The Mysterious Whiteboard

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Abstract. This paper raises the question of why electronic whiteboards are not ubiquitous. The paper provides a design-oriented analysis of traditional as well as electronic whiteboards in the context of collaborative and individual activities. We offer a novel perspective on whiteboards for collaborative activity based on a survey of the electronic whiteboard literature, a series of interviews with users of traditional whiteboards, and concepts rooted in Activity Theory. We identify a number of characteristics of the non-electronic whiteboard that are important to understand and preserve in the design of electronic whiteboard systems. Most importantly, we argue that the strength of non-electronic whiteboards is a combination of their simplicity and stability as well as a discontinuity between material on and outside of the whiteboard. We argue that the non-electronic whiteboard has uses and properties, which will require an electronic substitute to differ fundamentally in design compared to our traditional personal computing devices as well as most designs seen today. We present a set of themes for design of future electronic whiteboard systems that emphasize limitations as a main design principle. We conclude with three principles for design: The idea of installation rather than application; the principle of supplementing rather than replacing; and finally the principle of embracing and enhancing discontinuities.

Keywords: Electronic whiteboards, non-personal computing, activity theory, discontinuities, collaboration, science.

1 Introduction

Whiteboards and blackboards are ubiquitous in lectures halls, offices, laboratories and meeting rooms in most teaching institutions and workplaces. This suggests that whiteboards[1] have some generally valuable inherent qualities. However, whiteboards have obvious physical limitations in the form of space, persistence over time, and the possible content they can hold. Therefore, since it was feasible to size up an adequately advanced user interface to mimic the use of the whiteboard to the approximate scale of a board, researchers and industry have tried to develop hardware and software to replace the physical whiteboard. While two of Mark Weiser's famous trinity of devices (Weiser, 1991) *have* become ubiquitous, namely the *tab* (in the form of smartphones) and the *pad* (in the form of tablets) *boards* or electronic whiteboards

[1] For simplicity we use the term *whiteboard* to refer both blackboards and whiteboards.

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are not ubiquitous today 20+ years after some of the first experiments with board sized computing took place at Xerox PARC. It is easy to argue that the hardware is not quite yet there; that a 100" slim, high-res display with low power consumption and state of the art multi-touch and pen interaction is currently not a reality within a standard company or educational budget. Yet, there are areas where electronic whiteboards, with their current limitations, supplement or replace physical whiteboards successfully. SMART boards[2] and similar technologies have been particularly popular as presenter tools in schools[3]. In hospitals we find examples of successfully replacing whiteboards used for coordination with interactive displays (Bardram, 2010).

We hypothesize that it is not only because of hardware limitations that electronic whiteboards are not ubiquitous in our workspaces, offices, laboratories and meeting rooms. Hardware limitations should not blind us from the fact that the activities involving whiteboards have fundamental differences from the kind of activities we traditionally support with personal computers. For pads and tabs to become a success as general purpose personal computers required a whole new ecology of operating systems, user interfaces and applications – an ecology geared towards the particularities of those devices. However, whiteboards are not personal. It would be naïve to believe that interactive surfaces ubiquitously hanging on our walls replacing or supplementing physical whiteboards will be a reality before a software ecology akin to what we have seen evolve over the recent years for pads and tablets will emerge.

In this paper, we develop a new set of design-oriented perspectives on electronic as well as non-electronic whiteboards. We do so based on our reading of the history of research into electronic whiteboards, in combination with a series of recent interviews with scientists on their whiteboard usage. We conceptualize the whiteboard, its characteristics, qualities, and its role in praxis through activity theory. We collect a set of themes, each with a number of challenges, we believe will be essential to address in a future ecology of software for electronic whiteboards. Our focus is the whiteboard as a tool for individual and collaborative work in offices and laboratories instead of the whiteboard as a presenter tool in the classroom.

2 Whiteboard Systems and Research

2.1 Whiteboard Systems

Much of the seminal work on electronic whiteboards took place at Xerox PARC in the late eighties and early nineties. *Colab* (Stefik et al., 1987) was one of the first systems that directly tried to imitate the qualities of whiteboards. Colab explored the interplay between desktop computers and a wall-display under the paradigm of WYSIWIS ("*What You See Is What I See*"). Colab contained three applications

[2] `http://www.smarttech.com`

[3] For a critical review of electronic whiteboard use in schools see e.g. Smith et al. (2005) or Slay et al. (2008).

reflecting traditional meeting activities: Creating presentations, outlining arguments and sketching. However, interaction in Colab was still mouse and keyboard based from desktop computers in the meeting room. Commune (Bly & Minneman, 1990), another PARC project, would link multiple horizontally oriented interactive drawing surfaces together over network to explore collaborative drawing and sketching. The *Liveboard* project (Elrod et al., 1992) introduced electronic whiteboards similar to what we see in classrooms today, and the Liveboards played the role as the third device of the initial ubicomp prototypes. The Liveboards ran a software suite called *Boardwalk* that provided a whiteboard application with free hand drawing support, and the ability to handle multiple *sheets* through a flip-chart analogy. Hence, drawings on the electronic whiteboard could be stored and reloaded. Findings in the project indicated how an electronic whiteboard is a very different beast than traditional desktop computers. For example it was observed that the Liveboards would not be used regularly if the users had to turn them on. Hence the PARC security staff was instructed to turn them on every morning. Secondly that users were less inclined to spend time solving software related problems when at the board: *"While users may tolerate the intricacies of UNIX in the privacy of their offices, we have found that in group settings, people are much less willing to take the time to solve software mysteries"* (Elrod et al., 1992, pp. 606). *Tivoli* (Pedersen et al., 1993) was a software project running on the Liveboards, and a continuation of the whiteboard application of BoardWalk. Tivoli explored different interaction techniques suitable for electronic whiteboards such as gestures and was designed to allow up to three users to interact simultaneously at the same board. Building on the previous experience with the BoardWalk software, Tivoli deliberately did not provide handwriting recognition, as it was assumed that this would be disruptive in a meeting context and make the users self-conscious. A central goal with Tivoli was to balance functionality and simplicity that would allow walk-up-and-use by novice users–which turned out to be a major challenge. *Flatland* (Mynatt et al., 1999) explored a "computationally-enhanced whiteboard" where the system would perform automatic actions on the content on the electronic whiteboard such as auto-segmentation and let the user rearrange and resize these segments. The user could apply *behaviors* to the segments to for instance create a ToDo list that would allow checking off items, or to write traditional handwritten calculation and apply a calculator behavior that will compute the result, and update the result if the calculation changed. Flatland would also let the users explore the history of the content on the board by dragging a slider back and forth in time. Unfortunately the effect of the ideas in Flatland in actual use was never documented.

The PARC electronic whiteboard systems targeted non-domain specific support for meeting activities. *Knight* (Damm et al., 2000) on the other hand was specifically developed for object-oriented design and diagramming. Knight allowed users to mix informal sketches and formal UML diagrams on an electronic whiteboard, the latter through recognition of hand-drawn UML elements. Hence acknowledging the need for moving between the formal and informal in a design situation. This mix seemed to have a positive impact on diagramming object-oriented systems. *Calico* (Mangano et al., 2010) is, like Knight, an electronic whiteboard system for software developers.

Yet instead of supporting more formal diagramming, Calico supports sketching of software, and instead of recognizing shapes as UML elements, Calico allows its users to define their own drawing primitives called *scraps*. Calico groups strokes similar to Flatland and supports multiple canvases, similar to Tivoli, yet Calico provides a fixed set of spatially organized canvases that the user can zoom out and get an overview of. A comparative study by Mangano et al. (2010) indicates that Calico does support a software design activity better than a traditional whiteboard.

One good example of structured whiteboards traditionally used for institutionalized planning and coordination can be found in hospitals. Recently, at least in numerous Danish hospitals, clinical whiteboards have been replaced with large networked interactive displays (Bardram et al. 2010). These kinds of electronic whiteboard systems are very different from the general-purpose electronic whiteboards developed at PARC. Each screen is tailored specifically for a given activity in the context of a given hospital for instance to show an interactive overview of the occupancy and association of clinical personnel to e.g. a patient ward. Configuration and reconfiguration of these displays involve highly trained consultants.

Another type of electronic whiteboard systems is whiteboard capture systems that rely on a traditional physical whiteboard, but use digital cameras to capture the content. ZombieBoard (Saund, 1999) applies a ceiling mounted digital pan/tilt camera to capture the content of two whiteboards. Writing special marks on the whiteboard controls the capture mechanism, e.g. to choose whiteboard to capture or area of a board to scan. ReBoard (Branham et al., 2010) is another example of a capture system but where ZombieBoard relies on the user to explicitly control the capture mechanism through markings on the board, Reboard captures everything that is put on the whiteboard and makes it available through a web interface. Branham et al. studied the effect of fitting ReBoard to a group of whiteboard users' whiteboards, and observed how in fact practice changed. Users become less afraid of deleting content from their whiteboards and would more often wipe the board clean, knowing that everything was stored. Yet they also observed how more care was taken in what was written on the boards, as users knew they might retrieve it and share it with colleagues in the future; *"ReBoard can thus be seen as creating tension between the ephemerality and persistence of board content"* (Branham et al., 2010, pp. 82).

Interestingly the application area of the majority of the electronic whiteboard systems described above were meeting situations and collaborative work activities – yet in present day commercialized electronic whiteboard systems are mainly used in teaching as a presenter tool connected to a personal computer such as the teachers laptop.

2.2 Studies of Whiteboard Use

Historically blackboards and especially whiteboards are a relatively new invention[4], however throughout the 20th century they have become a ubiquitous instrument for knowledge transfer and knowledge creation. The literature on *how* blackboards and whiteboards are actually used, *why* they are used and *what* they are used for is

[4] The class-room chalkboard was invented in the early 19th century by James Pillans (e.g. mentioned in Pillans (1856)) and the whiteboard was invented in the 50s and started to appear on the market in the 60s.

relatively sparse. The first electronic whiteboard systems papers did not report on studies of actual whiteboard and blackboard use to inform the design of the systems, but relied on casual observations and common knowledge regarding the use of whiteboards. In the last decade there have, however, been a handful of HCI papers studying how whiteboards actually are used to inform the design of electronic whiteboards.

Mynatt (1999) studied the daily whiteboard use in offices over a two-week period through snapshots of the boards and interviews with the users. The goal of the study was to capture the affordances of physical whiteboards under the assumption that an electronic whiteboard will fail if such affordances are not transferred. She especially focuses on long-term use rather than shorter-term use for meetings and teaching.

Mynatt observes how whiteboards in general are used as a *working space* rather than a *production space* as one of her interviewees puts it. The content of whiteboards is typically highly context dependent and getting the content off the board e.g. to share information from the board following a discussion is a source of frustration. Mynatt observes how the content of whiteboards clusters, and a whiteboard can be involved in multiple activities simultaneously, she observes how people scavenge space leading to some boards with hotspots that change a lot while other content is preserved. Mynatt emphasize how space constraints are a weakness of whiteboards, yet that traditional desktop interfaces with multiple documents wouldn't be appropriate for electronic whiteboards. However, the conclusions of the paper does not go beyond stating that developing an electronic whiteboard system is difficult.

Tang et al. (2009) study how people employ whiteboards to transition between related tasks. Through the use of surveys and interviews the authors observe how the use of whiteboards transcends the boundaries of a classical 2x2 groupware matrix of independent/collaborative – synchronous/asynchronous use. The content of whiteboards relate to multiple activities, and the authors claim that whiteboards support transitions between independent and collaborative activities. The authors identify four types of whiteboards through their study: public, semi-public, personal, and notification whiteboards. Public whiteboards belongs to no one and is primarily used for synchronous activities. They are most often wiped clean after use. Semi-public whiteboards, e.g. in a shared office, exhibit similar use as a public one, yet they are sometimes used for storage and a common praxis for writing on them may be established. Personal whiteboards, located e.g. in a single office, is used for a large variety of tasks and only close colleagues are invited to write on the board. Notification whiteboards are purely personal used for reminders or task lists.

Tang et al. summarizes their findings with a set of implications for design of electronic whiteboards:

- Whiteboard practice is largely enabled by the conception of whiteboards as contextually located containers for visually accessible information
- Providing users with expressive primitives will allow them to flexibly generate meaningful applications themselves
- Supporting transitions on electronic whiteboards means designing functional primitives rather than applications
- Designers can rely on the situated nature of interactive displays to determine which primitives are appropriate for that context.

Summing up: Activities at a whiteboard are very different from activities at a desk. The content of whiteboards can be part of multiple activities, often collaborative and what whiteboards are used for is very content dependent. Mynatt refer to whiteboards as *working spaces* rather than *production spaces*.

3 The Interviews

To get a better understanding of actual use of whiteboards we conducted a series of situated open-ended interviews applying what we refer to as "hit-and-run ethnography".

Table 1. The type of whiteboards the interviewees describe they use. Office whiteboards are indicated personal/shared when they are located in a personal office but used collaboratively with colleagues in extended time periods. The majority of the interviewees describe public whiteboards in meeting- and classrooms hence these are omitted from the table.

	Office	*Laboratory*	*Other*
Interviewee 1	Personal	-	-
Interviewee 2	Personal/Shared	-	-
Interviewee 3	Personal	-	-
Interviewee 4	2 x Personal	-	-
Interviewee 5	Shared	-	-
Interviewee 6	-	-	Shared/Public
Interviewee 7	Shared	Shared	-
Interviewee 8	-	-	-
Interviewee 9	Personal/Shared	-	-
Interviewee 10	-	Shared	-
Interviewee 11	-	Shared	-
Interviewee 12	Personal	Shared	-
Interviewee 13	Shared	-	-
Interviewee 14	-	-	Shared

The interviews were conducted at the campus of Aarhus University where we approached colleagues at their offices and laboratories, asking them to show us their whiteboards and participate in an interview about their use of them. We did not announce the interviews before hand. We had prepared a short interview guide and a flyer informing about our project and us. We visited the departments of Physics, Mathematics, Geoscience, Bioscience, and Computer Science. The colleagues were positive and inviting. Only in a few cases, e.g. when a person was giving a lecture shortly, they opted out. The interviews lasted between 10 and 20 minutes.

In total we interviewed 14 people about their use of whiteboards, all fulltime employed at Aarhus University. We initially asked them to describe the whiteboards they used in their daily work.

Table 1 summarizes the types of whiteboards the interviewees described they used. Interviewee 6 mentioned a shared semi-public whiteboard in a hallway coffee lounge, and interviewee 14 mentioned a shared whiteboard onboard of a marine biology research ship (both indicated as other). Interviewee 8 was unique in reporting that he didn't use whiteboards at all in his daily work except occasionally for teaching. Interviewee 10 and 11 were interviewed in their laboratories, while the rest in their offices. *None* of the interviewees mentioned using electronic whiteboards when we asked about which whiteboards they had in their work environment, or when we at the end of the interview asked them about what they would want whiteboards to be in the ideal world.

3.1 The Use of the Whiteboards

A number of our interviewees used whiteboards in a very traditional fashion. The whiteboards of interviewees 1, 4, 7 and 9 were used with math heavy notation, typically collaboratively with colleagues or students discussing a proof of a theorem, a mathematical argument or data analysis (example in Figure 1). Interviewees 2, 3 and 5 used their whiteboards for traditional meeting activities such as project planning or paper outlining. Interviewee 12 used it purely personally and kept very neat and aesthetically pleasing notes on the board representing ongoing work. Interviewee 13 shared a whiteboard with his colleague and office mate. The whiteboard was used to represent ongoing experiments with notes and printouts of plots held by magnets. The whiteboards described by interviewee 10 and 11 exhibited the most elaborate use. The whiteboards were located at experimental setups in a physics lab and displayed information relevant to ongoing experiments and the equipment. The whiteboard of interviewee 11 was extremely dense with information and we were told the overall structure of the information on the whiteboard hadn't changed for more than 6 years, while it was updated on a daily basis (Figure 2).

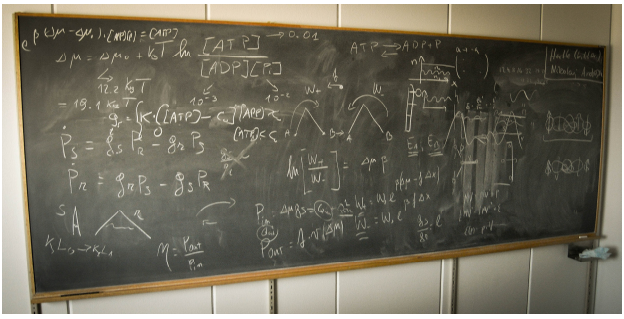

Fig. 1. The "whiteboard" of interviewee 9, a theoretical physicist

Fig. 2. The whiteboard of interviewee 11 located at an experimental setup in a physics laboratory

Two categories of use of whiteboards emerge from the interviews. The whiteboard as *information container*, where the main function is to show information with some purpose, and as *graphical workspace* where the main function is to develop, or transform something. We saw two aspects of the content of a graphical workspace; as *ephemeral externalization*, supporting collaborative creativity and problem solving, or as *in production*, where the results of the activity is seamlessly sustained onto stable physical form, a product. We saw information displays that could be described as simple information *storage*, information displays that aggregated *knowledge* and information displays where the content was part of a *coordination* of activity or *governance* of surrounding state.

Interviewee 9, who used the whiteboard for theoretical physics (as seen in figure 1), described how what was written on the board was not always directly post-processed e.g. in a written note but instead the result was a new understanding. Interviewee 7 described how he would write out an equation from a textbook to review and discuss it with students. The content was in both cases ephemeral; after it had been written and discussed it could be deleted. In both cases the board is used as a graphical workspace, but the pattern of usage is as *ephemeral externalization*. Interviewee 9 describes how something that is written on the board *"… either it's something that is clarified and then it is stored up here (points at his head) until it is written in a paper. Otherwise the idea is elaborated on a piece of paper, where it can turn into a note on 2-3 pages …"*. Interviewee 12 described how notes on a whiteboard could later be used and written into a paper, and interviewee 3 described how papers would be outlined and project plans sketched on the board that could feed into actual papers and project plans. The transition was either handled by manually writing down notes from the whiteboard or more often by taking a photo with a smartphone and then typing up the notes at a later time. Here the content of the whiteboard represents an early stage of a product of some sort. Hence we refer to this use pattern as being *in production*.

In the case of interviewee 10 and 11, the whiteboard was used as an information display, however, displaying information that in some form was available other places (equipment displays or laboratory notebooks) yet it was made readily available on the whiteboard near the experimental setup. Hence, we refer to this as *knowledge aggregation*. Interviewee 10 explained: *"… so I guess we kind of mostly use it as a… mostly for reference and also for keeping track of some, where samples are in the equipment. So eh, yeah obviously we have labbooks, but then as the years go on we have a big stack of these and somewhere hidden in them is some very important information like these diagrams (points to the whiteboard) [unintelligible] and eh, it becomes really a pain to look for these things in the labbooks"*. Figure 2 also displays information pertaining to the state of the experimental setup, e.g. the placement of samples in compartments and it is essential that when the whiteboard is updated, so is the physical setup and vice versa. We refer to this aspect as *governance*.

The other type of information display is using the whiteboard for storing information – this may be phone numbers (interviewee 7) or a list of who has borrowed books from the bookshelf (interviewee 1). Interviewee 2 describes how currently on his board is a project brainstorm that was written 3 weeks earlier in a meeting, and that they continuously have returned to and extended in follow-up meetings. Hence, the whiteboard was used in a combination of production, information storage and coordination of a project activity. This implies that the categorization is not static. In fact we also observe how an equipment sketch on interviewee 11's whiteboard started out as an ephemeral externalization but remained stored on the whiteboard to explain newcomers about the equipment. This is very well in line with Tang et al.'s (2009) observations that whiteboards serve as means for transitioning between activities.

The electronic whiteboard systems in the literature (see section 2) have an almost exclusive focus on the whiteboard as a graphical workspace used in production. While this is an important aspect of the use of whiteboards we see in our interviews that it is not the complete picture. The clinical electronic whiteboards (Bardram 2010) are an exception in that they are information displays used by the clinical staff for governance of e.g. the state of a ward and coordination of clinical activities.

4 Demystifying the Whiteboard

To demystify and conceptualize the use of whiteboards, we will turn to concepts derived from Activity Theory. An important characteristic of the whiteboard is that content is not transferred seamlessly to and from it. Bertelsen and Bødker (2002) discuss design of computer artifacts in terms of *discontinuities*, pointing to three classes of discontinuities. The first one is between experience and desire and is the fundamental discontinuity in design between what exists and has been experienced, and what is to become. In the context of whiteboards and electronic whiteboards the two next discontinuities are mostly relevant. Between parallel rooms, is a discontinuity between differing perspectives on, or purposes of, an object (or artifact). A representation on a whiteboard, typically has an existence before it gets onto the

whiteboard as well as after. On the whiteboard emphasis may be on finding new solutions, while when the representation later is transferred into a document aimed to be shared and archived, exact conformance to conventional formalism may be the most important aspect of the representation. Between interpretation and implementation is the particular discontinuity between a formalized representation interpreted in a social setting, and the same representation when executed by a machine. In the later case we are dealing with strict causal relations between representations and changed state of a part of the world whereas the representation prescribes more loosely in the former. *"It is the discontinuity between de-contextualised principles and concrete historical practice; between artefact and situation; between technical implementation and cultural interpretation."* (ibid pp. 410-411). These discontinuities are seen as important resources that should not merely be bridged but rather be maintained and cultivated in design. And we will in the context of this paper argue that support for persistent discontinuity is an important quality of the whiteboard.

Historically, information technologies have blurred and removed discontinuities. While it is a clear advantage of modern computer based text production tools that separate typesetting and re-typing of manuscripts from version to version can be avoided, it is also problematic that parts of a text, with early phrasings etc. can survive from an early draft to the final publication.

When using a whiteboard something is actively transformed into writing/drawing on the board. This transformation is discontinuous. An idea takes an initial form, a formula from a textbook is rewritten and transformed into joint basis for a teaching situation, and the terrain of a problem at hand is sketched for the purpose of the situation. After the whiteboarding event, results may be carried away in memory, or they may be transformed into notes, or even refined and turned into a product for further processing. In all cases, again, we see a discontinuity.

There is a fundamental discontinuity between parallel rooms when using a white board; you go into the "whiteboarding room" where there are limitations to how much detail you can have, and there are limits to how much damage you can make because everything will be transformed later. The discontinuity between interpretation and implementation is also important to understand in relation to the whiteboard. When working with mathematical formalisms, several interviewees (e.g. 4 and 9) would use ad hoc notations hoping that they were not taking too many "liberties". Some time that would work and some times it would not. The important thing to observe is that the discontinuity between the writing/sketching of free ideas on the board and something that conforms to the formalisms, or is a direct implementation outside the board is what enables creativity and exploration on the whiteboard.

Thus, in design of electronic whiteboard systems, it is important to also maintain or redesign the right discontinuities.

Our classification of whiteboard uses can be rephrased in terms of the relation to the surroundings and the involved discontinuities.

Information storage does not depend on maintained discontinuity. A phone number, or information of who borrowed a book, should be complete.

Ephemeral externalization involves a quite abrupt purpose-driven discontinuity into the whiteboard, where only parts of formalisms or even ad hoc formalism is noted and worked with, similarly there is most often a substantial amount of processing following the whiteboarding session.

In the cases of *in production, coordination* and *governance* the relation in and out of the whiteboard is more complicated because both cases depend also on some degree of continuity. For these cases we need to understand the dual character of whiteboard writing as being both objects worked on and tools mediating action on something inside or outside the whiteboard.

Mynatt (1999) refers to the whiteboard as a working space rather than a production space. While we agree with Mynatt to a certain degree, the whiteboard can in fact be part of a production space, but what is written or drawn on the whiteboard almost never is the final product; an outline of an argument has to be written into actual text and a sketch of a figure has to be reproduced for print. This is very different from most modern computing where we constantly work on the actual "products" whether written documents, graphics, presentations or videos without these discontinuities.

In Activity Theoretical thinking the driving force for development are contradictions. Activity systems are permeated by contradictions, e.g. between the tool at hand and the object of work. Thereby, contradictions are constant sources of instability and development (Bertelsen & Bødker, 2001). In understanding collaborative inscription in artifacts Zander (2007) introduces the concept of *syntonic seeds* as inscriptions sublating contradictions by negating and containing them. Thus, the reminders placed around the lab of interviewee 11 could be understood as memory aids negating the contradiction between what should be collectively remembered about the experimental setup and the settings necessarily being hidden behind insulation, yet preserving attention to this contradiction. This kind of containment resembles how contradictions are maintained across a discontinuity. Interviewee 9 kept a sketch of an argument on his whiteboard to remind him to continue the discussion, thereby negating the insufficiency of attention.

According to Tang et al. (2009), Mynatt (1999), and our own studies, whiteboard content is typically pivotal in a number of activities. Tang et al. describe how a team-leader's whiteboard mediates planning, awareness and team discussions, similar to how the whiteboard in the laboratory of interviewee 11 serves as a means for representing the ongoing experiment, documenting it, and communicating the praxis in the laboratory. In the case of the team-leader the content of the whiteboard, a project plan, sublates a contradiction between a normal human's mental capabilities and the complexity of a big project, but at the same time it may sublate the contradiction between her and co-workers understanding of the progress in the project. With inspiration from the concept of syntonic seeds (Zander op cit.), we identify three key aspects of the whiteboard.

- The writing on the whiteboard has a double character containing (and possibly sublating) a contradiction between the form of representation on the whiteboard and outside the whiteboard.
- The contents is simultaneously and/or sequentially a mediator in one or many activities and an object of one or many activities

- Contents often oscillate between being a mediator and object of activity. To return to the previous example; the project plan oscillates between being the object of the team-leaders documentation of the project and being a mediator in discussion with the team.

Mynatt (1999) observes that the content on whiteboards is heavily context dependent. This means, in our vocabulary, that the content exists in its relation to something outside the whiteboard – something that is corrected, controlled, externalized. The content on the whiteboard is most often serving its purpose due to the discontinuity between whiteboard and other representations. The whiteboard in figure 2 may serve as nothing but an archeological artifact if the lab is shut down, only hinting at the kind of activities that took place in the lab. To move the content beyond the whiteboard requires re-mediation or requires the content to be de-contextualized e.g. when taking a sketch of an argument from a whiteboard and writing it into a paper.

The whiteboard is a *discontinuous artifact*; information has to be remediated both to and from the board. This is both a strength and a weakness. It is a strength as it provides an opportunity for critical reflection on what has been produced or is about to be (re)produced on the board. It is a weakness when the discontinuity is a source of error, e.g. when the whiteboard is used for governing critical state but updating it is forgotten. It is furthermore an inherent weakness that the discontinuity to and from the board may be a laborious for the user as it involves reproduction, and given that the content is context dependent; information may be lost in this process (e.g. when photographing and wiping a whiteboard clean after a meeting and not processing the content into written notes or similar right away).

As for electronic whiteboards there is a significant difference in whether the board is a self-contained computer or it is merely a display and input device for a personal computer. The latter is the current way of using electronic whiteboards; a teacher connects her personal computer to the electronic whiteboard in the classroom and uses its capabilities to make ready-made material interactive and dialogical e.g. through highlighting, annotation or hide and reveal (Mercer et al., 2010). This approach bridges the discontinuity to and from the whiteboard; content prepared on the personal computer can directly be presented on the electronic whiteboard and what changes are made during a presentation can be stored immediately and be distributed and reused. However, the electronic whiteboard goes black when the teacher disconnects the computer and leaves the room, and data is not shared beyond the teacher letting the students manipulate the content she makes available on the board for a limited amount of time.

5 Themes for Design of Future Electronic Whiteboard Systems

In this section we outline four themes that we find important to understand and consider in relation to the design of future electronic whiteboard systems. We discuss them in the light of our empirical findings, the literature and the conceptual basis of activity theory. The themes we want to point to are lifecycle of content, transition into

and out of whiteboards, the relation between formalism and immediacy, and the impact of digital materiality.

5.1 Lifecycle

We saw a variety of content lifecycles on the whiteboards. Somebody would write contents onto the board, and this content would serve a purpose for a while until it finally would die by being whipped out or simply loosing its meaning. Some of the whiteboards we saw had data on them that had been there for a long time, but the general picture was that data lived a shorter time.

In the office of interviewee 9, the whiteboard had short lifecycles by functioning mainly as an ephemeral externalization during collaborative problem solving. According to the interviewee, writing was only left on the board after a session, because he would not spend the effort to erase it. However, writings from a session that did not lead to the desired solution weeks earlier were still "surviving" on the board, possibly because they now served as a continuous reminder about this unsolved problem. In that way a seamless transformation from ephemeral externalization to a kind of information display had taken place.

A much longer lifecycle is seen in the case of the lab whiteboard of interviewee 11. It has been persistent over years, with a layout that has been added to over time. It is used for making things explicit, for coordination, and for conveying rules and established practice, as well as for recording and sharing the state of the ongoing experiment. Learning to work with the whiteboard is important when new students and new colleagues get to learn to work in the lab.

At the state of the lab whiteboard as we saw it, it was mainly a container in all the three aspects of that. When we visited the lab the whiteboard functioned as container in all the four forms. It was mostly for governance and coordination, by displaying important parameters and states of the experimental setup, rules of conduct and relevant constants. It was, to a large extent knowledge display by the presentations of experimental set up and overall mindset of the lab. To some extent it was information storage where parameters were stored. In a longer perspective, contents on the lab whiteboard had evolved or oscillated between the different roles described in 3.1. An example is the black drawing approximately in the middle of figure 2. It was originally created as an ephemeral externalization when explaining the experiment to a visitor, but it remained on the board as a knowledge display.

Whiteboard use is constantly reconstituted and negotiated. In particular it is important to observe the seemingly seamless transition of content between the roles. The physical form remains the same but the status and interpretation changes radically, and thereby the flexibility depends on the lack of hardwired formalization leaving openness to interpretation.

The lifetime of whiteboard contents seems to be characterized by seamless transitions between interpretations. However, most contents die after a while, and has something been deleted it can never return to the whiteboard in the exact same form.

5.2 To and from

We argue above that the whiteboard offers two main discontinuities that are fruitful for a broad range of purposes. The whiteboard normally has no structure, no limitation and no support for interpretation. When content gets written onto the whiteboard a process of selection, abstraction and reduction takes place and a mutual understanding between collaborators is established. In the same way, processing takes place when information is transformed out of the board. A horizontal line can mean the duration of a project, or something else. In the context of a specific session the meaning is sufficiently clear, but after the session it will depend on participants memory, interpretation and mapping back onto a more universal format. In other words, a process of *de-contextualizing* is involved with the transfer out of the whiteboard. Such de-contextualization can happen by writing the work on the whiteboard into some formalized notation, or by transforming it into coherent prose. It is important to acknowledge the value of these discontinuous transformations even if they seem to be time consuming and a source of inaccuracy.

In some cases a formal link between whiteboard content and the surrounding world can be established. In the lab of interviewee 11, we saw how the experimental setup was recorded on the board. Particularly, we saw the governance aspect of information containers, and to some extent the knowledge container could be extended into a live data connection. In the same way, it could make sense to offer support for the analysis of data sets on the electronic whiteboard. Conventions for the linkage between data in the electronic whiteboard and their counterpart in other media have to be settled for each area of application. In some cases it may be fruitful to have live data in the whiteboard. In other cases data should be static.

At the other extreme we saw examples of knowledge containers, serving merely as reminders, being constructed by mounting paper onto the whiteboard, thereby circumventing the discontinuity into the whiteboard. E.g., interviewee 2 had an early version of a project plan mounted on his board, interviewee 14 had a print of the first data from the experiment he and the colleague in the office were running.

Many of the interviewees reported that they would take pictures of their whiteboards, typically with their phone cameras. It was not clear, however, how these snapshots were used beyond being backups, or records for the unlikely case that the content could be used later.

5.3 Immediacy and Formalism

It is important that the installation is ready and running. Otherwise the overhead will make users go to other media to support the work they want to do. We saw good examples of this in the literature (e.g. Pedersen 1992). In particular for the large part of the interviews where uses could be characterized as ephemeral externalization, it seems important that there is no startup time, otherwise it would not be feasible when they “just had to scribble something down…”.

This need for simplicity and the reluctance to accept any overhead was expressed by Interviewee 11 when he wished for a better organized layout of the lab whiteboard

(fig 2). He did not hesitate to explain principles for a better layout. Still he did not seem to be willing to spend one hour re-drawing the board. *"Physically, so there is no reason why, so if I had time I would move things around in a different way because like there are things that you need more frequently and you would like to have them there and things that you have less frequently you would like to have them like on the corner or somewhere else."* (Interviewee 11, #00:14:28-5#)

In situations where a formalized notation exists, it would make sense to support the transition from ephemeral externalization to graphical workspace in production more systematically like in the Knight system (Damm et al. 2000). This transition could also be supported simply by supporting the transformation of free form graphics into structured graphics for further processing.

5.4 Digital Materiality

In ordinary whiteboards content is bound to a physically existing board. With electronic whiteboard systems it would be possible to move the content around between physical boards, as well as replicating it between boards. While portable workspaces could be an advantage, it is worth drawing attention to the way in which limitations, context dependency, and discontinuity are important features of the whiteboards, as we know them. Content on whiteboards continuously change roles and evolve over time–hence the traditional approach of well-defined file formats of digital data may not make sense. It may be necessary to revisit ideas like compound documents (as OpenDoc (Macbride & Susser, 1996)). Yet supporting governance of external state (e.g. something simple as controlling and displaying the angle of a motorized laser in an experimental setup through a widget) from the whiteboard would bring the digital whiteboard content beyond just being documents.

6 Design Principles to Explore

In the following we present three design principles for future electronic whiteboard systems.

6.1 Installation, Not Application

We observe that all our interviewees have idiosyncratic, yet over time established, ways, of using their whiteboards. Their whiteboards are physically bound to rooms where certain activities take place. If a goal is to maintain the immediacy of the physical whiteboard when creating an electronic counterpart we discourage thinking of the board as a general-purpose computer with multiple applications. An important reason for that is the general reluctance to spend time on setting up and negotiation observed in the literature and in our studies.

We suggest an alternative design strategy based on the concept of *installation*, meaning that the software running on the electronic whiteboard is permanently configured, and that it supports seamless invocation of the active components.

This strategy is useful for supporting specific praxes where institutionalized formalisms exist. Both theoretical physicists and software architects need boards for sketching, yet the kind of augmented support they could benefit from differ. The software architects may want support for turning free from drawings into formalized diagrams with possibilities for grouping and auto-rearrangement functionality. The theoretical physicists, on the other hand, may want handwriting detection and notation completion.

People dedicate certain whiteboards and certain areas of whiteboards to specific kinds of activities, and the equivalent should be possible in an electronic counterpart. This is the approach of the medical electronic whiteboard systems as described e.g. by Bardram (2010). The tools and information available on a board in an emergency ward differs significantly from what is available in the patient ward since the activities the boards are embedded in are different. Tang et al. (2009) implies a similar design philosophy of providing the users with functional primitives and using the contextualized nature of the whiteboards to decide which to use. However, it is an open question who will take care of the (re)configuration. In the case of the medical electronic whiteboards it is handled by trained consultants with insight into the clinical praxis, however such an approach would not necessarily be possible or economically feasible in a research setting.

The concept of installation, in particular the whole economy and division of labor around creating, installing and updating, should be investigated further and experimented with.

6.2 Supplement and Augment, Don't Replace

It is difficult to see how an electronic counterpart can reach the immediacy and ease of use of a physical whiteboard especially when it comes to supporting rapid ephemeral externalizations. Yet, as we see in our study, what was perceived to be an ephemeral externalization may change its role and become something more permanent. In the physics laboratory of interviewee 11 it would be meaningful to have a combination of a traditional whiteboard with a capture mechanism alike ReBoard (Branham et al., 2010), together with a digital surface for displaying sensor readings or storing and displaying (digitalized) drawings made on the physical whiteboard. An interactive electronic display is meaningful in the case where the information have a governing nature, since it will allow to electronically enforce a mapping that otherwise had to be done by hand.

6.3 Embrace Discontinuity

Discontinuity in some situations is a strength, yet remediating content from the whiteboard is laborious work. Our interviewees frequently photographed whiteboards to persist the content. Our hypothesis is that photographing the content of a whiteboard for later remediation may be a disservice to one self, because knowing that the content is persisted safely induces a reluctance to actually deal with it. We encourage exploring the design space of a capture mechanism of physical whiteboards

where captured content only is stored for a limited amount of time, and the user is reminded that she has unprocessed whiteboard content waiting to be remediated. This means creating artificial limitations on the medium, which we believe is necessary to maintain one of the central qualities of a whiteboard namely that when content is erased it is gone.

7 Conclusion

Returning to Mark Weiser's three devices: Tabs, pads are here but they required a new software ecology to be successful – one would assume the same of the last device, the wall size device.

In this paper we have reported on a study of whiteboard use in a scientific research setting. We have observed a range of different types of use, and analyzed how discontinuity is an important aspect of much successful use of whiteboards. We have analyzed our findings based on activity theory, and the existing literature and identify 6 roles contents on whiteboards can have.

Our main finding is that the discontinuities in and out of the whiteboard can be a strength. This finding implies that the focus on seamless integration seen in large parts of the literature may need to be modified or supplemented by context specific concepts of the value of breaking the continuity of objects being worked on.

We have pointed to four themes to consider in future design of electronic whiteboard systems. Firstly, we have discussed how content on whiteboards shifts seamlessly between functions and roles during its *lifetime*. Thereby, flexibility and openness to adaptation of notation is important. Secondly, we point to the transformations of content *to and from* the whiteboard, in particular we point to how content is contextualized on the whiteboard and how transferring it out of the board involves de-contextualization. Thirdly, we point to the combined issue of *immediacy and formalism*, emphasizing that a most important aspect of the whiteboard is its constant availability, and that we will have to take that kind of immediacy into account when supporting formalized notation. Finally, we draw attention to the necessary consideration of what kinds *digital materiality* to support.

We conclude the paper by introducing three principles to explore in future electronic whiteboard systems. Firstly, we suggest that software on electronic whiteboards should be understood as an *installation*, i.e. a stable configuration that is readily available and only changes with very long intervals. Secondly, we suggest that designers should aim to *supplement and augment* the existing non-electronic whiteboards, rather than risk loosing the intricate patterns of use. Finally, we suggest that designers should aim to *embrace discontinuities* offered in the use of non-electronic whiteboards, and distinguish between unwanted and wanted ones.

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