-benefit scrutiny and not a required component of software engineering.(Vredenburg, Mao et al. 2002) Thus de-mystifying CWA can only help its further use in systems engineering.

Bader, Nyce and Forsythe's claim that the development community makes the error of mistaking themselves for informants, including physicians consider themselves most qualified to design information systems for other physicians by virtue of their common profession.(Bader and Nyce 1998; Forsythe 2001) What is missing from engineering and medical informatics is an attempt to challenge or extend the physician's own lay or folk understanding of what is going on in medicine – a view supported by Vicente's belief (and the belief of my work) that complex socio-technical systems by nature are impossible for any individual user to comprehend or be aware of all the underlying and integrated processes in the system.Technical experts concentrate on descriptions of what they believe the users want and develop applications that reproduce those processes. Without additional training or instruction to examine the society and culture of workers and developers, there's no other recourse but to default to common sense cultural beliefs about "what's going on."

CWA is not replacement for expert ethnography. Any modeling method where choices are made is subject to these ethnographic pitfalls. However, CWA explicitly calls for examining the goals and values of institutions versus individuals, work tasks and situations, collaboration, and the capabilities of workers to understand what influences goal-seeking individuals. The goals and values at the top of the means-end analysis do not need to be computable to be valid and useful in framing systems design. Therefore CWA can begin to bridge this gap between the cultural and the technical.

6.3. Limitations

This study has a number of limitations related to sampling, scope and transferability.

6.3.1. Sampling

I observed 40 participants through purposeful sampling and interviewed 11 participants through opportunistic sampling. Within the interview participants, there was a mix of roles and experience. Each role (intern, senior, attending) was represented by a small number of participants. It was particularly challenging to secure interviews with physicians, especially residents. They were reluctant to schedule time, and the best method was to be available as long as possible during the day to take time where it was possible. Overall, I found the physicians generous with the very limited time available to them, but the time was often not available. Future work should include more institutional support to gather more data from more participants.

I focused on data triangulation—collecting multiple sources of evidence to increase the validity and perspective of my analysis. I reviewed my work with domain experts for member checking. The sample size and the data I collected are well-suited for this exploratory study to create validated models and results that will lead to the undertaking of a systematic large scale study using the same methods. The data collected is sufficient to show how clinical systems can be developed from an ecological rather than descriptive and functional perspective. The groundwork in applying the often esoteric CWA representations and methods to this domain will be invaluable to future researchers.

6.3.2. Limited Scope

In this study I focused on ordering which is only a subsection of the clinical work that the physician teams. I did identify other aspects of clinical work at the task level in the contextual activities template (Section 4.2.4) including documentation and handoff. However these were not explored in any further dimension. Work domain analysis and the contextual activities template analysis create a framework within which to complete the analysis of other tasks and decision-making processes (such as documentation and handoff) in future work (6.4.1).

6.3.3. Transferability

I was the only researcher available for this work. I studied one healthcare organization, Seattle Children's, that has a specific profile as a pediatric, urban, academic, teaching hospital. Within Seattle Children's, I studied one physician service, the general pediatric inpatient medicine service and within this service, I focused on physicians. Even within Seattle Children's, teams round differently depending on the service or the attending's style. In other hospitals, the work day is segmented differently and rounding includes different procedures and workers. However, the methods used in this research are readily applicable to other settings and other types of workers. With common CWA framework, the researcher can define a work domain (whether it be another service, hospital or clinical role) and study work constraints. As future work in 6.4.1, I propose to explore other roles and tasks at Seattle Children's and in 6.4.3, I propose to expand this work and codify a clinically focused CWA framework for reapplication in other clinical settings.

The transferability of this study is the framework and methods for the re-application of CWA in diverse settings. Although work environments are unique and generic commercial software requires customization to local processes and policies, these methods will permit for similar studies to be carried out controlling for various organizational factors and comparing themes and analysis across institutions. (6.4.2)

6.3.4. Hawthorne Effect

The Hawthorne effect occurs when participants alter their natural behavior in response to being observed.(Dickson and Roethlisberger 1966) While this may have occurred during this study, I believe it unlikely because I clearly presented myself as a student and a non-physician. I did not pose a professional or subject matter threat to any of the residents who admitted they were nervous about their performances in front of senior physicians and attendings. In addition to reducing the possibility of an observation effect, my position as a neutral outsider and non-clinician allowed me to observe from an etic and culturally neutral perspective thus strengthening the study in this case.

6.4. Future Work

The next natural step for this work is to actualize and build a testable interface. The result of this work (as described in chapter 5) is to define specific work domains interfaces that should be developed to support work. In order to build the actual interface, I would explore more examples of data processing activities and short cuts in the decision ladder by expanding the qualitative data collection to include more informants. This approach is a systematic method to develop CPOE systems to reflect quality measures, reduce errors, respond to dynamic workflows and use evidence-based guidelines. Thus it is compatible with national efforts that include CPOE in financial incentive models for health care organizations in order to improve care and reduce errors.

With a developed interface, I propose to test the interface in real-world or simulated conditions to explore flexibility, efficiency and the effect of presenting quality measures and evidence-based medicine on physician behavior. I would need to employ simulation techniques to study the effect on error conditions. Studying safety and responses to unanticipated error conditions in situ has been challenging for researchers in CWA because waiting for nuclear disasters such as the Three-Mile Island incident is to put it mildly, not feasible.

6.4.1. Increasing the Scope of Study at Seattle Children's

The development of a health information system needs to consider the other roles and their work and goals, using (as I would suggest) Cognitive Work Analysis to understand their work. Consider the patient work domain and patient interface I discussed in Chapter 5. I described the underlying functions in the means-end analysis that ties the physical resources to the goals of the patient. How those are goals are reached through the data processing activities and knowledge states of the workers will vary depending on the social organization. Nurses' work tasks, situations and tasks will differ from physicians, but the same framework can be used to systematically analyze their work, the work of other roles and services that comprise an integrated health system. CWA interfaces can show how physician work affects nursing and vice-versa. My work was also focused on ordering and order entry. Other tasks such as daily documentation or patient examinations should likewise be analyzed in terms of computerized support, but these were beyond the scope of this research and the time allotted to interview participants.

6.4.2. Applying CWA to a Similar Pediatric Work Environments

To study the broad applicability CWA and these specific methods, I propose to carry out this study at a similar institution, a pediatric, urban, teaching hospital and compare those results to the results presented in this work. Additional studies will allow for further refinement of the specific methods and analysis in this work and examination of common themes across institutions. The systems approach to analyzing work may provide new perspectives that lead to unique quality improvement insights or programs. The impact of this method should be studied across institutions to determine if they can affect quality improvement in more than one setting in a consistent and reproducible manner.

6.4.3. Developing a Clinically Focused CWA Framework

While the number of CWA studies in healthcare domains in increasing, the accessibility of CWA as an analysis method that is graspable by developers and clinicians will be critical to its future use. Although, as Forsythe says, developers mistaking themselves as informants is a problem in medical informatics, the reality is that clinicians and developers are the two indispensible roles in software development – developers to make the software, clinicians to provide or collect the content. Constraint-based approaches or derivative approaches could be the answer to supporting dynamic work in complicated distributed, interdisciplinary healthcare settings. However, more research is needed by those who are open to new approaches, and it is necessary that clinicians and developers can easily grasp CWA. Deep understanding of the epistemology and theoretical background of CWA may not be necessary, but understanding the CWA work products in clinical terms is.

In addition to expanding this work to other inpatient services, clinical roles, primary care settings or similar pediatric hospitals, I propose to develop a set of guidelines and templates for applying CWA in heath care settings and exploring the different types of health care work domains. I would explore how to apply the five phases of CWA and how to elicit knowledge to develop CWA work products. It is very possible that the era of homegrown health information systems is over. However, understanding a work environment in terms of constraints can aid in understanding system installations pitfalls, customizing and training.

6.4.4. Working with other design methods

As I have previously described, CWA does not focus on how human-system interaction should be (normative) or how human-system interaction currently exists (descriptive). Instead, it focuses on systematically describing properties of the work environment and of the workers that define constraints on the ways that human-system interaction might reasonably occur (formative). I showed in Chapter 5 how to extend CWA into an ecological interface design. The design method I described did not include users because of the limitation of designing based on descriptive and current usage patterns as well as the aspects of socio-technical systems I described in Chapter 1. However, CWA and user-centered methods are not wholly incompatible. I used field studies methods that include users which are found in user-centered design requirements gathering. I analyzed this data in terms of constraints, and identified data processing activities and strategies that need to be supported by the interface.

In Chapter 5, I proposed abstract representations of elements of the abstraction hierarchy model and the decision ladder template. In order to develop a specific design, user-centered techniques can be used to refine the design, choosing what type of visual representations are the most effective as long as the interface is fundamentally constraint-based. Usability testing including think-aloud protocols could be used to understand workers' thought processes as they use a new design. However, this must be triangulated through observations given the users may not be accurate reporters of their own actions. User-centered design techniques, guided by CWA can be useful methods for validating designs and processes as well as involving stakeholders in the design.

6.5. Concluding Remarks

Clinical environments are becoming increasingly complex and unanticipated interactions are inevitable. These systems are beyond the capability of any one user to comprehend or intuitively understand in situ and by extension no so-called "expert user" developer can describe the complexities without performing systematic fieldwork. Constraint-based approaches can be flexible, and they can support multiple workflows and unanticipated situations. The Cognitive Work Analysis framework provides a systematic method and tools to analyze the complexities of socio-technical work. I conducted a study using qualitative methods to gather data and CWA to perform model formulation and analysis, develop system requirements and finally visualizations and design implications.

Forsythe criticized many medical informatics studies for not investing the necessary time (and medical anthropology skills) to uncover and question the tacit cultural assumptions of both the participants and the researchers.(Forsythe 1999) Without understanding these assumptions, the chance of a mismatch of software to work increases. Informaticists aim to build systems to match the "truth" they see, and it is worth questioning the origin of this truth and better understand ourselves before substantial time and money are invested in building and implementing systems.

This study uncovered novel themes such as patient project management that have significant design implications for displays to support the work of inpatient pediatric teams at Seattle Children's. Through work domain analysis I illustrated the systematic means-end relationships between goals at the institutional, team and individual level and the physical resources in the environment. Using the decision ladder, I illustrated how clinical decision-making can map on to dynamic knowledge processing activities and states of knowledge. I extended the results of the CWA analysis to design implications and visualizations that illustrate an ecological and constraint-based approach to displaying data and representing work. This study is the foundation for future work customizing health information technology to support the work of physicians both presently and in response to unanticipated situations. In addition, these methods can integrate into existing quality assurance and quality improvement initiatives that aim to improve care from an institution-wide perspective.

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Appendix A: Interview Guide

Questions were pulled from this interview guide based on the time allotted to the interview.

What do you think is over all goal of the Seattle Children's Hospital?

What are the values and priorities of Seattle Children's Hospital?

What regulations or policies govern this hospital?

What is the overall goal of ordering? What is ordering?

How do you measure success or failure?

What functions are needed to achieve the goal?

What task do you do and what is it called?

What decisions do you make?

What questions do you ask?

What functions do your activities fulfill?

How do you know that you are successful in completing a job?

What tools do you use to do your job?

What information are you looking for?

Where do you look for information? Why in these places?

How is the work divided among members of your group?

Why did you get this task (ordering)?

Who decides when the task (ordering) is done?

How do you communicate with your peers?

How do you communicate with your boss?

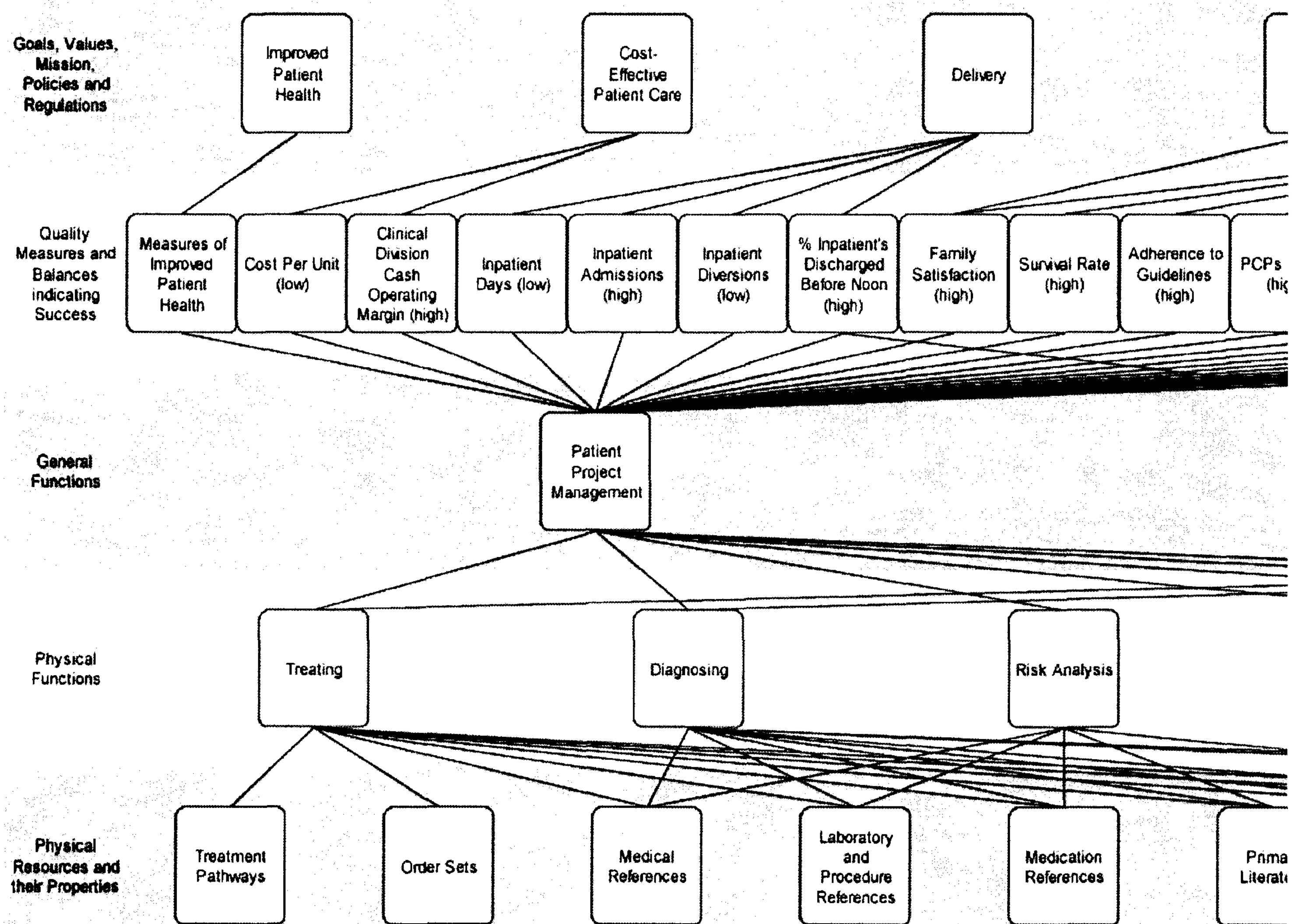
How long have you worked as a (job title)? How long have you worked at Seattle Children's Hospital?

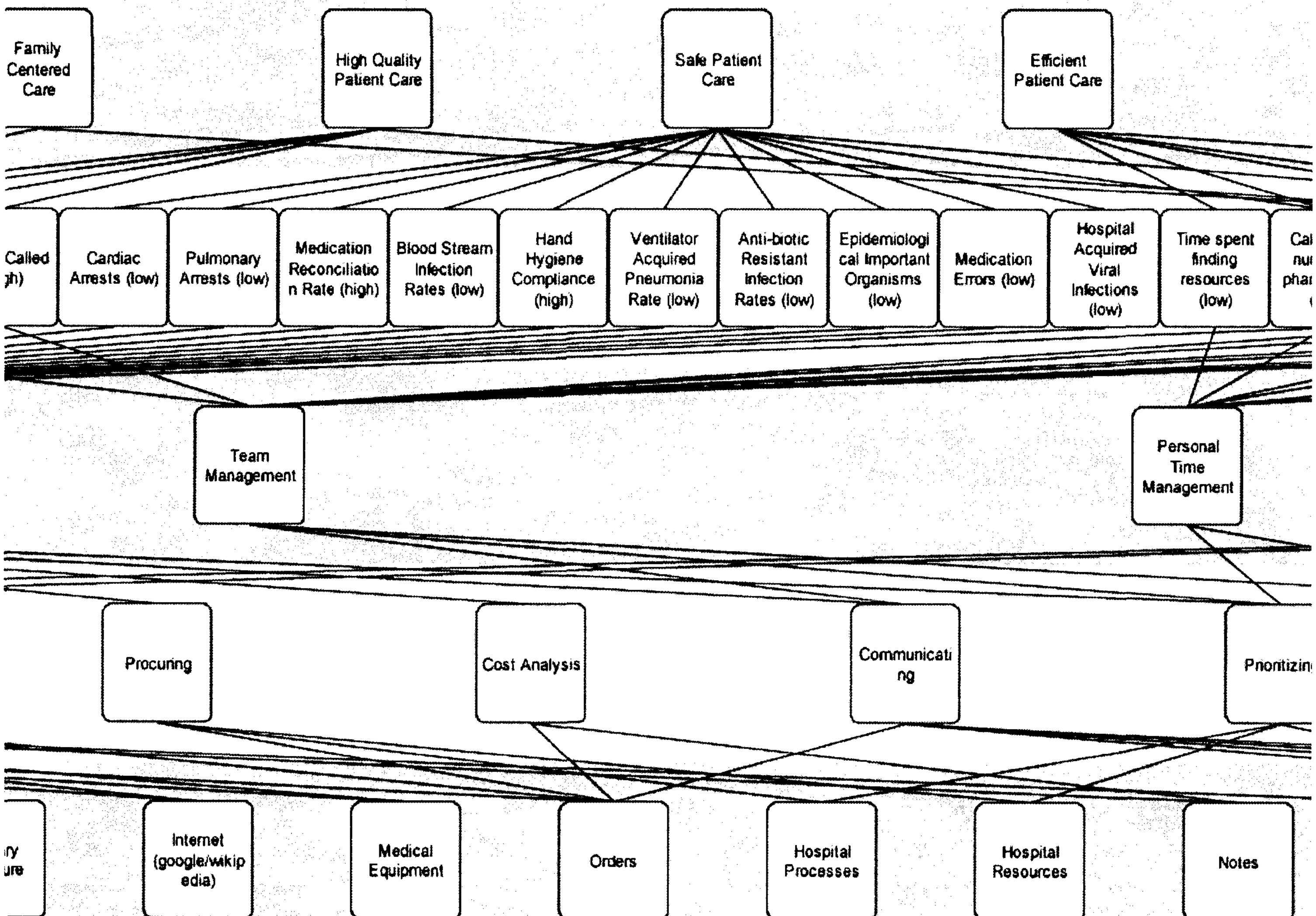
What formal training and education do you have?

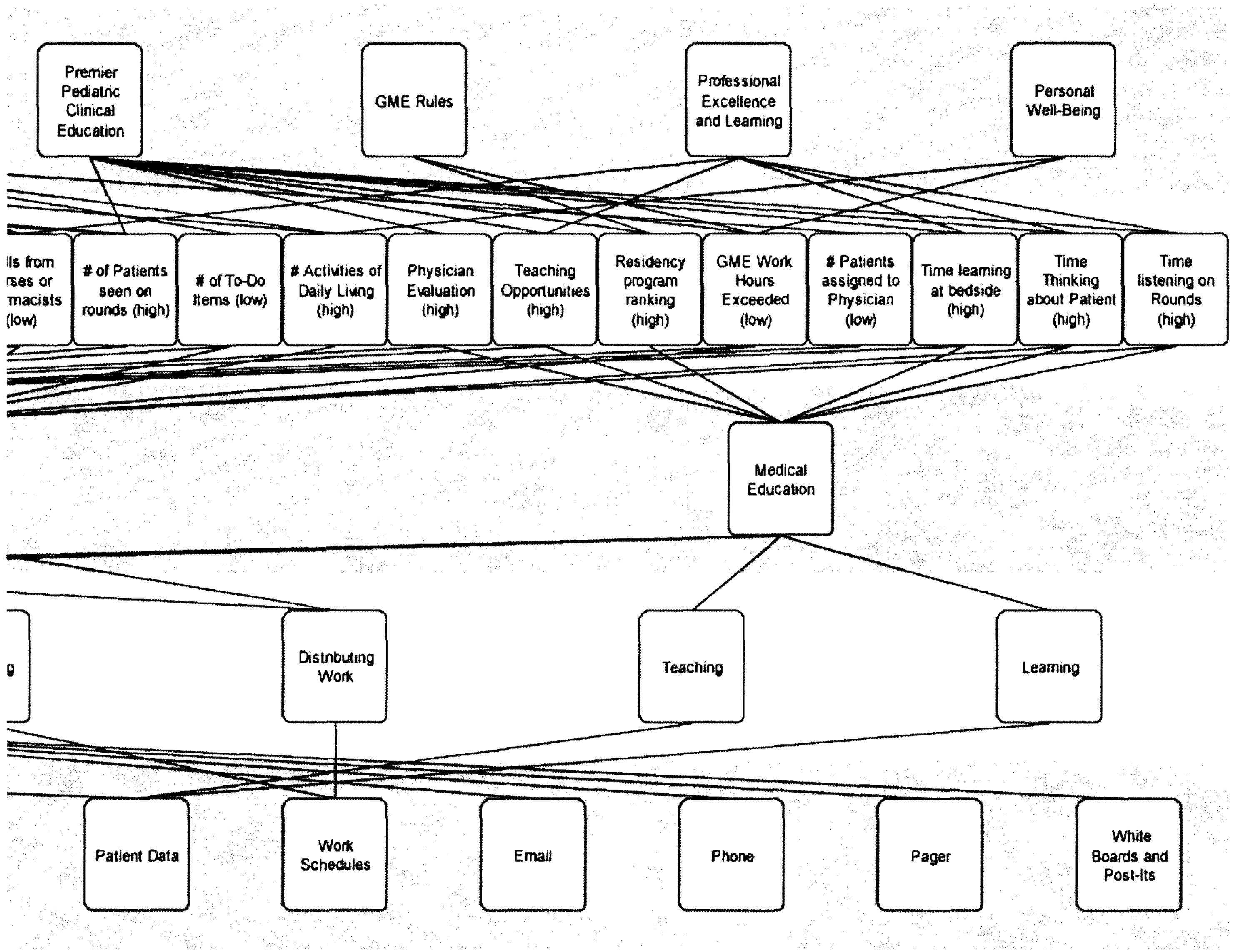
What year of residency are you in?

What is your area of expertise?

Appendix B: Complete Means-End Analysis


Goals, Values, Mission, Policies and Regulations
Improved Patient Health
Cost-Effective Patient Care
Delivery
Quality Measures and Balances indicating Success
Measures of Improved Patient Health
Cost Per Unit (low)
Clinical Division Cash Operating Margin (high)
Inpatient Days (low)
Inpatient Admissions (high)
Inpatient Diversions (low)
% Inpatient's Discharged Before Noon (high)
Family Satisfaction (high)
Survival Rate (high)
Adherence to Guidelines (high)
General Functions
Patient Project Management
Physical Functions
Treating
Diagnosing
Risk Analysis
Physical Resources and their Properties
Treatment Pathways
Order Sets
Medical References
Laboratory and Procedure References
Medication References


Family Centered Care
High Quality Patient Care
Safe Patient Care
Efficient Patient Care
Called
Cardiac Arrests (low)
Pulmonary Arrests (low)
Medication Reconciliation Rate (high)
Blood Stream Infection Rates (low)
Hand Hygiene Compliance (high)
Ventilator Acquired Pneumonia Rate (low)
Anti-biotic Resistant Infection Rates (low)
Epidemiological Important Organisms (low)
Medication Errors (low)
Hospital Acquired Viral Infections (low)
Time spent finding resources (low)
Team Management
Personal Time Management
Procuring
Cost Analysis
Communicating
Internet (google/wikipedia)
Medical Equipment
Orders
Hospital Processes
Hospital Resources
Notes


Premier Pediatric Clinical Education
GME Rules
Professional Excellence and Learning
Personal Well-Being
ils from rses or macists (low)
# of Patients seen on rounds (high)
# of To-Do Items (low)
Activities of Daily Living (high)
Physician Evaluation (high)
Teaching Opportunities (high)
Residency program ranking (high)
GME Work Hours Exceeded (low)
Patients assigned to Physician (low)
Time learning at bedside (high)
Time Thinking about Patient (high)
Time listening on Rounds (high)
Medical Education
Distributing Work
Teaching
Learning
Patient Data
Work Schedules
Email
Phone
Pager
White Boards and Post-Its

VITA

CHING-PING LIN

EDUCATION

2010 Ph.D in Biomedical and Health Informatics, University of Washington

1995 A.B. in Computer Science and Classics, Bowdoin College

RESEARCH EXPERIENCE

2006-2010 *Doctoral Candidate, University of Washington, Seattle, WA*
Division of Biomedical and Health Informatics
Cognitive Work Analysis of Ordering in General Pediatric Inpatient Medicine Teams
Dissertation project studies the workflow, tasks, decision making and work constraints of general pediatric inpatient medicine teams at Seattle Children's Hospital through the collection of qualitative data (interviews, observations and documents). Using a holistic, ecological analysis framework, this project proposes software design ideas that supports ordering, flexibility, error detection and team-based work.

2007-2010 *Research Assistant, Institute of Translational Health Sciences, Seattle, WA*
Research assistant for pilot project aimed at developing technical infrastructure to support data linkages across primary care family practice residency and tribal community sites across the Pacific Northwest region. Travel to rural clinic sites to perform technology evaluations. Meet with members of tribal communities to discuss community health priorities and build personal relationships between tribes and project members. Architect and evaluate data sharing systems based on feasibility, cost and socio-technical factors.

Consultant for providing EMR data to health researchers e.g. laboratory data for case reports forms, identifying eligible patients for clinical trial based on specific medical criteria. Evaluated informatics needs, performed necessary data extracts and manipulations.

2007 *Product Management Intern, Practice Partner, McKesson, Seattle, WA*
Intern for leading small practice electronic medical record company. Designed and prototyped new medication ordering alert user interface consolidating drug-drug, drug-allergy, drug-diagnosis, drug-age and drug-dose alerts onto one screen and unifying data and terms. Led user group discussion and

evaluation of new alert interface. Analyzed user feedback and worked with engineers to analyze the technical requirements of the interface to determine final version. Wrote detailed design specification document for new feature to be included in the next major release of EMR software. Aided QA department by performing unit testing on product release candidates.

2006-2007 *Research Assistant, UW Medicine Security Infrastructure Team, Seattle, WA* Part of the identity management project to implement UW Medicine security policies surrounding data access, data security and new user on-boarding. Developed and evaluated system metrics for new web portal applications. Wrote content and coded new website resource providing information on user account management. Developed online survey tool and conducted user surveys and focus groups to gather requirements to develop new user on-boarding process. Created workflow and organizational models based on data gathering to aid in understanding complex UW Medicine environment.

2003-2006 *National Library of Medicine Fellow, University of Washington, Seattle, WA* Research focus is on analysis of inpatient ordering at Seattle Children's Hospital, decision support and human-computer interface design of hospital information systems. Supported and trained house staff on new clinical information system features at Harborview Medical Center. Collaborated with VA Puget Sound to analyze order data to evaluate decision support system. Organized Clinical Informatics Colloquium, a forum to share information between research and industry professionals in clinical and medical informatics.

PUBLICATIONS

Lin, C., Payne, TH, Nichol, WP, Hoey, PJ, Anderson, CL, and Gennari, J.H. (2008). Evaluating Clinical Decision Support Systems: Monitoring CPOE Order Check Override Rates in the Department of Veterans Affairs' Computerized Patient Record System. Journal of the American Medical Informatics Association, 15(5), 620-626.

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Stephens KA, Lin CP Facilitating Health Data Sharing Across Diverse Practices and Communities: A Developing Network. 2010 AHRQ PBRN Annual Conference. Bethesda, MD.

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Lin CP, Gennari JH. Designing CPOE Systems Using an Ecological Approach. AMIA Annu Symp Proc. 2007. Poster presentation - Distinguished Poster Award.

Brogan, MW, Lin CP, Pai R, Kalet IJ. Implementing A Mandatory Password Change Policy at an Academic Medical Institution. AMIA Annu Symp Proc. 2007. Poster presentation.

Lin CP, Nichol WP, Hoey P, et al. Approach for analysis of order check overrides in a computerized practitioner order entry system. AMIA Annu Symp Proc. 2005:1033. Poster presentation.

EMPLOYMENT EXPERIENCE

2002-2003 *Java Developer, University of Washington, Seattle, WA*
Designed and coded in Java an XML output format module for the Protégé ontology building application.

2001-2003 *Bioinformatics Database Specialist, University of Washington, Seattle, WA*
Developed Cold Fusion web-based genotyping and phenotyping software for production and research of transgenic mice including database design, software workflow and interface and technical project documentation for the Seattle Comparative Mouse Genomics Center

1998-2001 *Database Administrator, Amazon.com, Seattle, WA*
Ownership of a multi-database, 24X7, highly-available, clustered, high-transaction Oracle environment and multi-terabyte data warehouse. Duties and skills included installation, database creation and SQL tuning.

1998 *Database Administrator, PlanetAll (now Amazon.com), Cambridge, MA*
Part of 2-person Oracle DBA team for a startup company that developed an online address book and calendar tool. Responsible for operational readiness.

1996-1998 *Database Software Engineer, HPR Inc. (now McKesson), Cambridge, MA*
Developed CCMS, a healthcare case management software product. Programmed and designed user interface, database schema and software work flow. Designed schema and SQL queries for clinical software. Gathered requirements from clinical product management. Created detailed technical specifications. Collaborated with clinical staff to design reports and custom reporting method.

1996 *Software Developer, Freemark Communications Inc., Cambridge MA*
Responsible for Advertising Management and Member Services applications. Created advertising traffic process including sales, accounting and engineering. Generated advertising metrics for management.

1995-1996 *Software Engineer, Boston Catalyst Group, Boston, MA*

Developed database software in PowerBuilder 4.0 to track and print foreign student and scholar information.