From Workplace to Development: What Have We Learned So Far and Where Do We Go?

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ABSTRACT
Development methodologies such as user-centered or participatory design require a commitment to the process at the beginning of the development project. However, it is not always possible to introduce a new development methodology. When new methodologies can not be used the question of how research can contribute to the design of systems becomes important. Studies of the workplace have provided one solution by offering insights into the work on a setting-by-setting basis. This paper argues that workplace studies as a corpus can also offer systems designers valuable information to support their decisions.

INTRODUCTION
The development of user and work-oriented system design methodologies has been a central concern for human-computer interaction (HCI) and computer-supported cooperative work (CSCW). For example methodologies such as participatory and user-centered design emphasize bringing users and their work into systems' development. What these methodologies — and others like them — share is the commitment to the process from the start of a project.

However, this commitment may not be possible when developers begin with an existing set of commitments. For example, sometimes designers begin with an existing system and have to integrate new functionality onto the existing code base. The existing code reflects a set of previous design decisions and often acts to constrain the range of possibilities (after all your new features ought to work with the old ones) [8, 35]. Existing commitments to a methodology also influence the design process. For example, companies that are ISO 9000 compliant must follow the processes that they have used to reach certification or spend considerable time revising those processes.

When introducing a new user or group-oriented systems methodology is impossible — for either methodological or technical reasons — then a way to influence design decisions is to offer developers snapshots into the work world. Over the last ten years, studies of workplaces have done this through providing details about specific work contexts. Although individual studies have provided some opportunities for systems developers to "see" the workplace the overall corpus of workplace studies has not been examined for common patterns of action. This paper surveys the corpus of studies and argues that it can offer designers valuable information to support them in their design decisions.

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Two surveys of workplace studies have been conducted. Hughes and others [25] surveyed their own studies of the workplace. The purpose of that study was to review the different ways of using one particular interpretative method — *ethnography* — to inform the design of systems. They offered a variety of different ethnographic techniques for use in different situations. This paper differs from that by reviewing the products of many studies of the workplace and using those observations to reconsider the design of collaborative systems.

Plowman, Rogers, and Ramage [32] have also reviewed workplace literature. Their report reviewed workplace studies that informed design and evaluated collaborative systems. While the authors did examine a number of the observations made in the literature, they concentrated on analyzing the challenges of bringing the conclusions of fieldwork to design. They concluded that translating the results of fieldwork into design ideas remains an obstacle in using workplace studies in systems development.

I take a different approach from Plowman, Rogers, and Ramage's. I examine the content of the workplace studies rather than categorizing the intent of the papers to inform design or evaluation. The studies reveal that some patterns of action occur repeatedly.

The paper begins with a discussion of the studies that were surveyed. Eight observations about how individuals collaborate and the role of technology in that collaboration are discussed. These observations are:

- People make assessments about data based, in part, on the status of the provider.
- Individuals make some of their work visible to others, and also monitor each other.

- People's perception of technology effects the ways that they use it.
- Researchers have shown that work is dynamic and involves many channels of communication.
- Spatial information provided by the arrangement of papers and personnel lets others know the current activities of the entire group.
- People construct and share interpretations of the work-in-progress.
- Work often deviates from the planned activity in order to accommodate situated action.
- Maintaining context supports long-term collaborations.

For each observation I summarize the contributions that workplace studies have made. In many cases there are studies that present different outcomes. Rather than offering specific design recommendations, the purpose is to present the findings as a whole. The paper finishes by examining the role of the corpus — and the observations contained within it — in informing new design methodologies.

STUDIES SELECTED

For this analysis I selected studies based on the following two criteria. First, the studies had to involve going to the place of work. As a result of selecting workplace oriented studies the primary methodological orientation was qualitative. Techniques used by the researchers included: participant observation, interviewing and artifact analysis. However a number of the studies also used quantitative data in their explanations of work practices. Second, the studies had to focus on the coordination of work. This is an artificial boundary in some respects; however, it was necessary to bound the scope of work to be included for a survey paper.

In the short time that researchers have studied work they have been to a variety of settings. Studies have reported on work at a number of different sites including control rooms, hospitals, research institutions, and accounting firms.

While these settings vary in the kinds of work that goes on there, a number of the observations transfer across these different settings. For example, current research suggests that the functionality of the technology needs to be aligned with people's perceptions whether they work as consultants or ship navigators. Other observations may span settings, but they are more obvious in some than others. For example, the affects of individuals' status seem to be easier to identify in medical settings.

The approach used to organize the studies consisted of searching through the relevant literature for examples. Once the candidates had been collected each study was read, and individual observations were recorded on cards. These cards were then reviewed and sorted into groups where the observations seemed to support, extend, or modify each other.

THEMES IN WORKPLACE STUDIES

The following sections discuss each observation. Each section surveys some of the key studies that identified the pattern of action. They conclude with a brief discussion about the implications for systems design.

Status Matters

Researchers have known for some time that the status of individuals influences collaboration. For example, Cicourel [13] described how a team of medical workers collaborate to perform a patient diagnosis. He observed how the medical workers judge the suggestions of each member of the team, based on their professional standing and experience, as well as the scientific merit of their opinions.

Other studies have also described how status affects collaborative work. Schneider and Wagner [38] examined the role of medical records in hospital work. They reported that nurses and doctors examined the handwriting on the record to determine the author of that information. Using that knowledge they assigned a relative importance to the information on the basis of the status they attributed to the author. Egger and Wagner's [15] study of how medical workers scheduled surgery reveals a similar pattern. They discovered that the status of surgeons — measured by how valuable their time was — controlled the scheduling operations. The process of scheduling operations was on-going negotiation between nurses who created the schedule, and the surgeons who subsequently reordered it to suit their own preferences. The surgeons used the status attributed to them to override the decisions of the nurses.

Decisions influenced by status do not only occur in medical practice. In a study of the use of an organizational memory system, Ackerman [1] described status issues that affected system usage. In this case the system supported "ask the expert anonymously" interaction between novices and experts. The system made experts' answers available to everyone to read as part of the organizational memory. While the novices stated that status cues had dropped for them, the experts felt under more pressure to provide "good" answers. In this case the system did not completely remove status barriers, but instead of novices feeling pressured to ask intelligent questions the burden of status shifted to the experts who felt obliged to provide good answers. Ackerman's work reveals that people who recognize their own status may feel the need to provide information that reflects their knowledge.

It may seem from this review that the majority of studies about status have used the medical domain as their workplace. Perhaps the reason for this is that the medical community has an established and well-known hierarchy, making status more observable. However, Ackerman and Perin [31] have studied status outside the medical community and examined how status affects the use of groupware.

Status matters to individuals at work. Individuals gather information about the status of their colleagues in person and from the artifacts used in that setting. Furthermore, in some settings individuals use other peoples' status in their

decision making. Other settings suggest that individuals regarded as having high prestige can use that to influence actions such as scheduling.

Making Private Work Public

Researchers have studied differences between work which individuals do publicly, whether they make it public, or others monitor them, or both, and work that remains private [29]. Heath and Luff [24] studied the collaborative work of London Underground controllers. They reported that the operators of the underground developed ways of working together without specifically coordinating their efforts, relying on speaking out loud and monitoring. One example of the coordination activities of the underground controllers involved the adjustment of a train schedule. In the control room one person took responsibility for scheduling and re-scheduling the operations of the trains while the other informed passengers of arrival and departure times. In this instance the scheduler communicated with a train driver and asked him to slow down. Overhearing this activity the announcer told passengers that the next train would be delayed.

Monitoring activities have also been reported in studies of air traffic control. A group of software engineers reported that some design requirements for a new air-traffic control system changed as a result of their sociology colleagues undertaking an ethnographic analysis of how air-traffic controllers work [41]. Customizable interfaces often seem like a desirable feature in new computer systems; however, the ethnographers cautioned against allowing the controllers to customize their screens. The screens delineate the airspace that the controller is in charge of and show all the planes flying in that space. Air traffic controllers often glance at the screens of those sitting next to them, because they represent the air space next to their own. In this way, controllers gather peripheral information about what's about to happen inside their airspace. If the controllers customized their own displays, then others would not be able to learn about the adjacent air space "at a glance."

More recently, a group of researchers who studied the Space Shuttle mission control center reported on the use of an audio technology that supported both speaking and monitoring activities [47]. The technology — voice loops — supports a number of audio channels for different topics. Any member of the flight center can monitor and participate on channels that are relevant to their work. However, the researchers report that a number of conventions have arisen, where certain people monitor but never speak on some channels.

Other studies report that people make information visible to others by highlighting it. Hughes, Randall and Shapiro [26] discuss the annotation of the flight strip in their study of air-traffic controllers. The flight strip is a paper record of a single flight and provides details of the destination of the aircraft, the flight number, and so forth. As controllers examine these strips they sometimes annotate them. Sometimes the controllers annotate the information to draw other controllers' attention to it. In this case annotation increases the visibility of certain information on the flight strip so that others see it.

In control rooms individuals draw attention to information that would otherwise remain private. At the same time others monitor their activities. Studies outside the control room though reveal that publicity is not always desired. In a study of a firm of architects, Harper and Carter [23] found that a video link between the designers and the engineers exacerbated existing tensions involving the division of work between the two groups. The designers' work involved generating quick survey plans presenting a solution for customers. However before the customer saw the plans the engineers evaluated them for structural consistency, and that always took longer than the designers wanted it too. This division of labor meant that designers wanted final plans much faster than engineers could produce them. In meetings the designers usually tried to "arm twist" the engineers into providing a plan on their time schedule. Harper and Carter concluded the video link did not help the two groups to work together because it revealed too much about each group's working practices weakening both group's abilities to negotiate during their meetings. Consequently the technology was not adopted.

Bowers [7] also raises concerns about the visibility of work in his study of the use of a network of CSCW applications. Part of the duties of the network users involved the production of monthly reports. Prior to the network, each individual produced the report on their own machine, privately. Once the network was installed individuals produced these reports on the network and managers could now "peek in" to the writing process and inspect the quality of the document. This led to the development of an uneasy relationship between the writing that individuals still did privately, and the visible part of the process.

The literature about visibility could be interpreted as suggesting that it has positive affects in the control room environment, and negative affects elsewhere. That would probably not be accurate. In the control rooms individuals often had some discretion about what to share with other people. Harper and Sellen [22] study of work at the International Monetary Fund (IMF) suggests that this is indeed the case. In their study of the production of reports they found that individuals found it easy to share some data that required little interpretation with their colleagues.

In studies of software developers Grinter [18] found that the development environment allowed individuals to monitor the current state of work. The tool provided this by using a formalism to represent the state of work. The information the system provided was fairly unobtrusive though as it simply consisted of the name of the developer and which files they were currently working on. Developers could look at the information and see what their colleagues were working on. Furthermore the tool allowed the developers to update their shared view, so they could see how the work was progressing. In summary, the system provided an awareness of others' work without revealing the details, a form of *shared feedback* [14]. At this level of granularity developers did not find this informative invasive, and at the same time they used to see what their colleagues were doing, and as a consequence to coordinate activities when necessary.

Individuals make some of their work visible to others through speaking and highlighting functions. At the same time they monitor the work of their colleagues looking for information that may affect them. This is especially true in control room situations where individuals need to make decisions quickly. The literature suggests that the technology in these settings — whether that was or was not their intention — support making information public and monitoring. It further suggests that sometimes low-tech solutions — like auditory-only systems — work well.

Away from the control room systems have also made information about peoples' work available to others. The studies suggest that sometimes providing information violates existing privacy conventions, and at other times it doesn't. What is more important is that collectively these studies suggest a range of alternatives in presenting information: full access to others' work, a view that provides a summary of the work environment, and no access. Finally, the studies also indicate that the range of alternatives may all be useful in the same work setting; for example, allowing some activities to be completely accessible while providing summary information about others.

Matching Perceptions to Functionality

Both Hutchins [27] and Orlikowski [30] have commented on the interaction between individuals' interpretations of technology and its functional capacity. Orlikowski defines individuals' understandings of technology as their *technological frames* that she describes as:

> ...frames of references that individuals have about the world, their organization, work, technology and so on. While these frames are held by individuals, many assumptions and values constituting the frames tend to be shared with others. Such sharing of cognitions is facilitated by common educational and professional backgrounds, work experiences, and regular interaction. ...those cognitive elements that have to do with information technology... I have termed technological frames... ([30], p. 364)

In her account of how Alpha Corporation adopted groupware Orlikowski discusses the relationship between individuals' technological frames and the uses of the technology. Specifically, she noticed that new users of the technology had very individual centered impressions of what the technology supported, and consequently used it for individual purposes. Because the individuals did not have technological frames that incorporated an understanding of groupware, the users did not understand the shared database applications so easily.

Hutchins also explores the role of individuals' perceptions about technology further in his study of ship navigation. Part of his study examined the role of navigational instruments in this work. Specifically, he focused on how the instruments provide representations of navigation problems the team faced. He argued that these instruments supported the work of navigators because of the way that they represent the problems. Much navigation work involves mathematical relations and instruments that have these formulae built into them, allowing navigators to find the solutions readily. In this way the instruments reduce the complexity of the problems of navigation work.

Orlikowski and Hutchins have made essentially the same point: that a relationship exists between technology and people's interpretation of it. Orlikowski watched the initial adoption of the groupware technology, and found that without technological frames that fitted the technology individuals found it difficult to use Notes™ as groupware. Hutchins studied established navigation technologies, some which have existed for several centuries, that rely on the user's understandings. Orlikowski suggests training users to develop the models that match the technology, and Hutchins suggests that established technology relies on those technological frames.

However, in a study of the adoption and use of a distance learning technology, Sharples [39] made an interesting observation about other factors that influence the technological frames explanation of how individuals use a technology. He described an audio and video link that facilitated teaching and discussions. Most of the participants wanted to use the technology even though they found it difficult to use and unreliable. They chose to use the technology because the alternative meant driving 50 miles to the site for the class. This study suggests that while technological frames remain an attractive prospect, when users have strong incentives to use technology then they persevere with a difficult technology.

Short, Mixed-Medium, Communications Often!

A number of researchers have studied communications in the workplace, and the results suggest that short, mixed-medium communications occur frequently. Bly [6] studied three possible configurations (face-to-face, remote with audio, and remote with audio and video) for a system supporting two individuals involved in design work. The design involved both writing and drawing elements. Bly observed that in all three configurations the participants switched frequently between the writing and drawing aspects of the work.

Reder and Schwab [33] and Whittaker and others [48] both examined how discussion about on-going work continues over time and involves differing media. Reder and Schwab followed three groups, managers, sales, and marketing, within a single organization. They found that individuals often engaged others in short, frequent discussions. These discussions often changed channel; for example, starting with a meeting and following up with electronic mail and the telephone.

Whittaker and others left a video camera continuously running in an office. They analyzed conversations and discovered similar patterns on a given topic at various intervals during the day. They also observed that these informal communications were brief, unplanned, dyadic and frequent. They suggest that desktop support for communications should support these traits.

Grønbæk and others [19] found that people often divert from planned work as crises arise. In their study of a construction project they noticed that some projects happen

spontaneously, for example, a phone call sometimes triggered an unplanned assignment. Rouncefield and others [36] found this "constant interruption" of the planned work activities also occurred within a small office setting. Ironically, this office group, who provided conference facilities for a university and local businesses, found the people requesting these services distracting in some sense, as they interrupted the job of processing the associated administrative work.

People communicate frequently with each other often changing between different kinds of medium. Furthermore, these studies indicate that these unplanned abrupt communications can radically alter the plan of action. The answer to the question of whether we can support spontaneous, frequent, mixed-medium communication is made harder by the mobility of many workers either in the office or in telecommuting arrangements [4]. Mobility raises questions about the kinds of hardware as well as software support individuals need to maintain these kinds of interactions.

Spatial Arrangements Provide Information

Some studies have described the importance of spatial arrangements in collaborative work. Specifically two kinds of layout have been examined: that provided by the physical arrangement of people, and that afforded by paper [2, 26]. Anderson and Sharrock [2] discuss the role of spatial relationships in accounts processing work. They claim that the arrangement of the people within the room resembles the flow of work through it, and that people can use functional and spatial information about others to locate the place where an invoice might be. Building on this idea of a "map" of the office, Rouncefield and others [36] examined individual layout of papers in an office as a mechanism that afforded others:

> ... an at-a-glance way of knowing who's doing what, what stage they are at, and how quickly it is going. ([36], p. 282).

This suggests that the seemingly individual work of arranging papers may turn out to be publicly significant, because it makes work visible to others.

Other researchers have pointed out the importance of spatial arrangement of papers. In their study of air traffic controllers Hughes, Randall and Shapiro [26] watched individuals arranging flight strips. During the arranging process the controllers learned about the latest flights and potentially the newest problems. The ethnographers determined that the final arrangements represented a paper "map" of the sky that the controllers managed, because controllers had arranged it to represent the relations between all the flights.

In a study of the publishing industry Bellotti and Rogers [5] also describe a number of critical spatial arrangements of paper. In their study they followed a traditional newspaper publisher and several world-wide web based publishing ventures. At the newspaper Bellotti and Rogers describe one daily activity that involves pinning up the entire paper published the day before. The editors then review the layout and discuss improvements. Bellotti and Rogers report that this paper based activity transferred to the web-publishing ventures. The editors of the on-line sites printed their entire site to examine its layout and discuss improvements. At one of the web publishers the paper review transferred from the editors of that site to the software developers who also worked there. The developers started to develop a practice of printing out their entire code, and laying it down on the floor to review it.

If the spatial arrangement of papers is as important as these studies suggest an important and difficult question is: how can we use technology to support this? In studies of air traffic control the computer scientists responsible for building the system implemented a design that allowed the air traffic controllers to arrange their flight strips on the screen. However, when the size or number of artifacts increases and the quality of image needs to be detailed, then screen real-estate soon runs out. Bellotti and Rogers suggest that rather than trying to replace paper with technology we should consider making the transition between the two mediums easier.

Spatial arrangements of paper and people provide information to others. As well as being useful for examining details, the arrangements provide another kind of information, an overview. People can use these overviews to learn about what's currently happening, and what events are about to happen. As a result they are able to make decisions about what to do next.

People Construct and Shape Interpretations of Work

In previous sections I explored how the environment provides cues for understanding the work-in-progress and how individuals monitor others' activities to learn about their work. Some researchers have explored another, more direct, way that people interpret the work in hand. They have examined how individuals work together to construct a shared understanding of work.

Lucy Suchman [46] studied a group of purchasing staff and described how they worked together to understand a problem they had with an invoice. Using a case where the actual work-in-progress differed from the formal procedure, she focused on how two people worked together to solve a problem involving a billing that they did not wish to pay for twice. Neither employee could find the invoice for the bill, and they needed to decide if the payment had been made. Suchman described the course of their meeting as being an exercise in reconstructing the official flow of work to determine, from the other paper in the file, whether they had paid the missing invoice. At the end of the meeting both participants left knowing that the bill had been paid because they had worked together to develop a shared understanding of how that transaction unfolded and what had gone wrong with it.

Sharrock and Anderson [40] reported on a team of developers who met together to solve a design problem they had with a printer. Using conversation analysis they scrutinized a section of the meeting pointing out the conversational mechanisms that the group used to ensure

they all understood the problem in the same way. Their observations demonstrate how groups work together to develop a common understanding of the current problem.

In another study, Anderson and Sharrock [2] took the idea of shared understanding further by observing that sharing knowledge reinforces the process itself. When the authors observed accountants at work, they found that in routine work accountants annotated the invoices by attaching paper to them:

> Marking up the invoice is not just a way of recording actions and sharing knowledge although it obviously these. Reading the invoice stamp is not just a way of accessing such stored knowledge, though that too is true. Both the writing and the reading are ways of re-producing within the day to day courses of normal activities the social institution, the cultural practice, of using the invoice as a socially available, stratified record of work. ([2], p. 156).

This adds to the idea of shared understanding by explaining how individuals work to maintain it over time.

Studies of air traffic control work have revealed the role of technology in creating and sustaining shared meanings [44]. Suchman explored the contradictions that controllers have to reconcile to make sense of in their work. The tensions stemmed from the differences between the central computer system and the reality of the airport. The centralized computer system coordinated flights for the entire United States from a location remote to the controllers. The system required the controllers to enter information about arrivals and departures into the system. The system kept records of flight arrival and departure times, and compared the data entered by controllers against its records to determine whether a plane was late.

In reality planes often arrive or depart just a few minutes outside their scheduled time, and carriers incorporate this into their flight time. A flight that leaves an airport three minutes after its scheduled departure may not be late. The controllers used their own judgment, based on experience, to decide whether delays meant that the flight was late or whether it was inside the allowed time. In this sense the air-traffic controllers constructed their own version of reality partially based on the truth, the times when planes leave on time, and the times when they record the plane as leaving late. However, this reality is also based on their judgments of what information is important, and what inconsistencies can slip by. The controllers did not share their constructions with their office partners, but shared them with air-traffic controllers across the US through the technology itself.

So far I have considered ways that people construct a shared understanding of their work and use it to collaborate. In a study of the Worm Community System (WCS), Star and Ruhleder [42] described some of the difficulties of learning about the work of another group. The WCS supports the sharing of data amongst the geneticists interested in c.elegans nematode research. It provides information about the organism, supports formal and informal communication, and a quarterly newsletter, among other information.

Star and Ruhleder described the challenges that the geneticists faced in getting the system up and running, which they view as a problem of communication between different contexts. For example, to make the system work geneticists needed to understand the intricacies of certain computing protocols. Furthermore these protocols were not part of their shared culture, something that made it harder to understand how to hook their computers up.

Star and Ruhleder highlight something missing from the previous literature about shared interpretations. Individuals worked together or formed part of a single professional group in the previous examples. In either case it appears to foster conditions that lead to a common understanding being shared among participants. Star and Ruhleder looked at how the geneticists had to cross a boundary into the world of computer science to hook up a WCS connection. Once on-line, the geneticists found a continuing need to understand the language of computer science to "ftp files," "run slip" and so forth.

Shared understanding provides individuals with mechanisms for collaborating. Systems that facilitate the construction and maintenance of shared understandings need to provide a number of features. First they have to make sure that the information is understood by everyone. In Grinter's [18] study of software developers the formalism provided a shared understanding of what the other developers were doing. In that case it worked because everyone understood the information being presented to them. Second, if people are going to work together on-line then the system probably needs to support them in such a way that they can produce this shared understanding and adapt it to meet new and changing requirements.

Boundaries among different social groups create further complications for collaborative work. Boundaries may occur among individuals in different disciplines or locations. In the building of the ARPANET — the most widespread case of computer supported collaborative work — the individuals were divided among many continents and institutions such as, commercial companies, governmental organizations, and universities. The solution was to find shared background, and using that common ground they established the technical and social protocols that influenced the development of the network and continue to do so today [28]. They achieved this using the technology available to them, and put their results back into the infrastructure that further supported their collaborative work. The ARPANET suggests that shared understandings can be built and maintained in computer supported environments.

Contexts of Action Influences Planned Work

Many of the studies I have previously described have illustrated an important point; actual work often deviates from what was planned. Lucy Suchman made this point central to studies of work in her highly influential book *Plans and Situated Actions* [43]. The book describes how plans are situated in a context that shapes their outcomes.

In this section I briefly characterize some studies that have examined the breakdown of plans and the role of situated action.

In a study of an accounting division of a furniture factory, Button and Harper [12] describe the failure to implement a new computer system. The new system was designed to support the formal accounting policies of the group. However, because of deadlines, the accounting group did not use the formal procedures anymore. No-one had previously detected this incongruity because the accountants reconstructed the formal procedures on paper to look as if they had implemented the formal process. Beck and Bellotti [3] observed that researchers working on a paper together did not stick to their assigned roles during the writing process. Instead they adapted to the changing environment. They call this behavior *informed opportunism* suggesting individuals read cues from their environments and redefine their writing role based on that information.

In a study of graphic designers, Rogers [34] describes how the situated actions that resulted from broken plans also broke down. She found that arrangements arising from the breakdown of the original plans are also susceptible to contexts of action. In this case the designers had a problem with their software, if two people worked on the same file at the same time the system hung causing the designers to lose the data they had entered. The designers could not fix the software, so they devised a manual file check-out system, writing down on a centrally located whiteboard which files they were using currently. This manual procedure broke down when individuals believed that they just had a quick change to make. Instead of marking the check-out on the whiteboard, they simply opened the file and worked on it. This led to systems crashes because others, assuming that file was free, would also begin work on it.

Suchman's observations emphasized the inherent contingency of work. Together these studies show that systems can create a need for unplanned work by being too rigid. However, more flexible systems — flexible with respect to the work in hand — actually support individuals unplanned actions.

Maintaining Context in Long Collaborations

Most ethnographic studies of collaborative work have examined collaboration as it happens in a specific setting. The accounts they present describe how people engage in day-to-day and minute-to-minute collaboration depending on their level of analysis. However some collaborations take place over longer periods of time.

Ruhleder and King [37] discuss a long-term academic collaboration. The authors studied the compilation of a database containing information about Greek classics that had been going on for many years. The database was developed by many classics scholars who came and worked on the project for a one to two year term. In this project the database supported the collaboration between the scholars. The data held within the database supported this collaboration, because the scholars used it to determine how to add new data. Specifically, the newest scholars looked at the previous data entered to determine what new data to add, how to order it, and what conventions for access and use to give their work. Thus, the database served as a bridge between the efforts of the successive scholars.

Fischer and others [16] describe similar kinds of collaboration in their studies of organizational memory systems The authors built and studied an organizational memory system to support a group of network managers in a regional campus. The network managers used the system to maintain a memory of how the network was constructed, recording decisions about why certain connections were used and so forth. Over the years new network managers have used the database to find out why previous decisions were made. The system also proved useful when a network manager left the campus because it provided information about that person's decision making process.

Both of the previous studies emphasize the importance of computer technology in facilitating collaborations that last over several years. In a study of software developers Grinter [17] found that the organizational memory holding design decisions was not always as helpful as it might be. The organizational memory system in use was discretionary; developers could choose not to explain why they had changed software. Developers often decided to get on with their next job rather than enter comments into the system when project deadlines were tight. Consequently, when other people subsequently reviewed the memory for explanations what they found was not always useful.

Organizational memory systems and archives are technological solutions that have the potential to make new kinds of collaboration possible. They allow dispersed — across time and space — groups to collaborate with each other. At the same time it's possible to see that these systems are subject to the same rules as other forms of computer support. They have to function in an environment where people have the opportunity and incentive to use them.

DISCUSSION

In the previous sections I reviewed eight observations about work. This section discusses what these studies can tell us as a collection. Specifically, as a corpus these studies provide a way of talking about the challenges of designing usable and useful systems. Furthermore they raise new questions about the design impacts of potential interactions among these observations, as well as the dilemma between innovation and replicating current practices.

Traditionally systems design has focused on what the system will do: the functions that it will provide to its users. This places the system, and the work that the system will do, at the center of the design effort. At the same time human-centered design methodologies have focused on ensuring that the real needs of the users are taken into account. Both approaches focus on the center of the design, giving the system appropriate functionality and ensuring that it is meeting users' needs. This is clearly a

very important part of design, but perhaps it should not constitute the entire design effort.

Collectively, these studies of workplaces raise an issue that I call *design at the edges*. Edges are the "interfaces" between the system and the world of work — people, other systems, and artifacts. Design at the edges involves understanding how computer systems fit into people's work in ways that make them useful as well as usable. Each one of these observations is one such edge, and others no doubt exist. From the perspective of a designer, these edges are often the places that present new and complex design challenges.

Although individual applications made design at the edges challenging, groupware raised the level of complexity considerably because those systems must either embody and reflect the work of the group or try to find places where they can gracefully transfer their contents to other technologies, people or artifacts. Grudin [20] describes how slowly the computer has been able to "reach out" and so the interface has slowly moved into the work setting. Bowers and Rodden [9] subsequently argued that work has also begun to reach into the system, that the interfaces are the places where different agendas meet and problems surface.

Brown and Duguid [10] have focused on one aspect of these edges — which they call *borders* — that they describe as the place where individuals pick up context. For example, a book has a number of social conventions that provide cues to its readers about the content. This survey reinforces and extends their observations about the use of border resources, and suggests that the distinction between edges and the center is valid.

Workplace studies reveal much more about the ways that individuals pick up context, and show how systems support or hinder that. Specifically, the studies show that the edges are the places where questions about how context is appropriated arise: how can systems be designed to support awareness of others; facilitate monitoring activities; and can they be built in ways that help people make aspects of their work available to others? The edges are also more than places to appropriate context, as they also raise questions about whether the system should incorporate a certain function or pass it off to another system, a person, or another kind of artifact. For example, the studies of publishing raised questions about the transition between paper and the systems used. Other questions arise when two systems meet at an edge, should they be integrated, or provide seamless transitions, or allow individuals to make that choice. Finally, critically, the edges are places where designers encounter challenges in fitting the technology to its environment.

Designers often meet many of these edges in the development of one application. Furthermore, the challenge of working with one edge may cause the designers to develop new directions that in turn open up questions about other edges, as there are relationships among the different issues. For example, a system designed to share data among two different groups encountered challenges in shared meanings. The group that commissioned the design thought of the data in units of hours, whereas the other team used a measure of months. Resolving this issue by adopting the hours unit revealed further challenges in helping the group that had used the months unit understand the new relationship between their perceptions of the technology and the way that they worked.

Many other relationships exist among the edges that I have described. Workplace studies and this analysis name and give character to the edges and as a result give designers a way to talk about them individually, and also collectively. Furthermore, it provides an overview of the challenges in a way that may help designers to select issues to resolve in order, and suggest potential outcomes or complications when multiple edges interact.

Adopting a context-sensitive approach to design raises another question — or dilemma [21] — of when should we innovate and when should systems try to replicate existing work arrangements? One tentative conclusion is that in some cases new opportunities provided to be times for innovation and those cases tended to occur when alternative solutions were not available or when people were designing for their own use. The organizational memory systems described in the long-term collaborations do not seem to have manual equivalents that they replaced (which is not to say that manual equivalents couldn't exist, simply that they didn't). In the case of the networks, individuals were building systems as part of their own research programs, and although ARPA was funding the project, it was still fluid enough to allow the developers to design many features for their own purposes.

The question of under what circumstances to innovate is not easily answered by workplace studies. Many workplace studies show us how complex work is, and how developing technologies that only marginally support current practices can create mismatches that prevent people from working. However some also describe how new technologies such as the Internet or organizational memory systems get adopted in workplaces and end up supporting some aspects of work in ways that seem useful. Together the studies can serve as a set of guidelines that highlight some of the challenges that designers may face when they attempt an innovative design. As more studies of the corpus of workplace studies occur perhaps we will be able to learn more about potential opportunities for innovation.

CONCLUSIONS

Where do systems designers find the ideas that influence their design choices? Suchman has suggested from her own observations that designers often turn to their environments and look for answers among their colleagues, or the literature that they read [45]. She argues that when designers are introduced to other influences then they begin to appropriate them in their work.

One way to influence developers is to introduce new design methods that foster tight relationships between the social sciences and systems engineering (for example [11, 49]). This has already begun in human-computer interaction, and

other methods more suitable to groupware technologies have been proposed. However, it may be impossible to introduce new ways of working when organizational, social and technical commitments have already been made to a project.

In this paper I have surveyed the corpus of workplace studies and offered eight recurrent observations about collaborative work. By summarizing and discussing these patterns and examining the sometimes conflicting evidence I have presented a collection of information that may be used in making design decisions. Furthermore I have used the corpus to examine a concept I call design at the edges, trying to focus attention on the interfaces between systems and work.

ACKNOWLEDGMENTS

Funding for part of this work came from the Engineering and Physical Sciences Research Council. I would like to thank Al Barshefsky, Lisa Covi, Paul Dourish, Jonathan Grudin, Neil Harrison, David Weiss and the reviewers for their suggestions. Errors and omissions are mine.

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