# *Technical Work Studies*
## *Understanding Human Work Amidst Complexity, Uncertainty, and Conflict*[1]

Richard I. Cook, MD, Christopher Nemeth, PhD, Marian Brandwijk, MD[2]
Cognitive technologies Laboratory
University of Chicago

Reactions to accidents remain the most potent driving force for work on patient safety. Because accidents are caused by the confluence of multiple contributors, understanding safety necessarily requires research approaches that can account for the complexity, uncertainty, and conflict that characterize the healthcare environment. A set of approaches, described here as *technical work studies*, can produce a continuing stream of insights about human practitioner work. These insights first help us understand how human practitioners cope with the conditions of work and later may guide development of effective aids. This paper explains why incident and accident analysis are insufficient as the basis to understand safety. It then provides two examples of technical work studies and suggests some fruitful avenues for additional research.

### *Introduction*

Operating at the sharp end of practice remains as complex, hazardous, and conflicted in 2004 as it was at the beginning of the patient safety movement a decade ago.[3] Our understanding of technical work -- the work that practitioners actually do[4] -- remains relatively primitive. Yet our need for this understanding is acute. In order to develop effective tools to aid them in their work, we must first understand how workers usually succeed (and sometimes fail) to produce good outcomes in the face of the complexity, hazard, and conflict that permeates this world. The complexity of technical work is closely matched to the complexity of the workplace but together these two complexities regularly foil efforts intended to improve safety.

The same factors that make technical work difficult to perform also make it difficult to study. Technical work is difficult because of (among other things) its high tempo, its variability, the ways that social and technical factors collude and collide, the guises and

---

[1] Presented at the *AHRQ 3rd Annual Patient Safety Research Conference*, Arlington VA, March, 2004. The authors gratefully acknowledge the many physicians, nurses, and technicians who contributed to the work described here as well as Michael O'Connor, MD, Alan Klock, MD, and Madelyn Kahana, MD, who provided guidance and support for the work. Preparation of this paper was made possible in part by grants from AHRQ (R18HS11816) and NLM (R03LM007947); past work was supported by a grant from the Department of Veteran's Affairs GAPS Center, Cincinnati, OH, Marta Render MD, Director. The opinions expressed are those of the authors.

[2] Cook & Nemeth, Department of Anesthesia and Critical Care; Brandwijk, Department of Pediatrics, University of Chicago. Contact information available at www.ctlab.org.

[3] See Cook & Woods: *Operating at the Sharp End*, available at www.ctlab.org.

[4] "Technical work" includes all the activities and details of performance that workers need and use to cope with the real life demands of work in real world settings. Although important to the conduct of work and, ultimately, to patient safety, many of the activities and details seem arcane when viewed from a distance. See Barley & Orr (1997). *Between Craft and Science: Technical Work in U.S. Settings.* Ithaca: Cornell University Press, and Cook, Woods, and Miller (1999) *A Tale of Two Stories: Contrasting Views of Patient Safety*. Chicago, NPSF, available at www.ctlab.org.

heavy burden of illness, and the grinding and sometimes corrosive economics of healthcare. The study of technical work is difficult because of the many ways these factors appear in combination. Each day's activities represents one work unit's consensus on how deal with these factors to get through the day successfully.

After an accident, it is sometimes possible to trace the effects that these factors had in shaping the path to an adverse outcome. Such investigations are, however, always accomplished in reverse. The accident, which is the thing to be explained, restricts the possible field of inquiry by drawing attention to some factors and diverting attention from others. Accidents are lenses that bring some work details into sharp focus. But, like lenses, the sharp focus exists only in one plane. Background details are blurred in ways that allow us to "see" the factors that contributed to the outcome. Critiques of post-accident investigations often identify this metaphorical lack of depth-of-field as a major fault of the investigation, taking it as evidence that the investigators have been deliberately and disingenuously narrow. Although this narrowness does limit the range of investigation targets, it also helps investigators by circumscribing the possible region of inquiry and providing direction for the investigation. Accidents make it possible to see clearly how particular sets of factors joined to create the catastrophe. The accident itself contributes to the likelihood that detailed investigation will tease out the contributing factor that joined to make the event occur.

Without the focus that accidents afford, however, it is difficult to know where to begin an examination of technical work. The combination and interaction of a wide variety of factors makes technical work difficult to analyze. It often seems as if everything is connected to everything and the myriad connections can easily frustrate attempts to study technical work. The complexity of work situations may lead researchers to simplify the inquiry, if only to make it manageable. But doing this can easily distort the resulting image of the problem space that workers confront: it is easy to produce research that is crisp, clear, unambiguous, and unrepresentative of the work world. This is one reason that so much patient safety research seems to be only peripherally related to safety.[5]

Rather than simplify the workplace complexity and lose the detail, the approaches that we and others have found most productive seek to characterize the complexity itself, using several different analytical lenses. Each lens produces a slightly different field of view, a different sort of image, and introduces its own particular distortion. Even so, we and others have found over time that the collective application of these approaches is a useful way to make work visible in ways that then allow us to understand how accidents are usually prevented. While the various lenses can be used in different ways, they are most powerful when we choose to treat the ordinary work world as a continuous, naturally occurring experiment.[6] Two of these analytical lenses are cognitive artifacts analysis and the study of communications between problem solvers.

---

[5] Much "error" research is in this category.

[6] Naturally occurring experiments are usually processes that are too complex, too dangerous, or too powerful to be created under laboratory conditions. As a result, they are not readily controlled by the investigator. For example, stellar spectra are naturally occurring experiments that astronomers can observe, but cannot control, using telescopes.

*Cognitive artifact based analysis of technical work*

Cognitive artifacts are the products that workers use to represent relevant states and conditions of patients and processes, as well as their own plans and expectations about the work world. Cognitive artifacts are ubiquitous in healthcare. They are a rich source of information about how work and information are structured and managed. They range in complexity and sophistication from simple work-notes and written reminders to elaborate, socially produced, multipurpose representations of entire work units such as the operating room schedule board.

Cognitive artifacts are usually created or modified by their users and are highly specialized in order to accomplish specific purposes. As physical artifacts, they are concrete representations of abstract or elusive phenomena. They are readily available to researchers and serve as direct, objective evidence of specific data and issues. They tend to be highly enriched forms of data representation, particularly when created by their users. They are concise representations of critical data that are replete with subtle timing cues and markers of local idiosyncrasies. They are elements of work that are created and modified throughout the work cycle. As a result, observing their use can provide a time-coded data stream that allows inferences about worker cognitive processes. Because they are often pen-and-paper objects, these artifacts are durable primary data, readily preserved for later detailed study. They encode the most important details of the work domain because they must closely match the currently relevant, underlying domain semantics in order to be useful. Because they include only this encoded data, cognitive artifacts are compact, dense representations of the temporally and physically bounded work unit and its work.

When they serve as shared representations, such as operating room schedule boards, artifacts become platforms for worker groups to detect conflicts and potential deadlocks and attempt to resolve problematic situations. Researchers who want to observe these activities can anticipate this and station themselves near the artifacts in order to watch the drama of the work day unfold.

Doctoral dissertation work by Christopher Nemeth[7] on the operating room schedule as a cognitive artifact demonstrates how these characteristics of cognitive artifact analysis may be exploited to gain new insights into the complex coordination and work activity of a suite of operating rooms. The research shows how expert coordinators exploit the subtle features of cognitive artifacts. It shows how the demands and current and potential conflicts that arise during an "ordinary" work day are accommodated by groups, providing a level of detail that is usually found only in after-accident reconstructions. The research also explains how coordinators employ subtle expertise to avoid deadlocks and to maintain smooth work flow. This flow occurs even in the face of uncertainty, rapidly shifting demands, and resource fluctuations. All this work takes place at a tempo so high as to make direct observation using other methods impossible.

Cognitive artifacts can also be used to evoke cognitive activity under more controlled conditions, recording workers "filling in" skeletal cognitive artifacts. For example, as operating room coordinators work out a schedule of assignments for the next day they

[7] Nemeth, *The Master Schedule*. Unpublished doctoral dissertation, available at www.ctlab.org.

seek to match available but diverse resources (different workers) with the expected, diverse demands (various operating room schedules). By having different coordinators work through the same set of assignments, researchers can investigate individual differences in the performance of a real complex task. Coupling cognitive artifact analysis with "thinking aloud" (verbal protocol analysis) makes it possible for the researcher to discover coordinator problem solving strategies, domain factor weighting processes, and explicit approaches to planning. Importantly, the approach also reveals the methods workers use to hedge against unpredictable but likely fluctuations in resources and demands. These are critical components of resilience engineering: the ability to anticipate and to gauge potential future difficulties and to develop plans that are suited to them. Nemeth's work demonstrates both the presence and significance these efforts to create that resilience. Understanding this aspect of technical work may lead directly to variety of useful aids to for this important activity.

The data and relationships that cognitive artifacts encode have a close relationship to the most demanding and problematic aspects of the work domain. This is arguably the most important characteristic of cognitive artifacts in research. Researchers who seek to understand technical work face a potential avalanche of data without any useful means to distinguish which data are important. Drowned in data that cannot be analyzed to produce insights into technical work, many failed research programs have simply vanished without a trace in the literature. Cognitive artifacts offer researchers a recurring, contextually relevant, efficient, albeit highly encoded representation of what matters in the domain *at the instant that the artifact is being created or modified*. Even through it presents a substantial challenge to the researcher, the effort that is required to decode artifacts is uniformly worthwhile. This is especially true in high-tempo operational settings. Artifacts provide a manageable "stripped down" representation of the problems workers confront, because workers encode and use only what they actually need to make work happen. Cognitive artifacts thus provide researchers an efficient "way in" to study technical work. Because they are so tailored to the relevant details of the domain, research directed towards cognitive artifacts is almost always at the "level" needed to produce useful results.

*Communications between problem solvers as technical work*

Post-accident analyses often attribute accidents to failed communications in the workplace. However, surprisingly little research attention has been directed to real communication in actual work situations. Communication between workers is a constant feature of the workplace because technical work usually spans work shifts and professional boundaries. The content and style of these exchanges have not been examined closely. Brandwijk et al.[8] examined the nature of handoff communications between pediatric intensive care unit fellows in a busy, tertiary care pediatric ICU. Two surprising results from this exploratory research stand out: the conversational, negotiated nature of what has been supposed to be simple, uni-directional reports and the dynamic, highly variable and yet highly relevant content of the exchanges.

[8] See Brandwijk, et al.: *ICU Handoffs Conform to Grice's Maxims*. www.ctlab.org

Handoffs of care have been widely recognized as a potential source of gaps in the continuity of care.[9] Shift change boundaries are one interesting instance of such handoffs and a variety of experts have sought to devise tools to improve data flow across them. Little attention has been paid, though, to the dynamics of such handoffs. There are no published accounts of systematic analysis of handoff content in the context of a relevant domain. Most accounts of handoffs concern details of single patients. Workers, however, rarely handoff single patients. In most instances, workers at shift boundaries hand off *collections* of patients. The relevant domain unit of analysis for such handoffs is the collection, or unit level, rather than the individual patient.

Brandwijk et al. (in preparation) developed a graphical method to represent the ICU itself as a unit of analysis. The work created and refined a data collection form to describe the ICU context, which is the population of patients on the unit and the approximate acuity of their illness. This tool was then used as a frame to interpret the content of a series of handoffs that occurred during ICU fellow shift changes. The handoff content was recorded on audio tape and transcribed. The recordings were then analyzed by playing them back while re-recording the analysis with video capture of the movement of tokens across the data collection form. This form of analysis produced explicit links between the speech acts that took place during the handoffs and the clinical context that surrounded the handoff communications.

Handoffs of this sort have been regarded as uni-directional reports from the off-going to the on-coming worker. The conversational analysis conducted here demonstrates something altogether different. Handoffs are actually complex, nuanced, and dynamic conversations that obey the logical rules of conversation that were suggested by H.P. Grice.[10] They also demonstrate a variety of conversational features that are found in other settings, including turn-taking, repair, and violations. Surprisingly, much of the content in these handoffs was not data-exchange in the usual sense that might be expected in uni-directional reports. Instead, the content included complex descriptions of processes and histories, tentative proffers of explanations, expressions of expectations about the future, and descriptions of uncertainties and their possible ramifications. These complex exchanges were embedded in a matrix of recurring tests of coherence and closure. The close proximity of patients and their location on the floor of the unit provided strong contextual cues. Those cues helped to maintain the coherence of the conversation and allowed participants to encode references and use gestures, leading to highly efficient exchanges. Instead of maintaining a roster of data items to be reported, the content was almost exclusively problem oriented.

Many present efforts to reduce the occurrence of gaps at handoff are framed as though handoffs are uni-directional reports. Aids that are developed to support such reporting, such as hand-held computer exchanges of patient data lists, are unlikely to be useful aids for the conversational handoffs that were observed in this study.

The remarkable subtlety and the complexity of the handoff conversations are exceeded only by the variability among handoffs. Participants work to structure not just the handoff of a *single patient* but the larger process of handing off *the unit itself*. The

---

[9] Cook, Render, Woods: Gaps in the continuity of care and progress on patient safety. www.ctlab.org

[10] See Grice, H.P., *Studies in the Way of Words*, Cambridge: Harvard U Press, 1989, Chapters 2-4.

order of patient handoffs varies from day to day, usually beginning with the sickest, most critically ill child and then proceeding more or less according to the location of patient beds. Variable amounts of time are devoted to patients; the most unstable and the most acutely ill get more time while those who are comparatively better get less. The main reason for this variability is the intense time pressure in this setting. Time pressure increases as the complexity and number of patients increases. This increases the premium on rapid, highly compressed handoffs. Data from Brandwijk et al. reveal that there may be an order of magnitude difference in the time that is spent handing off patients in different parts of the same intensive care unit. This plastic, adaptive quality of handoffs in not widely appreciated; research approaches that 'see' only one patient at a time are figuratively blind to the ways that the need to care for *all* the patients forces workers to tradeoff between individuals. Strategies that seek to regiment information exchange may paradoxically reduce workers' ability to match their investments of time to the uncertainty and criticality of the patients most in need of attention. There are both tactics and strategy here. The tactics are in the handoff of individual patients. The strategy is in the management of the larger process.

The handoffs that were observed reflect the exchange not only of information but also of *responsibility for care*. The function of handoffs in this setting is clearly to prepare the on-coming caregiver to assume the responsibility for care and the conversation marks this occasion. While the off-going fellow has most of the information and does most of the speaking, it is the on-coming fellow who controls the conversational pace and signals intermittent closure. Beyond the cold analytical details, the communications contain an intensity that cannot be encapsulated in a few words.

Do handoffs sometimes create gaps in the continuity of care? They most certainly do. Are these occasional failures easily remedied? Perhaps, but this study demonstrates that maintaining the continuity of care is a subtle and complex business. Although distant observers can (and do) regard "communication" as a remediable "cause" of accidents, this study suggests that they misunderstand the sources of vulnerability and resilience that are present in technical work. Closer investigations of this type of technical work offer a more nuanced view and the promise of further insight.

*Approaches versus methods*

Methodological issues are important to technical work research. However, it is not methodology *per se* that sets technical work research apart from other healthcare research. The studies that are described here employ multiple methods that draw on engineering and anthropology, sociology, cognitive science, and psychology. The result is not one method but a mix of methods. The methods are deployed at various times, in bits and pieces, in order to cover the large, irregular surface that is the technical work domain. The methods used for these studies were "hijacked" from within the academic disciplines where they were developed and applied opportunistically to technical work studies. Fascination with single method such as video recording analysis can easily limit progress towards the goal of pragmatic appreciation for the details of technical work.

Technical work studies look for settings and problems that are both available for investigation and that are also suited to exploration using the variety of available methods. All involve field work and so the opportunity to make such observations is a critical element. Technical work studies are inherently about human expert cognition which, while not directly observable, may be inferred. There are limits to this inference and there is always some uncertainty about its validity. Nevertheless cognition is described, characterized, and evaluated in ways that shed light on the work itself. In their original disciplines, the various research methods were grounded in and used to explore issues relevant to those disciplines. In the service of technical work studies, the methods are used in unconventional and sometimes novel ways. While healthcare technical work field studies resonate with those of, for example, anthropologists, they are not a variety of medical anthropology.

Technical work studies place the technical details of the work domain at the center, rather than at the periphery, of the inquiry. Technical work is about the way that technical issues influence the work, the workers, and the patients. Technical details provide the calibration and the context for results and validate the methods. In order to make the methods from other disciplines work, they must be re-grounded in technical detail. For this reason, successful approaches to technical work studies usually result from sustained, cooperative efforts between practitioners and researchers rather than work by either group in isolation. Work by researchers alone tends to misunderstand the technical issues that are, after all, subtle and complex even for the practitioners who encounter them. Work by practitioners alone tends to become bogged down in uninteresting details or to vagabond about without direction.

What do these two studies suggest are likely to be productive lines of inquiry in the future? Cognitive artifacts offer perhaps the easiest "way in" with the greatest likelihood of success. Shared artifacts are particularly worth close examination, especially those that are used to coordinate work. Interestingly, computer-based artifacts that supposedly duplicate a paper-based artifact are seldom as useful.[11] Virtually everything that appears in or on physical artifacts is meaningful because the workers created them for themselves. As a result, physical artifacts such as paper notes or conventional whiteboards are more likely to be fruitful targets for technical studies.

Good targets for technical study abound. They include activities that externalize cognitive states of workers through conversation with others, such as the expressions that are needed to coordinate cooperative work processes or the control of equipment. Specific "difficult" conditions may serve as naturally occurring probes and provoke explicit recounting or conversations about how the details of work situations are handled. This is especially true if the conversation is laden with significance, such as at shift handoffs. Situations are likely to yield interesting results if they put strain on normal reactions or plans, require deviation from routine procedures, or involve comparisons across boundaries (especially across patients).

[11] Current work in CtL is directed at understanding why this is so. Preliminary results suggest that computer-based artifacts only reproduce part of the functions provided by physical artifacts. The permanence and individuality of notation and the spatial dedication that is typical of manual artifacts are just some of the functions that appear to be lost in the conversion.

*Conclusion:*

These two examples demonstrate that technical work study is possible and that it can be an ongoing source of rich, diverse insights. These insights may in turn open new lines of research and provide benchmarks for other, more familiar research programs. Technical work studies are exciting because they get to the core of what makes work hard and what can sometimes make work unsuccessful. The studies go behind “human error” to discover the sources of resilience that usually work to forestall accidents. Technical work studies explore how workers create and sustain resilience and what happens when they are unable to do so.

Technical work studies are challenging because they are grounded in the details of technical work, rather than in the academic disciplines from which the research methods that are used for study have been taken. Technical studies require careful choice of a suitable target for inquiry. They also require patience and *sustained* collaboration between practitioners and researchers. Technical work studies can be difficult to start; close collaboration and field observations require long ‘dwell’ times and careful planning. However, once successfully underway, technical work studies can produce a steady stream of compelling insights into the complexity, conflict, and uncertainty that shape the essentially human work of caring for those who are sick.