Thinking with Erasable Ink: Ad-hoc Whiteboard Use in Collaborative Design

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ABSTRACT

Our work uses interactive workspace capture technology to investigate the hows and whys of whiteboard use in collaborative design environments. By showing excerpts from data collected in two collaborative design settings, we describe how collaborators use whiteboards in an opportunistic, task-oriented fashion. We illustrate the patterns collaborators follow in their interactions with the whiteboard and each other. We demonstrate that sketches generated in these ad-hoc design sessions ground real-time discussion, but seldom convey much information after the fact. These findings are analyzed to help us reexamine our approaches towards computer-supported collaborative design activity outside of the formal meeting environment.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces—synchronous interaction

General Terms

Documentation, Performance, Design, Human Factors

Keywords

Collaborative Design, Physical Environments, Workspaces, Whiteboards, Ad-hoc

1. INTRODUCTION

It is the erasability of whiteboard ink that makes the whiteboard a mainstay of collaborative design environments everywhere. The ephemeral nature of whiteboard ink allows users to share ideas quickly—and just as quickly, to amend those ideas. The *improvisational* quality of whiteboard use is a good match for the *provisional* ideas that are generated in informal design meetings, when designers are more concerned with entertaining possibilities than communicating fact. The ubiquity of whiteboards in dedicated design spaces (such as war rooms, and project rooms) and informal meeting spaces (such as offices, break rooms, and hallways) is a testimonial to the utility of the whiteboard to designers everywhere.

A good understanding of how and why whiteboards are used in collaborative design, then, can provide guidance into how we might support design activity outside of the formal meeting environment. The fundamentally opportunistic nature of ad-hoc design meetings has made them difficult to study ethnographically, and almost impossible to study experimentally. Fortunately, the development of knowledge capture tools to support cooperative design and project awareness for users in interactive work environments has also enabled researchers to observe, post-facto, the on-going activities and behaviors of designers "in the wild."

In this paper, we present and discuss typical examples of ad-hoc whiteboard use from dedicated design spaces and informal meeting spaces where design teams are working on actual projects. By showing excerpts from data collected in two collaborative design settings, we describe how collaborators use whiteboards in an opportunistic, task-oriented fashion. We illustrate the patterns collaborators follow in their interactions with the whiteboard and each other. We demonstrate that sketches generated in these ad-hoc design sessions ground real-time discussion, but seldom convey much information after the fact. These findings are analyzed to help us reexamine our approaches towards computer-supported collaborative design activity outside of the formal meeting environment.

1. BACKGROUND

Design is an iterative process of synthesis, analysis and evaluation. [2][3] Although the generation of ideas occurs in the synthesis phase, it is the analysis of the implications of each idea, and the evaluation of the value of the idea, that moves designers closer to a solution that meets their requirements and specifications. This dialectic cycle between generative and critical behavior is apparent at all scales of design activity, from the momentary thoughts of a single designer to the large scale development behaviors of product companies. [22]

Sketching is an important aspect of design activity because it allows designers to externalize the concepts they are proposing, so that they may more easily analyze and evaluate their ideas. In addition, the commitment of ideas to visual form provides designers with scaffolding from which to extend their ideas into a coherent plan.

Sketches also serve as a valuable form of communication from one designer to another, helping to *ground* their conversations in a common understanding of what is being proposed, what that proposal means, and if that idea is desirable. While work groups of all types engage in shared sketching activity, it is of particular value to designers because of the unconstrained nature of their work.

Whiteboards are a natural locus for collaborative design activity because they provide a large shared surface on which

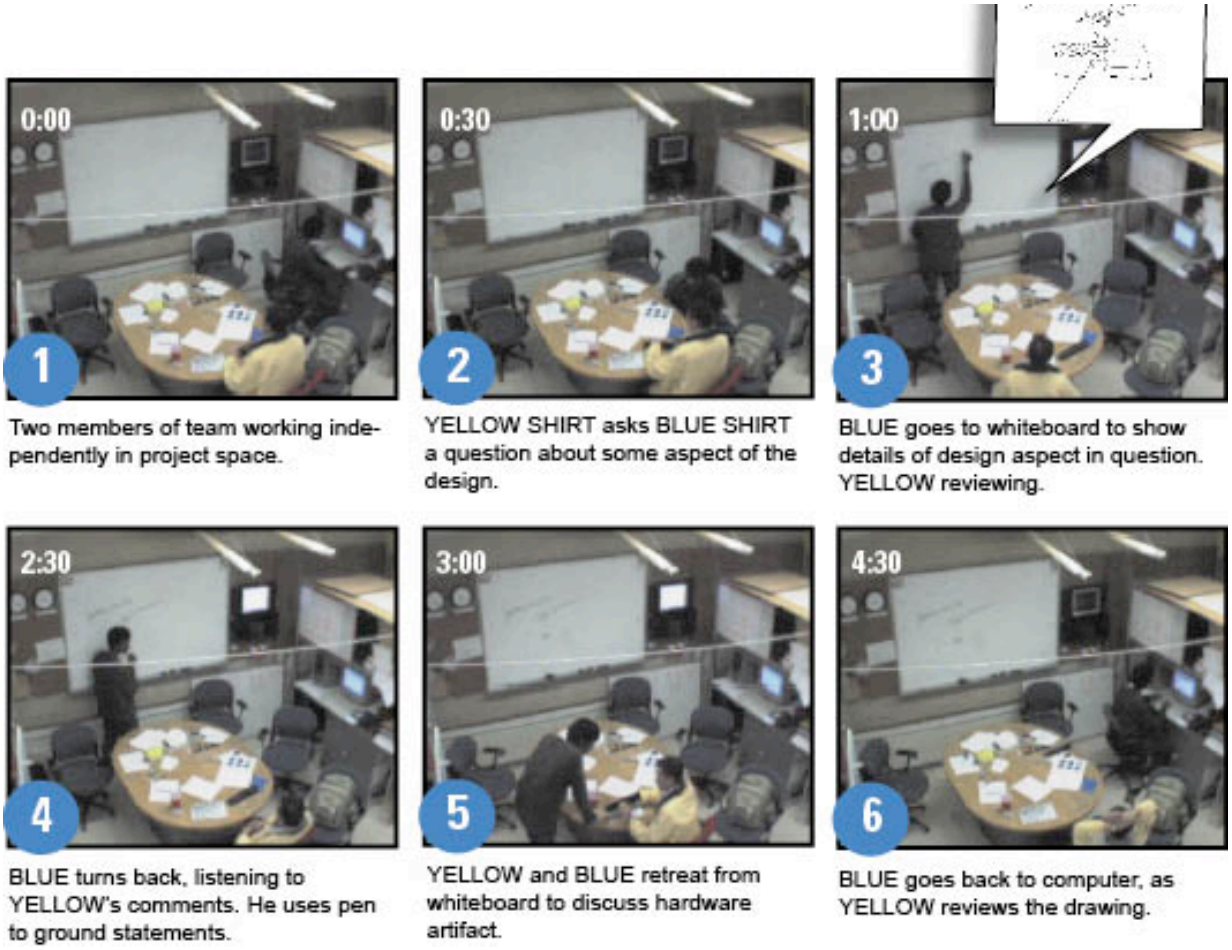


Figure 1. Initiation of ad-hoc whiteboard meeting

to proposed ideas. Also vital, however, is the erasability of the whiteboard ink. The dry-erase ink is clearly useful for retracting discarded ideas, but it also helps to frame the psychology of the design activity.

Sketches are deliberately and glamorously informal. "some cool quote." Because the generation of ideas is part of a process in which participants suspend thoughts of what is true or untrue to consider what might be, the activity needs to occur in the context of a "bull session." These types of informal meetings, which are characteristically unstructured, denying of roles, interactive, and free from agenda, have been recognized as being valuable to the work process. The opportunity for informal meetings is one primary reason that collocated groups out perform distributed ones [15]. It is in these bull-sessions that we feel that people are truly collaborating, rather than just throwing ideas "over the wall."

2. RELATED WORK

The desire to support informal workgroup meetings was present from the interactive whiteboards conception. The Tivoli electronic whiteboard [16] developed at Xerox PARC supported these meetings with easier access and retrieval of pre-existing electronic data, easy storage and sharing of generated artifacts, and support of distributed teams.

While the electronic whiteboard's growing presence in boardrooms, meeting rooms and classrooms across the world is a testament to its success, the interactive whiteboard is still struggling to meet the needs of its original target market. The challenges presented by the informal workgroup meeting are being tackled on many fronts. The MessyBoard [8] acknowledges and seeks to preserve the "sketchy" loose nature of whiteboard drawings. The Designer's Outpost [12] introduced tangibility into the equation, enabling quick and easy manipulation of post-it-notes to restructure the relation of bits of information. In developing the IBM Blueboard, Russell et all [18] identified the problem with interactive whiteboards not to be in its toolset or operation, but in how the tool fit into the actual work environment. To support ad-hoc shoulder-to-shoulder interactions, Russell alleges, it is critical that systems be instantly available and immediately easy to use.

Part of the difficulty in designing interactive whiteboards to suit these ad-hoc meetings is that these sessions are difficult for researchers to observe in the wild. Many researchers [4][23] have studied design collaborators in interactive environments, but these studies are limited to observing a few hours of interaction, rather than the weeks of activity that design projects usually entail. The studies performed to evaluate the performance of various whiteboard systems in development are also informative, but the toy scenarios with which researchers necessarily initiate observable activity are often different than the scenarios collaborators might face in the wild. Another approach to understanding design collaborations are use of retrospective reports [5]. To date, these studies tend to focus on the drawn artifacts generated by collaborators, rather than the conversations and behaviors which are the most important aspect of informal group work.

More recently, the integration of ubiquitous computing technology into interactive workspaces has introduced

synchronous multi-channel data capture [11][16], and has made long-term deployments of knowledge capture, access and reuse systems possible. This technology has been used to support the ongoing collaborative activities of NASA scientists [21], engineering design teams [12] and educational environments [19].

This increasing affordability, extensibility, deployability and robustness of collaboration technology extends the purview of computer support beyond episodic meetings. As a result, we have gained new tools with which to gain insight into the very collaborative processes we would like to support.

3. METHOD

To observe ad-hoc collaborative design behavior in-situ, we observed six physical design spaces, each of which had a whiteboard. These design workspaces are associated with two graduate courses in the Mechanical Engineering department. Both courses involved team-based design projects and had large laboratory spaces with specific areas designated for each team's use. The study and data collection took place over a period of nine months.

3.1 Users

We instrumented four dedicated project spaces used by teams of three to five people working on industry-sponsored projects to produce a final functional product prototype. The projects ranged from consumer products to automobile technologies. Each team had their own dedicated space which they were given rein to outfit as they saw fit. The duration of these projects was six months long.

We also instrumented a shared group space in the vicinity of these spaces where these and any other project groups could and would sometimes meet.

The other design space we selected was in a shared laboratory environment used by students working on term projects in mechatronic (mechanical-electronic) design. Students were assigned to work in teams of 3 or 4 people, building and programming interactive games from scratch to completion in 3.5 weeks. In this environment, the team's personal project spaces were outfitted with a lab bench, a computer, an oscilloscope and a power supply, but no dedicated whiteboards. Collaborators in these last two spaces all had free access to the whiteboard, day and night.

All the members of the project teams had substantive previous design collaboration experience. These design teams were chosen because we felt that their environments were sufficiently representative of actual work environments in many corporate environments, and that the designer collaborators representative of actual designers in the "real world." Studying in a project-based learning environment allowed researchers free access to the physical facilities to maintain the system, helped to unify the project schedule which more readily enables comparisons across spaces, and mitigates the potential of intellectual property issues in the data collected.

Information from this study was not shared with course instructors and did not influence the academic evaluation of team performance.

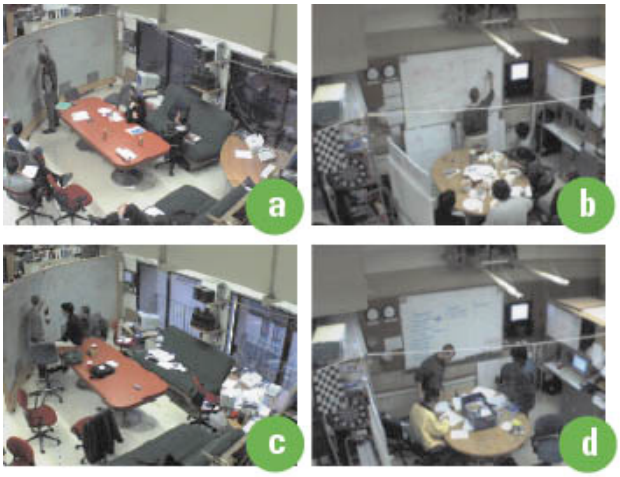


Figure 2. Formal (a)(b) whiteboard meetings vs. informal, ad-hoc (c)(d)

3.2 System

Information from each design space was captured using a knowledge capture, access and reuse system made available to the students to augment their design activity.

The systems featured networked, multi-channel data capture. Design activity was captured using overhead web cameras and whiteboard drawings were captured using a commercially available system (http://ebeam.com). Successive images from these inputs were analyzed to detect changes, to filter potentially relevant time slices. Data was captured in 30 second intervals and logged to a database by a remote server. Data is time-stamped to enable cross-referencing of information from different data sources. For the purposes of this paper, none of the other channels of data captured are relevant.

Flat panel monitors installed next to each whiteboard gave design teams feedback about the information being captured.

The data capture system is always on, capturing data, although users could "blackout" capture by using their whiteboard pen to press a designated soft button on their whiteboard. Flat panel monitors installed next to each whiteboard gave users feedback about the data being logged.

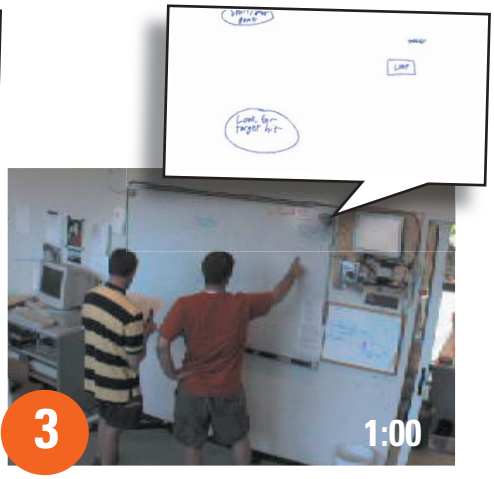
3.3 Analysis Protocol

We would like to highlight that although the data capture system, though "always on," this system is a long ways from capturing all the moments of design activity on the projects in question, even in the dedicated design spaces. In addition to periods of system downtime, significant gaps exist in the record because of our low temporal resolution, because of the "black-out" option and because the teams would often work in other spaces, particularly as their prototypes grew too large for the spaces. Also, occasionally it was difficult to make out what activity was taking place in the design space because of the density of objects in the camera's view.

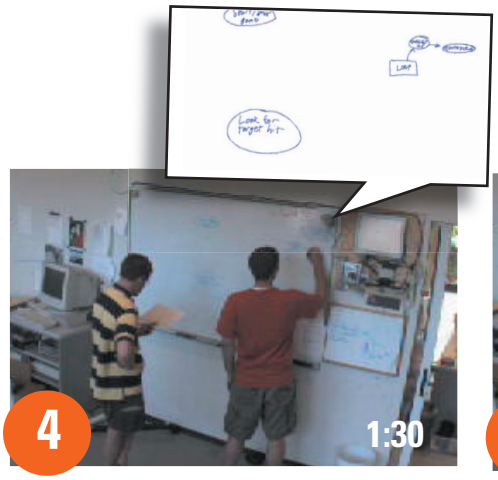
That said, the data corpus captured a large part of the conceptual design activity of many project teams. In the data log, we found a total of 37identifiable whiteboard sessions by design teams. These were observed and analyzed design researchers familiar with the course material and the design teams in question for regular patterns of interaction. Although each team had its way of working, met different amounts,

Preliminaries: STRIPED SHIRT erasing board.

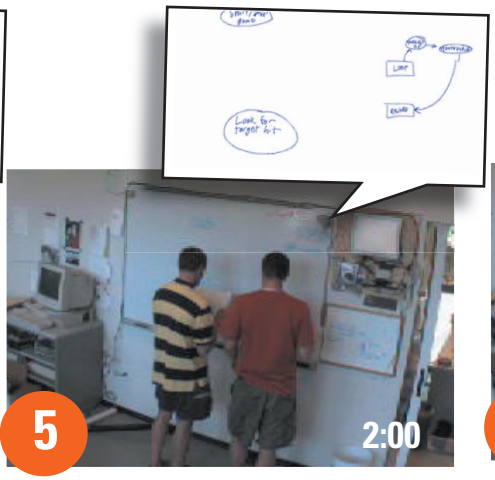
Initiation: STRIPED drawing, RED SHIRT overseeing



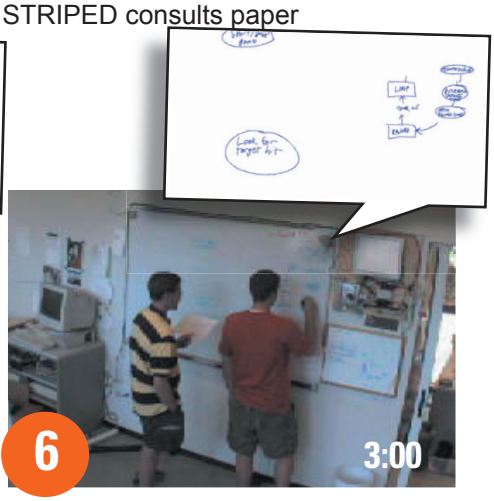
Reflection: BOTH further from board, RED points at drawn artifact, STRIPED consults paper



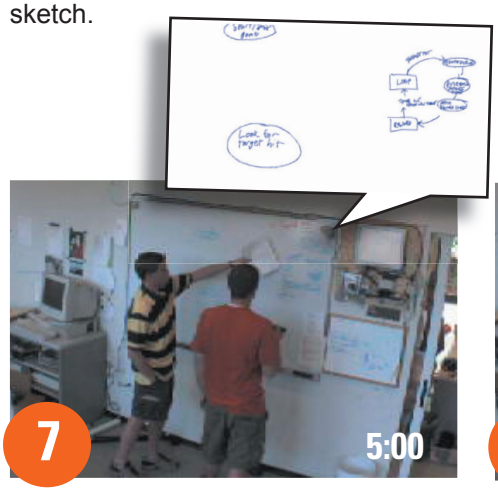
Role switch: RED drawing, STRIPED overseeing. Note not editing prior sketch.



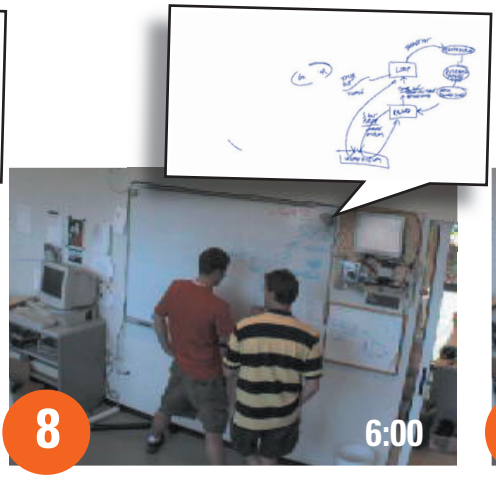
Interruption: STRIPED promps RED to review paper.



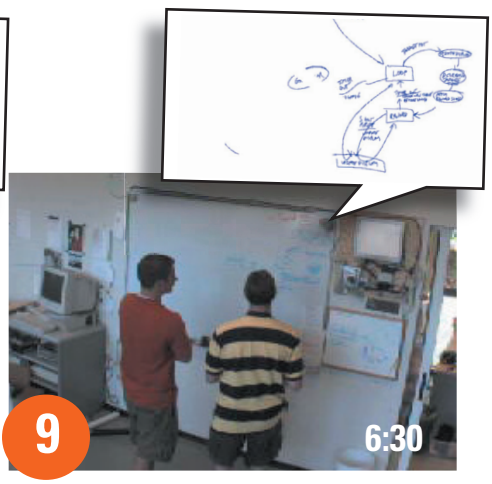
Resumption: RED drawing, STRIPED reviewing. Note erasure in drawing.



Navigating: STRIPED gestures while suggesting next steps



Steps 6-7 are repeated 2x more. Note initial sketch now erased.



Reflection: Both stand back to evaluate the work so far.

Figure 3: Typical interaction pattern in whiteboard design session. Two people working on a state diagram for an interactive game. In this sequence, you can see the activity transition between synthesis, analysis , and evaluation. Note how the proximity of the interactants to the whiteboard relates to the the phase of the design activity. Also note the role switch between shot 3 and 4.

Figure 4. Examples of critical stances by navigators.

consulted each other on design questions of different granularity, we observed many behaviors common among the design teams and across the design environments. Representative sequences in which it was easy to make out behaviors and visually distinguish collaborators were chosen for illustration of these patterns.

4. OBSERVATIONS

4.1 Whiteboard sessions

How do ad-hoc whiteboard meetings come together? In Figure 1, we picked a typical example sequence drawn from a dedicated project space:

(1) Two designers in their shared team workspace, working independently.

(2) BLUE scoots over, presumably due a question posed by YELLOW about some aspect of the design.

(3) BLUE goes to the whiteboard and sketches a diagram, labeled "Inverseq Groc-Clip"(sic) , showing a box with two antennae protruding from the top. The antennae are annotated with an arrow, "tends to open up."

(4) BLUE turns back to discuss diagram with YELLOW. He points to ground aspects of the conversation on specific sites in the drawing

(5) BLUE and YELLOW retreat the examine hardware at end of desk.

(6) BLUE and YELLOW resume independent activities, with YELLOW continuing review of diagram.

In total, the time at the whiteboard was less than 2 minutes, and the overall engagement lasted no longer than 4.5 minutes. This type of consulting and discussing behavior recurs numerous times over a period of ~3 hours, albeit with different team members. A more typical physical interaction would have YELLOW getting up and standing at the board.

Although these types of sessions were observed throughout the design duration, these types of exchanges were far more prevalent during the conceptual phase of the design process. This took place about a month and a half into a six month project.

This interaction highlights some common aspects of ad-hoc whiteboard interaction sessions, how they convene and dissolve:

a) The whiteboard meeting itself is *opportunistic*. The meeting is not scheduled or planned; it comes about when an individual runs into a problem that is best reasoned through with the help of others.

b) Prior to the ad-hoc meeting, however, participants are co-located. This observation is actually more remarkable in the environment with graduate students working on a course project than in a typical work situation, where proximity is often a given. By making a point of working separately in the same space, the students *avail* themselves to ad-hoc meetings.

c) Visual artifacts are exceedingly brief. This follows the principle of *least collaborative effort.[6]*

d) Ad-hoc whiteboard meetings are *specific in purpose;* the meeting begins with one issue, and concludes as soon as that issue is resolved. In the meetings we observed, they tend to run less than 15 minutes, although sometimes design teams would come back later to the same problem, and build on their previous drawings.

These features are significantly different from the patterns we observed in formal meetings. (See Figure 2). In formal meetings, the presenter works at the board and all the other participants hang back, whereas in ad-hoc meetings, the participants all huddle near the board. Also, while we only ever noticed one person writing at the board at one time (in exception to the commonly-held belief that collaborators sometimes write simultaneously), the amount of passing of the pen to another collaborator occurred far more frequently and spontaneously in the whiteboard sessions. (See Figure 3).

4.2 Interaction patterns at the whiteboard

How do people interact during the course of an ad-hoc whiteboard session? In Figure 3, we review a typical interaction pattern:

AD-HOC WHITEBOARD INTERACTION PATTERN

Set: Interaction in front of a whiteboard, and the open space in front of it. Although there is often enough space for more than

one group at the board, only one group seems to convene at a time.

Roles: Usually 2 people engaging in roles as "driver" (the person with the pen) and "navigator" (the person reviewing). Note that at a traditional whiteboard, it is possible for both people to drive simultaneously, but we never observed this behavior occurring.

Sequence:

(1) Preliminaries. Board is erased, participants take positions

(2) Initiation. STRIPED starts drawing. RED usually adopts critical stance (see Figure 4 for more examples)

(3) Reflection: After some period of generative activity, the STRIPED pauses, and steps back to analyze and evaluate. In Figure 3.3 Notice RED indexing aspect on board as STRIPED reviews paper in hand.

(4) Generation: Note role change between STRIPED and RED. Note that STRIPED now stands back and has adopted the critical stance. Also note that RED has forked from the intial drawing and started a new drawing in a new place on the board.

(5) Reflection: Similar to (3). STRIPED calls RED's attention to something on paper. Note both stand back from the board.

(6) Generation: Similar to (4). Note Drawing has been erased and redrawn different since (5)

(7) Review: RED steps back from board, while STRIPED steps forward, commenting and gesturing in the space where nothing is drawn yet.

(8) Generation: Similar to (4). Notice original drawing from (2) now erased.

(9) Reflection: Similar to (3) RED and STRIPED both stand far back from the board.

This interaction pattern highlights some specific aspects of whiteboard interactions which we found to be common:

a) The orientation and location of designers with regard to board reflects design activity. .Changes in proximity to the whiteboard correlate with design phases when designers are distancing from the ideas at hand and seeking of perspective. This is more apparent when people are standing, because that enables them to move.

b) Ad-hoc meeting participants take on different roles at

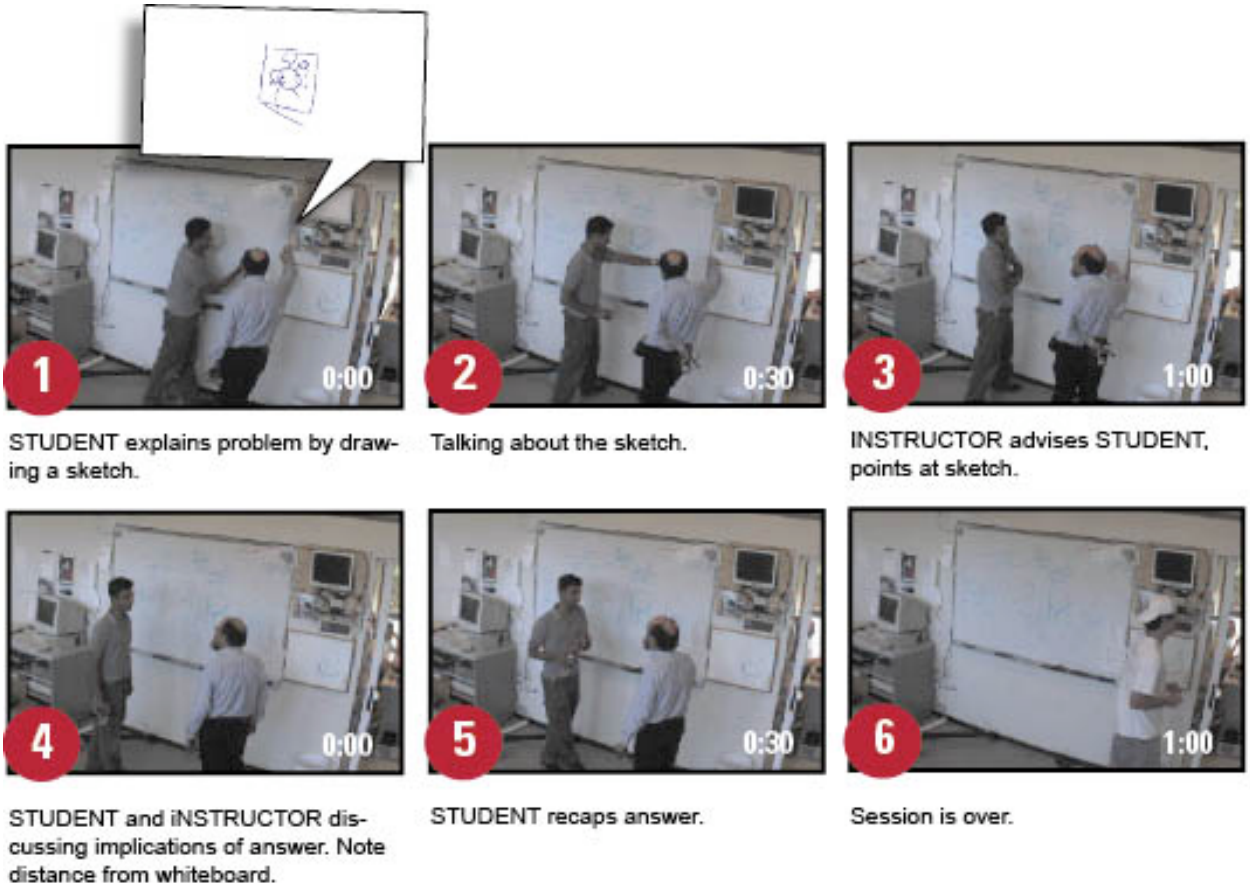


Figure 5. Ad-hoc whiteboard interaction with student and instructor.

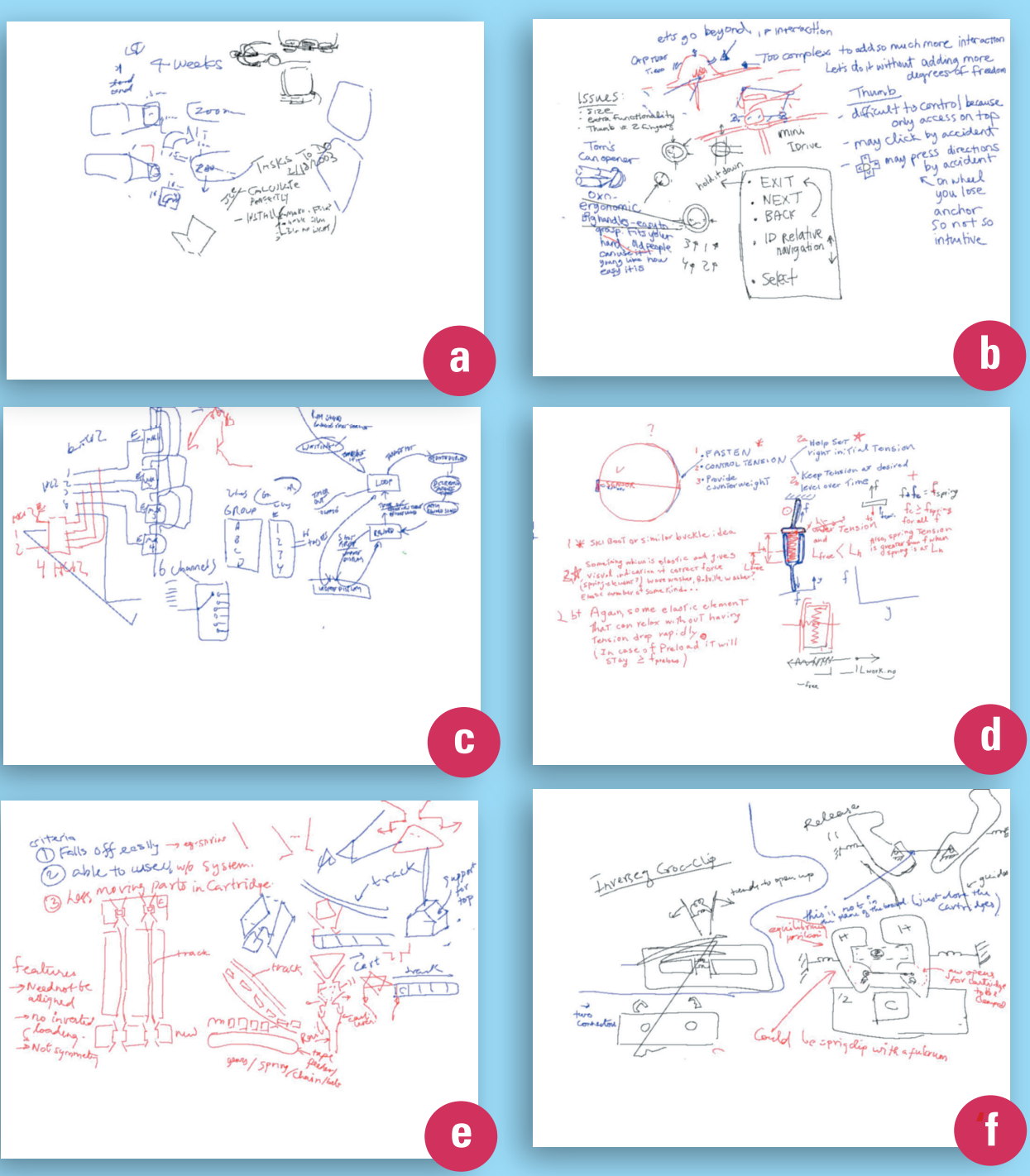


Figure 6: Sample captures from whiteboard design sessions. The sketches here show the range of design activites undertaking at the writeboard, froma) scheduling: morphological analysos. b) Form, function, behavior of thumb input mechanism c) Pin diagram and state diagram d) Engineering model of damper system, e) Functional design of cartridge release system, f) Behavioral mechanism of a clip release

the whiteboard. While both participants are actively engaged in the design process, one adopts the role of DRIVER, wields the pen and consequently drives generation. The NAVIGATOR adopts a critical stance (see Figure 4) and acts to analyze and evaluate the proposed ideas as they are being generated.

c) The design process is iterative. Although the meeting collaborators did not generate many versions of their state diagram, the progression of board drawings in Figure 3, shows a significant degree of on-going revision, likely in response to the real-time feedback generated by the NAVIGATOR

d) "Props" such as external documents, maps, relevant hardware, etc. are usually held and referenced by the NAVIGATOR.

e) If there are additional people involved in the meeting (see Figure 4) they take on the roles of auxiliary navigators, contributing, though not so prominently, to the review and feedback.

f) A large percentage of the time at the whiteboard is spent talking and pointing, rather than drawing.

The last point is also shown in Figure 5, we can see the STUDENT and the INSTRUCTOR discussing an issue. The STUDENT raises the issue with a sketch, and uses the sketch to describe his issue. The INSTRUCTOR points to index his subsequent statements, but then a long period of discussion ensues wherein no drawing takes place at all.

These patterns serve to underline Sara Bly's assertion that the process of creating the drawings is as important as the drawings themselves[4]. In fact, in the case of collaborative design meetings, it seems clear that engaging in the iterative process of design, having a collaborative conversation about the many possible solutions and eliminating false leads is more important than the drawn artifact.

4.3 Whiteboard sketches

Looking at representative products of various ad-hoc whiteboard sketching sessions in Figure 6, we see that the drawn artifacts of ad-hoc whiteboard meetings have a limited capability to convey what occurred during the course of the meeting to anyone who was not there.

This is often surprising to people, so it bears a thought exercise. Let's say you and I are discussing when we'd like to get together for a meal during CSCW. We might write up the days of the week on the whiteboard, and then point to each day and discuss what we were doing that day during the conference. We would very likely not write up each appointment mentioned during that conversation. All that we would have after the discussion is a series of numbers or days of the week on the board. The numbers provided us a way of visually categorizing our time resources, but only peripherally related to our actual conversation.

Given that example, we find that the drawings captured in our study are quite vivid. What one can discern from many of the drawings is the topic of discussion. What can't be seen is why they were talking about it and what exactly was said or decided.

There are a few key reasons for the lack of information in the sketch outputs of whiteboard meetings.

a) People are actively engaged in conversation, so they are not attending to the details of the drawing. As we mentioned before, the percentage time spent engaged in drawing is relatively small.

b) Some content is actually erased in the course of getting to the final product

c) Much less drawing is needed to scaffold conversation than is necessary to recreate it.

This is a primary difference between whiteboard use in formal meetings and ad-hoc whiteboard use. Since the purpose of formal meetings is to communicate ideas that are often already wholly formed, wholly formed ideas are represented visually for everyone's consumption. However, this is not the case for ad-hoc meetings.

5. DISCUSSION & ISSUES

Our study has important design implications for those working on CSCW projects involving interactive whiteboards.

5.1 Enabling opportunistic interaction

One important aspect of the whiteboard interactions is that they arise suddenly, and often end quickly. Any start up or orienting activity required by an interactive whiteboard system hampers this quality of ad-hoc whiteboard interactions. Because of, this whiteboards for informal design collaborations need to be "always on," and very straight-forward to use, much as argued by the creators of the Blueboard[18]. This provides a strong argument for tangible interfaces in these environments—while it maybe somewhat problematic to have too many tools floating around the whiteboard tray, those tools have a much higher likelihood of usage and hence usefulness than tools nicely hidden away in menus.

One of the potential problems with making interfaces that do not demand attention and silently do their thing is that interfaces that do not call attention to the fact that they are capturing data in the background are potential privacy problems.

5.2 Incompleteness of written artifacts

Because the whiteboard drawings in ad-hoc meetings are artifacts rather than the intended product of the interaction, the focus that has been placed thus far on the content of such drawings is misplaced in the ad-hoc meeting scenario.

Whiteboards drawings might be made somewhat pithier if they are made to represent the whole of the conversation rather than the final state; some graphic representation that embodies all the ins and outs of the iterative design , such as the design history in [14], might be more valuable.

Even more valuable would be images that were augmented with the conversation that was had at the time that various things were drawn on the whiteboard.

5.3 Supporting social interaction patterns

The primary strength of ad-hoc whiteboard sessions is that they enable participants to use social roles to make the interaction between the iterative design activities of synthesis, analysis and evaluation easier. As members of the CSCW community, we might ask ourselves:

Since the behaviors of whiteboard collaborators do follow regular interaction patterns, it maybe possible to help guide and streamlines such behaviors using technologies like that of the Coordinator.[10]

We might also investigate: Can the computer take over the role of navigator? As driver? Better yet, how can computer technologies act as navigational assistance? Our development of interactive whiteboard technologies has tended to focus on technologies for the driver, on the pen and the screen. Maybe the time is ripe to do something for the design navigator, standing neglected back from the board, hands on hips.

6. SUMMARY

If the ad-hoc whiteboard sessions are not about the drawings, then what are they about? We argue that they are about *design thinking*. Ad-hoc whiteboard sessions help people think aloud and on board about various possibilities. Design is different from presentation, and hence collaborative tools need to take this difference into account.

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