Building boundaries on Boundary Objects: A Field study of a Ubicomp tool in a Design Studio

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Abstract In this paper, we provide the results of a field study of a Ubicomp system called CAM (Cooperative Artefact Memory) in a Product Design studio. CAM is a mobile-tagging based messaging system that allows designers to store relevant information onto their design artefacts in the form of messages, annotations and external web links. From our field study results, we observe that the use of CAM adds another shared 'space' onto these design artefacts – that are in their natural settings boundary objects themselves. In the paper, we provide several examples from the field illustrating how CAM helps in the design process.

1 Introduction

Boundary objects are objects which are both plastic enough to adapt to local needs and constraints of several parties employing them, yet robust enough to maintain a common identity across sites. …The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds.

<div align="right">Star and Griesemer (1989)</div>

Over the years, CSCW research has established notions such as boundary objects (Star and Griesemer, 1989), common artefacts (Robinson, 1993), common information spaces (Schmidt and Bannon, 1992) and organizational memory (Ackerman and Halverson, 2004) to refer to shared informational objects that can be used by different groups for their own purposes. In the design studio context, design artefacts such as drawings, sketches, collages, storyboards and physical models can be seen as boundary objects, as these help in communicating and establishing a common ground between designers. When design ideas are communicated through these design artefacts, each artefact represents a space of possible interpretations. Within these spaces the designers can negotiate over further developments to the design (Eckert and Boujut, 2003).

With a goal of developing a Ubicomp technology (Weiser, 1991) to support communication within the design studio culture, we carried out ethnographic fieldwork in design studios (Vyas et al. 2008; Vyas 2009; Vyas et al. 2009a and Vyas et al. 2009b). Building on the results of our fieldwork, we have developed and deployed a Ubicomp technology called CAM (Cooperative Artefact Memory). CAM is a mobile-tagging based messaging system that allows designers to cooperatively store relevant information onto their physical design objects in the form of written messages, annotations and external web links. Using CAM, design artefacts could have an individual digital profile on the Internet where relevant information can be added, updated or changed by designers. In other words, CAM allows designers to build an added layer of communication onto these boundary objects, in full, it builds "boundaries" on boundary objects.

We have studied the use of CAM in a Product Design studio for three weeks, involving three different design teams. The purpose of the field study was to understand the role of augmented design artefacts in supporting creative work. Our results show that CAM was used not only for communication and coordination but it also facilitated designers to appropriate their design artefacts to be explorative, playful, and evocative – supporting creative aspects of design work. In the rest of the paper, we will briefly describe our ethnographic fieldwork in design studios and point out important design implications. We then describe CAM and provide the details of our field study. Next, we describe our findings and using examples from the field show how CAM facilitated design artefacts for supporting creative design practice.

1.1 Ethnographic Fieldwork

In our ethnographic fieldwork, we studied a mix of professional and academic design environments over a period of 8 months, with nearly 250 hours spent in the field. Our ethnographic approach was informed by ethnomethodological orientation (Randall et al. 2007). We intended to understand the everyday work practices of designers, methods and procedures they use to support their work and the resources they use to make sense of their design world. We used naturalistic

observations, contextual interviews and video recorded collaborative design sessions of designers and design students. Overall, we explored three major themes of collaborative practices that designers frequently apply: *externalization*, *use of physical space*, and *use of body* (Vyas et al. 2009b). Our results show that material and visual nature of design practices support coordination through the use of physical design artefacts (Vyas et al. 2008). We explored the role of physical surfaces of design studios in supporting creative design practices (Vyas 2009). Moreover, our results also show that design artefacts play an experiential role (Vyas et al. 2009a) in supporting designers' exploration and communication activities. Figure 1 shows a few examples from the fieldwork.

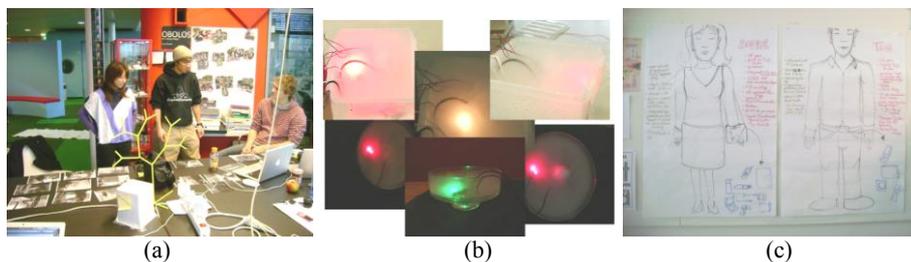(a)   (b)   (c)

Figure 1: Examples from the fieldwork. (a) Use of physical space, (b) Exploring and exploiting material richness, and (c) Personas as design artefacts for communicating design ideas.

1.2 Design Implication

From the fieldwork, we develop four main implications to design a Ubicomp technology to support designers' everyday work.

- *Artefact-mediated Interaction*. Designers develop a multitude of design artefacts in the form of paper sketches, drawings, physical models and so on over the course of their design projects. The materiality, stigmergy, public availability and knowledge landmarks left on design artefacts help in establishing and supporting communication between designers. We believe that a Ubicomp system should be able to incorporate these artefacts (at least partially) into its design space so that artefacts' experiential and natural qualities can still be exploited by designers.
- *Utilize Spatial Resources*. The way designers keep these artefacts and organized them in their workspace affects their work communication, organization, and coordination practices. It is this spatial flexibility of, for example, sticking sketches and drawings on a shared office wall that allows designers to discuss, criticize and explore new possibilities of their design work. In order to provide technological support for spatial flexibility, we need to think beyond desktop computers and involve the spatial aspects of design studios.

- *Creative Explorations*. We observed that designers spend a considerable amount of time in exploring new ideas and concepts by utilizing different techniques and design representations. Our fieldwork suggests that for creative explorations there is a need for a technological infrastructure that allows designers to collaboratively generate innovative ideas.
- *Social Flexibility*. We observed that the use of design artefacts and physical space allowed a level of flexibility in designers' everyday social interactions. This helped designers to discuss things anywhere and anytime. We believe that a Ubicomp system should not impose a social order onto the designer, on the contrary it should allow designers to bring about and establish new practices for design.

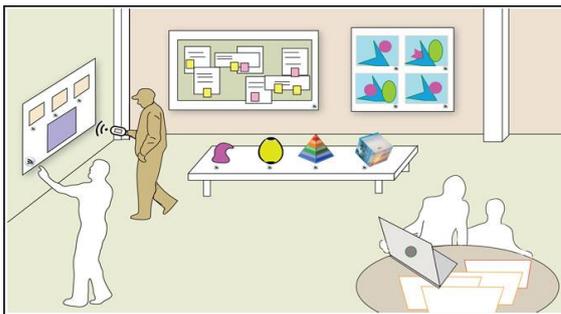# 2 CAM: Cooperative Artefact Memory

2.1 Vision

Figure 2: A vision for design studios.

Following the design implications, we developed a vision for a ubiquitous computing system in design studios, as can be seen in Figure 2. According to this vision, using mobile devices and barcodes or RFID tags design professionals can collaboratively store relevant information onto their physical design artefacts (e.g. sketches, posters, collages, post-its, physical mock-ups, prototypes) and can access this information though their mobile devices. Designers can exchange ideas and collaborate via these design artefacts, hence supporting collaborative work in ubiquitous ways. The relationship between these design artefacts (i.e. how a design sketch is connected to a physical model and a prototype) can be established via the technology. By this vision, design artefacts would eventually serve as a "memory" for all the events within a design project.

2.2 Technology

Figure 3: CAM running on an iPhone (a); Reading a design sketch using TagReader client (b).

CAM uses low-tech, off-the-shelf tools such as Microsoft's mobile-tagging application TagReader, 2D barcodes, a JAVA web server that uses Twitter API and camera based mobile phones. Using CAM, design artefacts can have an individual digital profile on the Internet where relevant information can be added, updated or changed by all designers. CAM has a very simple interface (Figure 3a): "Check Updates" allows viewing of all the messages about a design object and "Post Message" allows writing and sending a new message to it. The central idea in CAM is that it associates each 2D barcode to a Twitter account. Hence, when one reads a 2D barcode attached to a design sketch (Figure 3b), for example, one can read a set of messages about the artefact in the Twitter interface.

   In a typical usage scenario, a designer can attach a 2D barcode to his/her physical design object and write messages to the barcode via the TagReader client. Whenever a designer writes something to a barcode, the message is sent as a Tweet to that barcode's Twitter account. Similarly, when one reads a barcode, he/she would see a log of Tweets in the form of messages, annotations and comments about that particular design object. In a collaborative design project, this would eventually lead to a collection of Tweets written by different group members that will provide information about different design activities in the project.

3   Field studies of CAM

In a Product Design studio, we studied the use of CAM over three weeks. We asked three student design teams to use CAM for their one week long design projects. Table 1 shows the details about our design participants and their design projects. Our design participants knew each other very well and were familiar with each other's individual design expertise and qualities. Also, they had all been in comparable group projects before, and were aware of the issues that might be important in a group project. In the current design projects we wanted to

investigate possible ways of using CAM and explore how useful it can be for supporting creative work.

Design Team #	Educational Year	Design Subject	Number of Participants
1	1st Year	Remote Control	4
2	3rd Year	Alarm Clock	4
3	5th Year	Intelligent Lamp	4

Table 1: Details of participants

For the study, we gave each of the participants a camera-based smart phone. We also gave them 2D barcodes generated from Microsoft Tag, and we created several temporary Twitter IDs. They were first given a demonstration about how CAM works and how they could send and receive messages. They were asked to use CAM during their project as a tool to store information onto the design objects. Our intention was to use CAM as an explorative tool to learn what role design objects play in supporting creative work. Hence, we completely left it to the design teams to use CAM in their preferred ways. They were only encouraged to use CAM as much as possible. We also encouraged them to use the Internet from the mobile phones. We videotaped their design sessions throughout the course of the projects, and we interviewed all team members at the end of the sessions. We collected the logs of the 2D barcodes. We also analyzed the messages to individual design objects from their Twitter logs.

4 Results
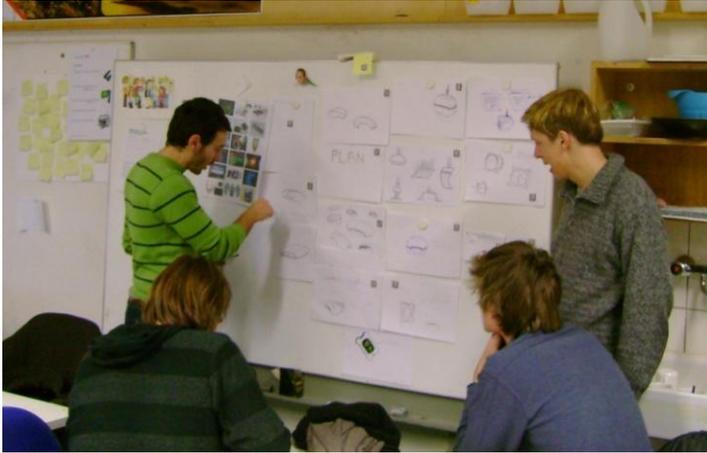
4.1 How CAM was used…

Figure 4: An example design session. Tagged sketches are kept on a white board.

As can be seen in Figure 4, design teams integrated CAM in their everyday design practices. During their design sessions, designers attached 2D barcodes to their design sketches, physical models, collages and Post-it notes and using CAM they added annotations, messages and other relevant information to these artefacts. Since all the team members had access to the Internet through the mobile phones, they also added web contents to their messages.

An example of a design artefact can be seen in Figure 5a. The design sketch describes a conceptual alarm clock that is augmented by a 2D barcode. The creator has added details about the design of the alarm clock on the 2D barcode and subsequently his co-workers have commented back on his ideas. When one reads the 2D barcode on a mobile phone, one will be able to see a complete log of comments as shown in Figure 5b. This log shows the dialog that took place between co-designers.
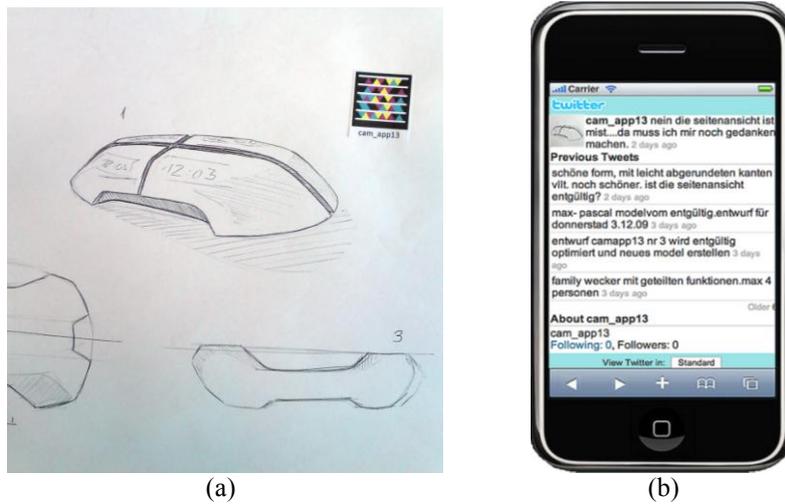
<center>(a)   (b)</center>

Figure 5: Design sketch of an alarm clock (a) and the log of messages sent to the design artefact.

It was observed that not all the design artefacts, developed during projects, were tagged with a 2D barcode. Designers tagged their artefacts only when they wanted to show or communicate their ideas to others. Using CAM they would discuss the artefact by writing and reading messages from the Tweet log.

During the interviews we received several encouraging comments from the design teams. Here are a few comments:

> "CAM makes the sketch interactive not only because of the details of the sketch but the communicational support it provides us, because all the team members can read what others have written about a particular design object."

> "If you stand in front of these things [design artefacts] and scan everything, it helps to think about and understand what's going on in the project."

In addition to its communication functionality, CAM was described as a tool for reminders, triggers, notices, exhibits and resource sharing. The use of CAM was also seen as a tool for storing "minutes" of a particular design session, as relevant information can be read readily from the artefacts. A team member suggested:

> "These 2D barcodes provide immediate access to the information that you want without a need to switch on the computer."

A few of the design students suggested that design artefacts with 2D tags can also be seen as archives for future projects.

> "If I have to design a new alarm clock again, I can go back and retrieve all the information that is stored and see how I can continue with that."

> "It is important to collect a kind of archive of your ideas. So, you can always retrieve all sketches and all the ideas so that you can include what you and others have written into the work."

Between the three design teams a total of 53 design objects were tagged with 2D barcodes, 197 messages were sent to these objects and these were read 488 times in total. The team-wise distribution is presented in Figure 6. Our approach

<center>287</center>

also allowed us to analyze the use of 2D barcodes. Figure 7 shows a graph that shows the number of scans per design artefact (with 2D barcodes) from one of the design projects. In this project a total of 19 design objects were tagged with 2D barcodes and in total they were scanned 133 times. The tag that was scanned most (15 times) was a Planning object. This kind of information helps in understanding which design artefacts had more collaborative importance than others.
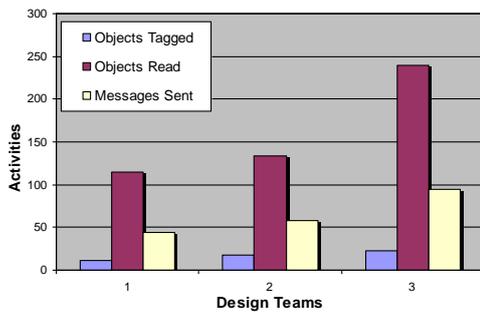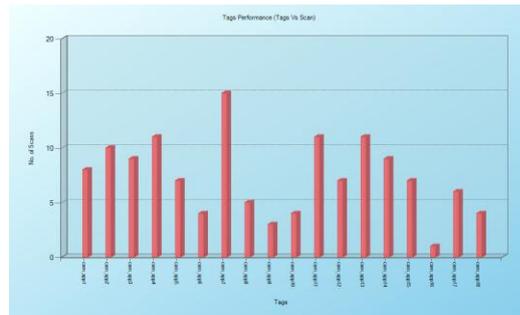

Figure 6: Team-wise usage of CAM over three weeks

Figure 7: Usage of 2D barcodes during design project 2. (Generated by Microsoft Tag)

4.2 Tagged Artefacts

(a)   (b)   (c)   (d)
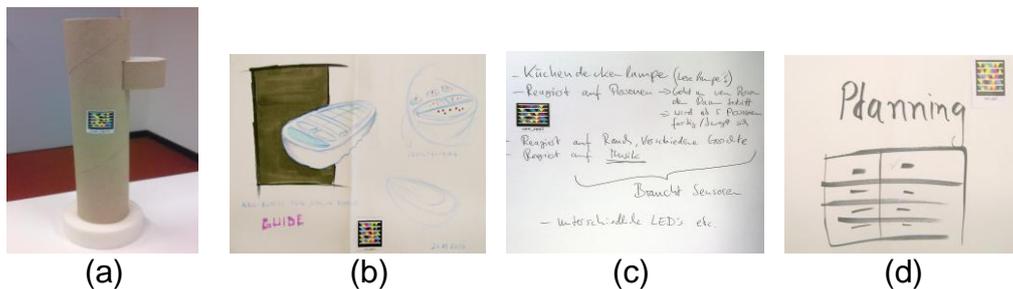
Figure 8: Different types of design artefacts tagged during design sessions. (a) a physical model of an intelligent lamp, (b) a sketch of a remote control, (c) a written note, and (c) a reference object for planning.

From the fieldwork, we observed several types of design artefacts being tagged to support different design activities. We explored four types of artefacts tagged: 1) Physical objects, 2) Sketches, 3) Notes, and 4) Reference objects.

The *physical objects* are three-dimensional objects or models made from wood, foam or cardboard that product designers create once their design ideas become concrete. Figure 8a shows a model of an intelligent lamp that was tagged with a 2D barcode. The paper-based *sketches* are the representations of design mainly used for exploring and communicating design ideas between co-designers. Figure 8b shows a design sketch of a remote control device tagged with a 2D barcode. The purpose of written *notes* varied from descriptions of a design artefact to a collection of brainstorming ideas. Figure 8c shows an example of a written note.

The *reference objects* are abstract, mainly pointing to a digital content. These artefacts themselves do not contain much information as such. Figure 8d shows an artefact that was created by designers to mainly create a storage point for all the planning and coordinating activities – which can only be accessed using mobile phones.

These four types of artefacts show a transition from physical, information rich artefacts to artefacts that do not contain information themselves but are references to digital contents. From the perspective of 'boundary object' theory, an important issue in this categorization of artefacts is to understand where the relevant information about design lay. These design artefacts are by their very nature boundary objects in themselves. And the use of CAM allows designers to store additional information onto the artefacts' digital profiles. If we take the example of the physical model of the lamp (Figure 8a), one can get information about its form, size and can experience other kinds of interaction with the lamp. Hence, the physical object itself can provide important information to co-designers. At the second layer, when one reads the tag, one can read information about the design artefact as described by designers and the dialog and information exchange that subsequently took place between them. If we move onto the reference object (Figure 8d), the artefact itself does not contain useful information for the design activity. However, on the second layer of boundary object, one can read information related to the planning of the project. In this case, we see the second layer of boundary object containing more useful information than the first layer of boundary object. This example is elaborated in Figure 12.

4.3 Manifestations of Artefacts

In this section, we provide different ways CAM helped in supporting design activities.

4.3.1 Design Narratives

The narration and description of design activities during the course of design projects was depicted through different Tweets that were sent using CAM. Although, the technological changes most likely lead to changes in narrative structures, these narratives do provide a clear indication of how design was carried out. An example of such a narration is described in Figure 9. Figure 9a shows a designer's annotated sketch of an intelligent lamp concept with a 2D barcode attached to it. Figure 4b shows the Tweet log of the sketch showing the description of the concept and different questions and issues raised during the course of the design process. In Figure 9b, one could read information about the size of the lamp and its functionality. Importantly, the log also shows questions and issues raised by co-workers such as: "where the lamp should be placed", "what material should be used" and "what should be its size".
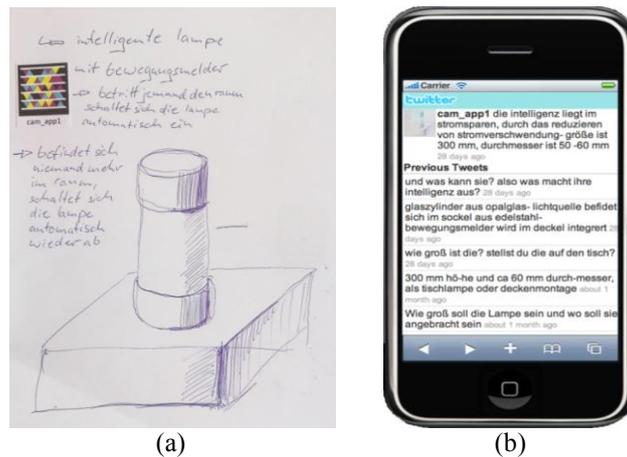
<div align="center">(a)   (b)</div>

Figure 9: Sketch of an Intelligent Lamp concept with 2D barcode (a), and Tweets sent by the co-designers to provide a design description written in German (b).

One of the important aspects of these design narratives was their 'cooperative' nature. The design narratives in the form of Tweet-logs represented different views expressed by co-designers in a particular design project. To an extent this form of interaction provided an opportunity for collaborative concept creation. The design narrations depicted in the form of Tweets provided information about the design process that was used by the design teams. When asked about what they thought of these design narrations, designers had the following comments:

> "In my opinion, this is like making a design story. Maybe not the complete story. But it has a great deal of information about the conversation that we had while we were working".

We were interested to understand how our design participants viewed the narrative support provided by CAM and how useful they found them for their ongoing design activities. The narrative characteristic supported by CAM also triggered different uses. A collection of these design narratives can lead to providing an overview of the project. Here is a comment that we received during the group interview sessions:

> "If you stand in front of these things and scan everything, it helps to think about and understand what's going on in the project."

We also received some interesting comments about improving the current prototype of CAM. Here are some of the comments we received:

> "It would be nice, if we can administer these comments and filter out redundant and less relevant comments from the sketches."

> "It is sometimes difficult to squeeze some complex problems into such as short message. So, sometimes the results are strange formulations. It might be possible that you might not understand a particular message and there is a danger that something completely wrong might result from this."

It was clear that not all issues related to a design artefact can de described in the form of messages, and this was certainly not our intention. CAM is not meant to add large descriptions to the design artefacts.

4.3.2 Expressions & Aesthetics

The way designers used CAM and wrote messages onto their design artefacts had expressive and aesthetic qualities. Some of the Tweets that were written on the design artefacts had a certain amount of enthusiasm and affection. One of the designers had the following comment:

> "Sometimes you do see an enthusiasm of the designers in their messages. In some cases, I have seen detailed descriptions of a design sketch in the messages and sometimes its not detailed enough. So, then I had to ask them questions and asked them to elaborate some ideas."

Although, most of the messages had a neutral quality, in some cases, we did observe that design artefacts had some level of evocative and provocative qualities or an 'invitation' for co-designers to comment back on the work. The following is a comment of one of the designers who intentionally wrote messages to get co-workers attention.

> "I would like to know if others like my sketches and design ideas. What do they think about my work? When they don't have a chance to speak to me, they can write something on these sketches using CAM."

The use of CAM allowed designers to express aesthetic qualities in their messages. Making a connection between the physical design artefacts and relevant messages as Tweets provided an interesting opportunity to the designers to express something that they would not express during their everyday cooperative design sessions. One such example can be seen in Figure 10. It shows the final sketch and concept developed by the group 3. In this case, a designer wrote a poetic message to express the aesthetic quality and functionality of the lamp. In Figure 10 we also include the original poetic messages in German and then their English translation.


```
German:
strahlemann, der strahlt uns an.
ob tag und ob nacht, wäre hätts gedacht

English:
the Shiny-man, who shines on us.
whether day or night, no matter what.
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German:
die sonne am morgen,
die sterne am abend,
die langsam begleitend in den schlaf uns tragen

English:
the sun in the morning,
the stars at the night,
slowly accompany us into sleeping tight.
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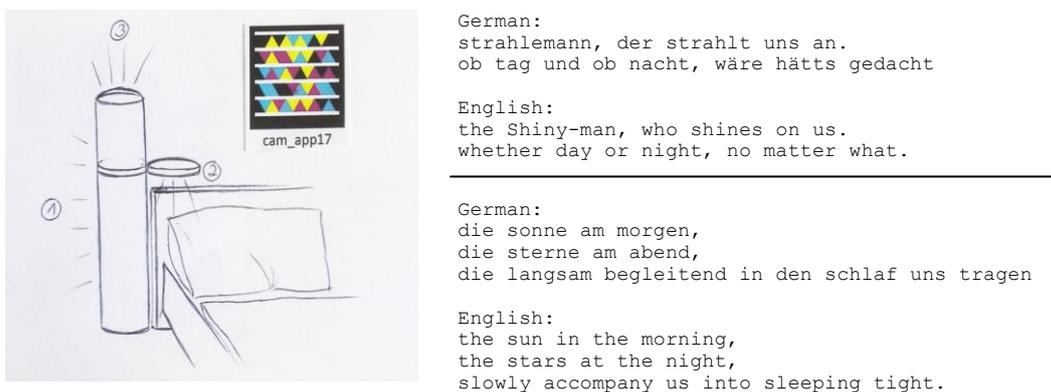
Figure 10: Final sketch of a conceptual Intelligent Lamp and A set of poetic messages adding aesthetic qualities to the Intelligent Lamp concept (with added English translations).

During the final group interview session with the design team, we asked about these poetic exchanges.

D#: "Somebody wrote a poem about the lamp. It's just funny. It describes the lamp in an artistic way. And the cool thing is that you are totally anonymous. This is something that makes this sketch beautiful."

D#: "The poem shows the poetry of the product. It is something about a good sleep and have a good night and wake up."

D#: "I didn't know who wrote it. And when I first discovered it, I thought look somebody wrote a poem. It was really amusing. It could be something to tell the customers who might buy this lamp. This could be something that separates this product from others."

D#: "I think it makes the concept of our lamp more romantic and magical, if you like."

More importantly, the setup and interactive opportunities provided by CAM were seen as intriguing by all the designer teams. To an extent, the idea of adding digital information to an ordinary physical object such as a sketch was very interesting for some of the design participants. Several designers commented that they saw Tweet messages as an extension of their physical design objects.

"To me it's a fascinating experience to read the details about the lamp that we designed in a mobile phone. It is like seeing the same thing in a different way"

"For me, it is an extension to the usual way we work. It is just like sending an SMS to somebody, but the messages are stored on the object."

4.3.3 Coordination

We discovered interesting coordination and communication patterns while observing the use of CAM. As we showed earlier, design teams used a large whiteboard to keep their design artefacts and all the team members could see one another's work. When 2D barcodes were added, other co-workers could read the information that was attached to different design artefacts.


```
Message log of Alarm Clock

1.  Yes, ok. I have also touched on this
    once.
2.  Perhaps you can tilt the clock view more
    towards outside. Four different clocks
    might confuse family members. Not
    intuitive.
3.  Perhaps you could also consider the outer
    edges down further.
4.  I would think more volume :)
5.  Off when you push the lead of the alarm
    clock. The alarm can be switched off from
    each points of the housing.
```

Figure 11: One of the prototypes of an alarm clock

The design artefacts were in fact an important source of communication between co-designers. However, the 2D barcodes added an extra channel for communicating additional information. Designers could make comments about each other's work and negotiate specific ideas using CAM. Figure 11 shows one such example where a physical model of an alarm clock that has a 2D barcode.

The message log shows the information about this object and shows how designers negotiated (latest message at the top).

To give another example, Figure 12 shows a "Planning" object that design team 1 developed in order to make a specialized access point for organizing and planning their ongoing project. It also shows the Tweets that were sent to this object over the course of the project (latest message at the top). We have translated the Tweet log into English for better understanding. The purpose of this design artefact was to divide work responsibility, create a work schedule and for sharing important decisions between themselves. We observed during the course of their project that the design team iteratively added contents to this object. This kind of practice led to designers frequently checking the "Planning" object in order to 1) review their previous activities, 2) coordinate their ongoing activities and 3) create milestones for future activities.


```
Message Log of "Planning" object

1.   Thursday: Grigorios - presentation
     Sketch
2.   Thursday: Eric - technical drawing
3.   Thursday: Tarek & Julia – finishing
     the design model
4.   Make technical drawing
5.   Wednesday: planning, task
     distribution. Grigorios
6.   Wednesday: Braille design with Eric
7.   Proposals on the buttons:
        1. Payment
        2. Volume
        3. Channels
        4. Program Selection
8.   Joey's?
9.   What else should we add for
     supporting touch-based facilities?
10.  I would very much like to order pizza
     for tomorrow. Better designs with
     full stomach
11.  Touch screen OUT. Agreed on the use
     of Braille writing system. Any
     proposals on the form?
12.  How many keys does a blind remote
     control require?
13.  I propose that we combine both the
     concepts, your form and our concept
     of designing for "blind people"
```

Figure 12: A "Planning" object and its message log.

One of the main advantages of CAM, as seen by the design teams, was its asynchronous and flexible communication support. One of the designers suggested:

> "When you talk to a lot of people during design meetings, you get too many opinions and issues that are not really important. But when you just write it on the sketches in black-and-white using CAM then you can quickly focus on the design".

We also observed that CAM could be suitable for large groups of people collaborating over a long period. In large corporations, where teams from different

disciplines work together on a project, CAM can provide additional and relevant information of a multidisciplinary nature. One of the team members suggested:

> "In a scenario, where we have to hand over our work to product developers and engineers, these 2D barcodes can help these professionals who have not been closely informed about the kind of design process that we have applied to these design objects. So, I think CAM could also be helpful for inter-team collaborations."

The communications were both named and anonymous. Regarding anonymous communication, a team member suggested,

> "I thought confusion did occur after reading these comments on the objects. And I do think that there could be an identification mechanism for these messages."

4.3.4 Creative Explorations

We were also interested in exploring the role CAM plays in supporting design exploration and creativity in general. Some previous research has indicated that designers do not work in a pre-determined, mechanical fashion (Jacucci and Wagner, 2007). In fact they apply different approaches in different situations, involving different media (ranging from papers, foam, woods to digital tools) to understand and solve their design problems. Being able to explore and try out new design ideas is central to their design work. We observed that the social and collaborative nature of CAM allowed all the members of a design team to actively participate in the exploration process.
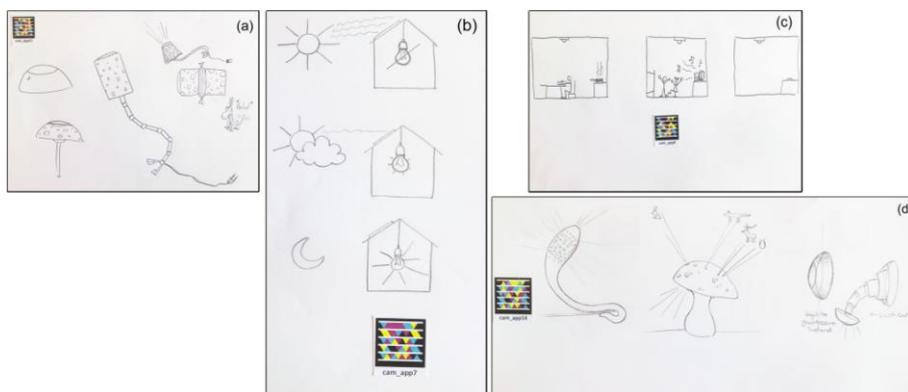

Figure 13: Design sketches to explore ideas for Intelligent Lamp.

In one instance, a team member developed several concept sketches for the Intelligent Lamp project (Figure 13). Sketching is clearly one of the quicker ways to express and communicate design ideas to co-workers. However, in this particular case, the team member's intention was to gather co-workers' comments about different exploration ideas that she developed. Figure 13a was meant to explore different shapes of lamp; 13b and 13c show the ways to apply intelligence into the lamp; and 13d explores different projection styles for the lamp. The intention here was to have a discussion via sending views and ideas onto the

design artefacts and discuss these during the face-to-face meetings. Here is a comment from that design member:

> "CAM does help in creative thinking. Sometimes when I am drawing, I wouldn't know all the technical details. So after reading these comments about my sketches, I did find some tips about changing my original ideas."

By receiving comments from each other, members of design teams collaboratively learned and improvised their ongoing design projects.

> "The useful thing about CAM is the new ideas that we get from others. I found this very stimulating for my creativity. For example, Max had this function of pushing in the alarm clock and I had a separate switch. From Max's design and my design we merged the interesting ideas and came up with a combination in the final design idea."

4.3.5 Reflective Practices

Reflection – a mechanism for learning and improvising from experience is seen as an important aspect of professional design practice (Schön, 1983). In this section, we will focus on how the use of CAM facilitated designers to critically look at their own work and the work of others. The asynchrony and serendipity of messages and comments helped design teams to reflect on their own work at the same time being able to learn and constructively criticize each other's work.

> "The system does help you to reflect on what you designed and what you wrote about it. At the same time what others have said about your work."

Reflections were triggered by the Tweets sent by the co-workers about some previous design activities. These Tweets, which contained comments and suggestions, then lead designers to critically look at their design sketches and other design artefacts. Sometimes, these reflections seemed to prompt decision-making and also lead to some face-to-face discussions between team members.

Moreover, CAM required designers to write down their activities in the form of messages. This actually helped designers to organize their ongoing design projects and to make themselves accountable. One of the team members said:

> "I think it might be a good thing if we can write down what we are thinking about during the process of making sketches. This would be a good practice as well."

5 Discussion & Conclusion

Traditionally, when we talk about boundary objects, we mainly refer to them within the context of a collaborative work that focuses on bringing productivity and efficiency. As we observed from our own (Vyas et al. 2009a-b) and others' field studies (Jacucci and Wagner, 2007) that creative work, especially within the design studio culture, is defined as much by experiential, aesthetic and explorative activities as it is by task and productivity-related activities. Given this scenario, how should boundary objects in creative work behave? Should boundary objects provide opportunities for explorations and a scope for 'trial-&-error' activities?

Should they provide ambiguity and provocation to stimulate creativity in design work? There is an 'interpretive flexibility' attached to the notion of boundary objects. By this different group of workers (communities of practices) can interpret the object in question in a way that can be useful to their domain of work. The work of Stacey and Eckert (2003) shows that ambiguity in design communication (e.g. through sketching) can lead to confusion and suggests that systematic use of meta-notations for conveying provisionality and uncertainty can reduce these problems.

By bringing a technological intervention into a Product Design studio, we attempted to understand how CAM could help the collaborative activities of design and the consequences CAM may have on the work practices of designers. As our results showed, CAM facilitated designers to utilize their design artefacts for 1) developing design narratives and stories, 2) expressing of the aesthetic qualities of the design artefacts, 3) providing communicative and coordinative resources, 4) providing exploration support, and 5) allowing designers to reflect on their own and other's work.

The use of CAM showed that design artefacts can expand their static and ordinary nature to become more dynamic and active objects. As we explored during our field studies, the design artefacts became "living objects" where designers could collect and send information. Design participants continuously scanned the barcodes to gather updates from different design artefacts and took advantage of the anonymity and asynchrony of CAM.

One of the important aspects of the "logs" generated by CAM was their communicative and coordinative abilities. Using their mobile phones, participants were able to read updates of different design artefacts and were able to get a sense of what was going on in the project. The "Planning object", described in Figure 12 was an example of a design team's organizing activities. These logs were also triggers for reminders and future actions – hence working as memory aids. Additionally, CAM was not just used for the sole purpose of storing information onto the artefacts. Design participants used CAM to establish a creative working culture in the design team. We observed that after reading updates from the design artefacts the participants were triggered to build on each other's work and learn from each other. The collaborative and social nature of CAM fostered creativity amongst the group of designers. Additionally, the serendipity and anonymity of Tweets played an important role in establishing curiosity and playfulness. Moreover, the designers were also triggered to reflect on their own as well as each other's work in a critical manner.

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7 References

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