Between Chaos and Routine: Boundary Negotiating Artifacts in Collaboration

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Abstract. Empirical studies of material artifacts in practice continue to be a rich source of theoretical concepts for CSCW. This paper explores the foundational concept of boundary objects and presents the results of a year-long ethnographic study of collaborative work. This research questions the assumption that artifacts exist necessarily within a web of standardized processes and that disorderly processes should be treated as "special cases". I suggest that artifacts can serve to *establish and destabilize* protocols themselves and that artifacts can be used to push boundaries rather than merely sailing across them.

Introduction

Much CSCW research has been devoted to the role of inscription and material artifacts in cooperative work. Myriad ethnographic studies have documented the importance of inscriptions and material artifacts to the creation of shared understanding (Star and Griesemer 1989; Tang 1989; Bucciarelli 1994; Heath and Luff 1996; Pycock and Bowers 1996; Mambrey and Robinson 1997; Harper 1998; Perry and Sanderson 1998; Bechky 1999; Henderson 1999; Hertzum 1999; Brereton and McGarry 2000; Eckert 2001; Lutters and Ackerman 2002; Schmidt and Wagner 2002; Subrahmanian, Monarch et al. 2003). In particular, the relationship of material artifacts to coordinative practices has rightfully attracted a great deal of interest.

Empirical studies of material artifacts in practice continue to be a rich source of theoretical concepts for CSCW. Concepts such as boundary objects (Star 1987-

1989; Star and Griesemer 1989), coordination mechanisms (Schmidt and Simone 1996), prototypes (Subrahmanian, Monarch et al. 2003), ordering systems (Schmidt and Wagner 2005), and intermediary objects (Boujut and Blanco 2003) have been proposed as ways to theorize the role of material artifacts vis-à-vis coordinative practices, and by extension, to theorize collaborative work in general. These concepts overlap to form a patchwork quilt of frameworks that are moving us towards an increasingly sophisticated theoretical understanding of collaborative work.

The concept of boundary objects, in particular, has attracted a great deal of attention as a useful theoretical construct with which to understand the coordinative role of artifacts in practice. I will discuss how the concept of boundary objects came about and how the concept has been used as a catch-all for artifacts that fit uncomfortably within the definition. After an exploration of the foundational concept of boundary objects and presentation of the findings of a year-long ethnographic study of collaborative work, I question the assumption that artifacts necessarily exist within a web of standardized processes and that disorderly processes are to be treated as "special cases". I suggest that artifacts can serve to *establish and destabilize* protocols themselves and that artifacts can be used to push boundaries rather than merely sailing across them.

Boundary Objects

Boundary objects are a key innovation in the study of collaboration and information practices and systems. Many have suggested that the creation of boundary objects is key for collaboration between communities of practice (Star and Griesemer 1989; Wenger 1998; Bowker and Star 1999; Henderson 1999) and I agree. However, I believe there is some danger in relying too heavily on the concept when theorizing collaborative work.

Since Star and Griesemer (Star and Griesemer 1989) initiated the concept of *boundary objects*, it has been used in a wide variety of research areas including research on collaborative information systems, organization science, and information science (Krasner, Curtis et al. 1987; Mambrey and Robinson 1997; Albrechtsen and Jacob 1998; Van House, Butler et al. 1998; Bechky 1999; Henderson 1999; Garrety and Badham 2000; Pawlowski, Robey et al. 2000; Karsten, Lyytinen et al. 2001; Lutters and Ackerman 2002; Diggins and Tolmie 2003; Larsson 2003). Research employed the concept of boundary objects to show that a single object can be used for different purposes by different people (Larsson 2003), to theorize information systems as boundary objects between communities of practice (Pawlowski, Robey et al. 2000), and to explore activities surrounding boundary objects within information or work flow (Mambrey and Robinson 1997; Lutters and Ackerman 2002).

Boundary objects are described as objects that coordinate the perspectives of various communities of practice (Wenger 1998; Henderson 1999). The concept of boundary objects relies heavily on the concept of standardization and examples of boundary objects are typically things with a standardized structure such as forms, maps, and grades—or things with a naturally predetermined structure such as a bird. The question then arises as to how groups of people who lack standardized structures begin to collaborate.

When Star and Griesemer (Star and Griesemer 1989) first introduced the term *boundary objects*, they introduced boundary objects as one of two major factors that contributed to the successful cooperation between biologists and amateur naturalists. The other major factor, *methods standardization* was the less glamorous and less innovative of the two concepts and the title of the article reflects the favored status of the boundary objects concept; the title refers to boundary objects but not to methods standardization. Despite this, the concept of standardization is important to the boundary objects itself. Star and Griesemer discuss Joseph Grinnell, the museum's first director, and Annie Alexander, the museum's founder and amateur naturalist:

> Grinnell and Alexander were able to mobilize a network of collectors, cooperating scientists and administrators to ensure the integrity of the information they collected for archiving and research purposes. The precise set of standardized methods for labeling and collecting played a critical part in their success. These methods were both stringent and simple—they could be learned by amateurs who might have little understanding of taxonomic, ecological or evolution theory. They thus did not require an education in professional biology to understand or to execute. At the same time, they rendered the information collected by amateurs amenable to analysis by professionals. The professional biologists convinced the amateur collectors, for the most part, to adhere to these conventions—for example, to clearly specify the habitat and time of capture of a specimen in a standard format notebook (Star and Griesemer 1989).

The director and founder of the museum, two people in managerial positions, engineered methods standardization. While Star and Griesemer found methods standardization to be necessary, they did not find it to be sufficient for cooperation across diverse social worlds. Other means for cooperation, namely boundary objects, were found to be necessary. Boundary objects are created when groups from different worlds work together. Shared work creates objects which inhabit multiple worlds simultaneously. In *Sorting Things Out*, Bowker and Star (1999) describe the concept of boundary objects.

> Boundary objects are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use. These objects may be abstract or concrete. Star and Griesemer (1989) first noticed the phenomenon in studying a museum, where the specimens of dead birds had very different meaning to amateur bird watchers and professional biologists, but "the same" bird was used by each group. Such objects have different meaning in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of

> boundary objects is a key process in developing and maintaining coherence across intersecting communities (Bowker and Star 1999).

Boundary objects arise over time from durable cooperation among communities of practice. Star lists four types of boundary objects (Star 1987-1989; Star and Griesemer 1989):

- *Repositories* which are 'piles of objects that are indexed in a standardized fashion such as libraries'.
- *Ideal Type* which does not accurately describe the details of any one locality or thing but is abstract and vague and therefore adaptable, such as a diagram or atlas.
- *Coincident Boundaries* which are common objects which have the same boundaries but different internal contents, such as the political boundary of the state of California.
- *Standardized Forms* which are standardized indices that serve as methods of common communication, such as forms.

While Star notes that this list is by no means exhaustive, it is interesting to note that two of the four types of boundary objects listed have standardization as a key component. Repositories are indexed in a *standardized fashion* and standardized forms are *standardized indexes*. Furthermore, it could be argued that political boundaries or atlases also relay on standardized forms of both measurement and representation. This is particularly interesting given that methods control and boundary objects were said to be two different strategies for cooperation across social worlds. Standardization is integral to the definition of boundary objects.

Standards and boundary objects are entwined concepts that both arise over time from durable cooperation among communities. The dependence of boundary objects on the concept of standardization is inherently problematic for theorizing incipient, non-routine, and novel collaborations. Theories are needed to explain how collaborators from different communites of practice, that lack pre-exisiting standards, use material artifacts to collaborate. The empirical research undertaken for this study follows a newly-formed, interdisciplinary design group. Lacking standardized processes and objects for collaboration, the collaborators created what I will call *boundary negotiating artifacts*. My point is not that there is a strict dichotomy between standardized and nonstandardized processes and work. Rather I am seeking to increase the profile of the role of material artifacts in the non-routine work commonly found in incipient interdisciplinary design. As I will discuss later, boundary negotiating artifacts and boundary objects are likely to be related and to vary in prevalence along a continuum from routine to non-routine work.

Building on the Concept of Boundary Objects

Since the introduction of boundary objects, ethnographic research has expanded on the theory. Studies have revealed the importance of providing contextual information about boundary objects in order for the objects to be useful. For example, understanding the context of a boundary object's inception, including its history and surrounding negotiations, is a necessary precursor for boundary objects to be intelligible to those in the receiving community of practice (Mambrey and Robinson 1997; Bechky; Henderson; Lutters and Ackerman 2002; Diggins and Tolmie 2003; Subrahmanian, Monarch et al.). Boundary objects may need to be augmented with additional contextual information in order to be effective in other words.

Research has also documented cases where boundary objects failed for various reasons (Henderson 1999). Bechky's (1999) ethnographic work of engineers, technicians and assemblers involved in the production of semiconductor equipment manufacturer found that boundary objects were not always enough to negotiate shared understanding:

> The occupational communities negotiated a shared understanding through the use of boundary objects, but they were not always enough. Boundary objects can fail to serve as a translation tool when they are not plastic or flexible enough to be used by all groups. Because these groups had different experiences with the objects and spoke different languages, misunderstanding resulted, particularly between engineers and assemblers. These misunderstandings were resolved through verbal translation into the language of drawings or by the offer of a tangible definition, which provided the context needed for shared understanding (Bechky 1999).

Bechky found that the assemblers found engineers' drawings to be too abstract and ambiguous. The drawings were clear to the designers who created them because they were familiar with the context in which they were created, but the assemblers need additional context in order to understand the drawing. While Bechky does not go so far as to suggest that these drawings are not boundary objects, one may conclude that they are not. By definition boundary objects are supposed to satisfy the informational requirements of different communities of practice.

In her ethnographic work on design engineers, Henderson (Henderson 1999) found that the boundary object concept required amendment in order to describe the way that designers actually use artifacts. Consequently, she coined the term *conscription devices* to mean a type of boundary object that enlists group participation, are receptacles of created knowledge, and that are adjusted through group interaction.

> The focus of conscription devices is the process, while the focus of boundary objects is product. During the design process conscription devices exert a powerful influence. Participants find it difficult to communicate about the design without them (2003).

Unfortunately, Henderson does not elaborate on the concept and ultimately posits conscription devices as a type of boundary object. I would argue that objects that are used and adjusted through simultaneous group interaction are not a new type

of boundary object, rather, while similar and related, they are not actually boundary objects at all.

Examples of boundary objects such as birds, political borders, or repositories are described as passing from one community of practice to another with little or no explanation. Boundary objects are supposed to "satisfy the informational requirements of each community of practice." Yet some of the things we call boundary objects do not seem to actually satisfy the informational requirements of each community of practice because they required considerable additional explanation and discussion to be intelligible.

Other work has suggested more strongly that the boundary object concept requires amendment (Boujut and Blanco 2003; Subrahmanian, Monarch et al. 2003). Subrahmanian et al (2003) propose the broad concept of *prototypes* based on their observations of artifacts and activities that support systematic updating of boundary objects and their observations of organizational changes that rendered boundary objects unable to support activity. Prototypes are described as verbal, gestural, and virtual representations and models, protocols, process graphs, and physical artifacts that serve as partial or complete representations of the product or process that is being produced. Prototypes are described as boundary objects but also as representations that are necessary to support the understanding of boundary objects. The first case study found that even in a stable organizational environment, boundary objects may require a fair amount of updating in order to continue to satisfy the information needs of the collaborating parties. The second case study highlighted that boundary objects can be somewhat brittle. In the face of organizational instability, existing boundary objects failed and new prototypes and boundary objects needed to be created to support work. Subrahmanian et al (2003) raise important points: Boundary objects may fail due to changes in the organization context or structure; There is a broad class of representations and activities that dynamically change their representational status in the achievement and breakdown of shared understanding that are not boundary objects.

Another concept that amends boundary objects is that of Intermediary Objects (Boujut and Blanco 2003). Intermediary objects are intermediate states of a product. Intermediary objects are representations, but they are also the traces as well as the outputs of a collaborative transformational process. A sketch, for example, is a conjecture that is evaluated and confronted by collaborators who have other constraints.

> More precisely we think that co-operation can be considered as a process of "disambiguation" if it is properly framed. Negotiation and compromise setting are particular ways for creating specific shared knowledge. The concept of intermediary objects can provide a tool that allows the production of a conceptual frame that formalizes and represent this shared knowledge through objects and various representations (Boujut and Blanco 2003).

While Boujut and Blanco (2003) note, in passing, that intermediary objects act as boundary objects. I suggest they may be something quite different.

Rather than pushing the limits of the concept of boundary objects, it would be fruitful to consider that the concept of boundary objects may not be up to the conceptual heavy lifting that many of us have been trying to assign it. Others have noted this before, not only critiquing boundary objects but also common information spaces, workflow systems and coordination mechanisms as forming a picture that is "rather patchy and incoherent" and as collectively forming a defective foundation for CSCW (Schmidt and Wagner 2005). While I don't presume to singlehandedly lay that foundation. I may be able to identify weaknesses in the existing foundation.

Case Study: Museum Exhibition Designers

This research used ethnographic methods to understand how a team of designers used physical artifacts and social practices to collaborate. I wanted to find out what communities of practice were involved, what sorts of practices they used, and how they used artifacts.

The site for the fieldwork was a project to design a traveling exhibition about wild and domestic dogs. The project was sponsored by a large natural history museum, hereafter referred to as the Natural History Museum. An interdisciplinary team of designers, most of them located on-site, was charged with the responsibility to design the exhibition.

At any given time there was a core group that worked intensively on the project and a peripheral group of participants who made occasional contributions through participation in meetings and provision of information or artifacts. The core design team was comprised of educators/writers, exhibit designers (an industrial designer and graphic artist by training), a builder, and off-site scientific advisors/curators.

I used ethnographic methods such as participant-observation and interviewing and also used documentary analysis. Data was collected at the Natural History Museum for over a year between December 2001 and March 2003. I spent well over two hundred hours in the field with members of the exhibition design team and collected over a thousand pages of field notes, documents, and photographs. I have used pseudonyms for the names of people and places to protect the privacy of individuals who have participated in this research.

The Dogs Group as Intersection Between Communities of Practice

Design is often fraught with conflict. Rather than characterizing such contests as a battle of individual wills, it is helpful to explore the Dogs project group as an intersection between different communities of practice. In a very real way, the members of the Dogs Group brought sets of practices, values, and meanings with them to work. Some of these practices are embodied in staff member's know-how and expertise regarding exhibit-oriented reifications (e.g. how to build a kiosk,

how to write at a certain grade level), but along with task-oriented practical skills, communities of practice teach members related practices, attitudes, and norms as well. Sometimes these practices, attitudes, and norms conflict directly with those of other members of the Dogs Group.

Interviews revealed that each team member had multiple self-identified affiliations to communities of practice such as departments, functional units within departments, previous occupations, education, training, other museum genres, and professional associations. They each cited these affiliations as motivation for specific actions (Lee 2004).

To a surprising extent, contests in the collaboration between communities of practice were invisible to participants. The curators worked on the project off and on over a period of two years and yet never became privy to the communities of practice at work within the museum. Certainly they understood that there were conflicts and that different people had different jobs, but even after the exhibition had been successfully opened they were unclear about the roles of each of the team members and to what extent they had been involved in the creation of the exhibition. They certainly never came to understand what functional units were involved in the creation of Dogs and that they mapped to different communities of practice.

The curators were never privy to the participation and affiliation of three key team members in a professional museum studies association that advocated a reduced role for exhibition curators. Knowledge of the philosophical differences engendered by this association, would likely have changed the way that things transpired amongst the team if not the ultimate outcome. While not always resolved to universal satisfaction, the conflicts and negotiations that occurred enabled the team to coordinate themselves and successfully collaborate to produce a complicated museum exhibition.

Boundary Negotiating Artifacts

This research found designers using artifacts and surrounding practices to iteratively coordinate perspectives and to bring disparate communities of practice into alignment, often temporarily, to solve specific design problems that are part of a larger design project. The discussion that follows will describe five types of boundary negotiating artifacts that do not fit the definition of boundary objects: 1) self-explanation, 2) inclusion, 3) compilation, 4) structuring, and 5) borrowing. Self-explanation *artifacts* were created by and for either a single individual or two to three members of the same community of practice working in tight collaboration. Four types of artifacts were created for crossing and negotiating boundaries between communities of practice: *inclusion*, *compilation*, *structuring*, and *borrowing*. Each artifact was created for specific purposes and was used differently by members of the Dogs Group.

1) Self-explanation artifacts (e.g. notes, tables, concept sketches) were the most difficult to study as they were rarely presented directly to others and were typically created while Dogs Group members worked in the privacy of their offices. The designers used self-explanation artifacts for learning, recording, organizing, remembering, and reflecting. While created and used privately, self-explanation artifacts were sometimes indirectly presented to others through the creation of inclusion artifacts or compilation artifacts.

Self-Explanation Artifact Example 1: Hannah's Table for Section 4

Hannah, an educator, was responsible for generating the label copy for a section of the exhibition about what people do to help dogs, section 4. While working on her own, Hannah created a table to organize elements of section 4. Hannah's table was an innovation because up to that point she, and also Emma, had relied primarily on the narratives, which were essentially scripts for the exhibition, and her meeting notes. Hannah used her table to organize the information that she was getting from various sources, to remind herself of the artifacts associated with each exhibit and the personal stories and a scientific issues to cover in the label copy. Eventually, Hannah used her self-explanation artifact to develop and refine her label copy, a structuring artifact. Self-explanation artifacts are surrounded by a web of practices such as recording, remembering, collecting, and organizing.

Self-Explanation Artifact Example 2: Martin's Journals

For over twenty years Martin has been keeping journals relating to his work as an exhibit designer. His journals included illustrated notes on science and technology topics and sketches of ideas for interactive electrical-mechanical museum exhibits. Martin also used his journal as a place to collect ideas and images. Sometimes he would visit a museum and would see a quote that he particularly liked and record it in his journal. When his work took him to foreign countries he made rough sketches of things he had seen and he pasted local postage stamps in his journal. When I asked him about the quotes and postage stamps, he said that they were things that he liked that were potential material for future exhibitions.

In his role as a designer at NHM many of Martin's exhibit concepts were brand new, but his ideas were also very much influenced by what he had seen and created in the past and had recorded in his journal. On one occasion, Martin used a concept from an old journal for a new exhibit idea. He then created a new sketch that was used as an inclusion artifact (discussed below). Martin used his journals to record pleasing, useful, and potentially useful information and images, to remind himself of personal stories and feelings, and to explore scientific issues and exhibit ideas. His journals were a tool for learning, remembering, and reflecting.

2) Inclusion artifacts were used to propose new concepts and forms. These artifacts were created from self-explanation artifacts and went through an informal screening process of group discussion whereby an idea embodying different concepts and forms (e.g. sketches or text) originating from one community of practice would be proposed to others. This screening process entailed communal gatekeeping whereby the group would use the inclusion artifact as a reference or symbol for the new idea.

Inclusion Artifact Example: Object Theater

Inclusion artifacts can be used to create alliances with sympathetic communities of practice to exert pressure on still other communities of practice. Martin tried to include an inclusion artifact on his own behalf, but also on behalf of the curators, when he designed an exhibit he called Object Theater. Object Theater was a theater that displayed artifacts depicting dogs from different cultures and eras and related those artifacts to dog myths and legends using audio or video recordings. The theater was important to Martin because he wished to emphasize that dogs are part of human culture—a theme that had been strongly encouraged by the curators. In fact, the curators had expressed disappointment that the exhibition did not have more content about dogs and culture.

The educators were initially very reluctant to include the theater for practical reasons—the exhibition was already well behind schedule and the object theater required a large amount of additional work including researching and choosing specific myths and legends, identifying, locating, and borrowing appropriate artifacts, writing and recording a script, or filming a storyteller, and editing the audio or video. Many of these tasks would need to be undertaken by the already over-burdened educators themselves. While the educators liked the concept and visual impact of the theater, they were wary of the amount of work it would entail. The educators actually discouraged Martin from presenting his drawing of the object theater, an inclusion artifact, to the curators because they feared that the curators would then insist upon its inclusion. Eventually, this is exactly what happened. During the next meeting the curators again complained about the lack of culture in the exhibition and Martin took advantage of the opportunity to engage in including practices, specifically presenting a sketch of the object theater.

When the curators saw Martin's drawing they recognized a chance to include more culture in the exhibition and they then persuaded the rest of the group to accept the theater as part of the exhibition. Martin belonged to a community of practice of traditional exhibition design whereby exhibit designers would translate curator's ideas into exhibits and Martin used the object theater to create an alliance with the curators who held views similar to his own.

Martin successfully used including practices to have his including artifact incorporated into the exhibition, but it is important to note that engaging in

including practices does not necessarily entail the successful acceptance of an inclusion artifact. One can engage in including, yet fail to gain acceptance of one's inclusion artifact. Inclusion artifacts are embedded in a web of practices that can be considered including practices—presenting, accepting, rejecting, and reserving judgment.

3) Compilation artifacts (e.g. tables, technical sketches) were used to coordinate both media and the designers themselves. The designers used compilation artifacts to bring two or more communities of practice into alignment just long enough to develop a shared and mutually agreeable understanding of a problem and to pass crucial information from one community of practice to another. This process of alignment and sharing of information facilitated the creation of shared understanding about each exhibit and the exhibition as a whole. This process of alignment was continually necessary as knowledge was distributed across functional specialties (e.g. sculpture, taxidermy, education, etc.) and elements of each exhibit were constantly evolving. While inclusion and compilation artifacts often fully or partially incorporated self-explanation artifacts, structuring artifacts often fully or partially incorporated inclusion and compilation artifacts.

Compilation Artifact Example: Angela's Table for the Graphic Designers

One day I observed Angela (Exhibit Designer) and Emma (Educator) cooperating to turn Emma's images and artifacts table (a self-explanation artifact) into a compilation artifact that was to be given to the graphic designers. Angela explained to me that she was trying to help the graphic artists by putting together a new table. Emma's document, Dogs Images and Artifacts, listed the images and artifacts for each exhibit, but within each exhibit were several discrete labels. Emma's document did not relate each image and artifact to its corresponding label. The graphic artists didn't know which images went with which labels.

Angela, with help from Emma, created a compilation artifact by collecting information from various sources. The information necessary to create Angela's table came from Emma's table, label copy, folders, and from Emma herself. By going through the act of compiling, all this information was funneled into one table that was formatted specifically for the graphic designers; Angela created a bridge between Emma and the graphic designers. As they filled in the table, they innovated with terminology and with the information structure of the table. For example, they had to figure out how to represent single labels that contained multiple images, they also had to figure out how to indicate that the graphic designers may choose amongst several images, or if they had to include all the images listed. Additionally, they created shorthand for: the state of an image, how to code the component type, and how to indicate repeating items. While Angela's table came very close to being a boundary object, it was not a boundary object because Angela developed names for the fields on the fly and needed to decide

how to communicate instructions to the graphic designers as she went along. Additionally, when it came time to give the tables to the graphic designers, Angela found it necessary to explain how to read the tables.

Compilation artifacts are involved in a web of compiling practices: remembering, gathering, organizing, discussing, anticipating needs, presenting, and explaining. Angela and Emma used the table to coordinate both media and themselves. The table provided a focus for finding and organizing media. Lacking a boundary object, Angela was able to use her tacit knowledge of graphic design to create a compilation artifact that augmented her brokering role. Ultimately Angela used her table to bring two communities of practice into alignment just long enough for the communities to pass crucial information from one to another.

4) Structuring artifacts (e.g. exhibition narrative, exhibition concept map) were plentiful throughout the design of the Dogs exhibition. The structuring artifacts created by different members of the Dogs team often competed with each other for primacy. The curators, the educators, and one of the exhibit designers each had a vision for the exhibition and their vision was made manifest in their structuring documents and their expectations for how their structuring documents would be used. Like compilation artifacts, structuring artifacts are used to coordinate media and understanding but, unlike compilation artifacts, structuring artifacts are also used to establish ordering principles, establish tenor in narrative forms, and to direct and coordinate the activity of others.

Structuring artifacts were often at the center of heated struggles between communities of practices and were sometimes used to push and negotiate boundaries themselves—quite different from boundary objects which move across boundaries from one community of practice to another with relative ease.

Structuring Artifact Example 1: The Curator's Narrative

The curators, Brad and Elaine, wrote a large text that I'll call the *curator's narrative*. The curator's narrative contained chapters for each of the topic sections that the NHM Dogs staff had agreed upon. Within each chapter, the curators had isolated sub-topics and written one to four paragraphs about each. Additionally, the curators included detailed suggestions for illustrations or photos, indicated what should be wall panels or kiosks, and suggested what exhibits might look like. The curators believed that their narrative provided the framework for which topics and sub-topics would be included in the exhibition and how they would be organized. One of the curators was stunned to discover that the museum staff seemed to be removing and changing whole concepts.

In fact, the educators were using the curator's narrative, but they were using it as a source of material, rather than as a framework, for the whole exhibition. Because of their affiliation with the visitor studies community, Emma and a few other members of the staff believed that it was their professional responsibility to

remove, shorten, and simplify the text of the exhibition. The educators did not accept the curator's narrative as the primary structuring artifact for the exhibition—a fact that the curators fought throughout the duration of the project.

The curator's narrative was a structuring artifact. Like all structuring artifacts, the curator's narrative showed the structure of the final design product. As a structuring artifact, it was concerned mostly with the organization of concepts, however it also dealt with how those concepts would be expressed in text, graphics, and physical forms. The curators had introduced one structuring artifact, but Dogs Group members introduced structuring artifacts of their own. Sometimes structuring artifacts were compatible and sometimes they competed.

Structuring Artifact Example 2: Educator's Narratives and Label Copy

The curators produced a narrative, a structuring artifact, but the educators Hannah and Emma, created their own narrative for the exhibition which quickly supplanted the curator's narrative as the structuring artifact for the exhibition. The educator's narrative was derived from the curator's narrative and was intended to facilitate the organization of the exhibition as a whole. The educator's narrative, like the curator's, was divided into agreed-upon sections and corresponding topics. From there the educators began to impose their own structure on the narrative. Topics were moved, combined, and finally given exhibit titles and component and label numbers. The resulting educator's narrative also provided a concise summary of topics and any preliminary ideas for the physical design of exhibits. Early narratives dating from late 2001 covered the first three sections of the exhibition and were quite similar in structure to the curators' narrative. Changes from that point on were incremental with some topics being rethought, added, or eliminated based on discussions amongst the NHM Dogs staff and, to a lesser extent, also the curators. The narrative was redistributed every few months to keep people apprised of changes in the order of exhibits, additions of sub-topics, or the assignation of different numbers for existing exhibits. The narrative became the dominant structuring artifact.

From December of 2001 through early February 2002 Emma and Hannah gradually began to spend less time deciding and elaborating on what should be listed in the narrative and more time conveying and explaining listed items to Martin, Angela, Evan, and Brent. Hannah and Emma began to spend more time on several other exhibition-related activities. One of these activities was writing the label copy for the exhibition. The educator's narrative had distilled the curator's narrative to its simplest form, essentially an outline form that could be easily scanned and reorganized. The label copy then took the educator's narrative and constructed new text based on a combination of the curator's narrative, conversations with the curators and other dog experts, the educators own investigations, and encounters with artifacts created by other members of the Dogs Group such as Evan's Dog Component List and Martin's concept maps.

Gradually the label copy supplanted the educator's narrative as the dominant structuring artifact—the master artifact.

The educator's narrative, and later the label copy, was used to coordinate the activity of the entire Dogs Group. Like compilation artifacts, structuring artifacts are used to coordinate media and understanding, but unlike compilation artifacts, structuring artifacts are also used to establish ordering principles and tenor of narratives.

Structuring Artifact Example 3: Concept Maps and the Notion of Hierarchy

Martin's concept maps were bubble diagrams that showed the structure of sections of the exhibition. Early drafts of the concept maps were hand drawn and were created by Martin, Elaine, and Brad and were comprised of a large bubble with the main idea for the section and smaller bubbles containing sub-topics that were linked to the main idea with simple lines. Each sub-topic could be linked to a set of lesser sub-topics that were in bubbles that were smaller yet. Later versions of the concept maps were drafted by Martin on his computer and printed out for meetings. The maps also included section numbers from the educator's narrative and replaced the singular bubble shape with three or four different shapes to indicate hierarchic level.

Martin intended for the concept maps to fulfill two functions: re-organize sub-topics into related clusters within the exhibition sections, and establish a hierarchy of ideas so that more important topics could be visually emphasized in the exhibition. While Elaine, a curator, was familiar with the purpose of concept reorganization, unlike the educators, she was unaware of the role of the concept map as a tool for establishing a visual hierarchy. In contrast the educators, Hannah and Emma, believed that the concept map was purely for helping the exhibit designers with the three and two-dimensional design of the exhibition. It was no wonder then, that they expressed some frustration when Martin presented later versions of the concept map to the Dogs Group and Brad and Elaine began to rearrange concept bubbles. With their understanding of the role of the concept map, Emma and Hannah saw Brad and Elaine's second round revisions of the concept maps as an unfortunate side effect: changes on the concept map generated a lot of additional work. The act of the curators rearranging the concept map meant that the educator's narrative would also have to be rearranged and the label copy that had already been written would have to be revised.

Martin believed that his role as a designer went beyond the design of the two and three dimensional elements of the exhibition. He believed that his role should include designing the structure of the concepts within the exhibition. He also thought that the concept map was a way that he could directly engage the curators in the conceptual design of the exhibition. Martin's structuring artifact was produced partially to help his own community of practice, but he also used it

indirectly to help that of the curators because he believed that the message of an exhibition should come from the curators.

Hannah and Emma sat patiently through a couple iterations of Martin's concept maps with the understanding that they were helping Martin to put concepts in a hierarchy of importance for the purpose of emphasizing concepts visually. But ultimately, the concept map was hardly used for that purpose. Most of the exhibition was comprised of kiosks and the size and shape of the kiosks were limited to two basic styles. The decision to use only two basic styles was a business decision to make fabrication easier and faster. The exhibit designers had control over placement of kiosks, wall panels, and islands within the space of each section; However, these decisions were largely determined by practical (e.g. safety and flow) and aesthetic concerns (e.g. making the view of the next section attractive from the point of view of the section in which one is standing). Ultimately the exhibit designers themselves actually had fairly little to work with in order to visually emphasize concepts deemed particularly important. Furthermore, the graphic designers never saw the concept map. Despite Martin's intentions, the concept map was hardly used to influence the visual prominence of the various exhibits. However, it was very much used to promote an alternative to the structuring artifact of the educator's narrative.

The concept map structuring artifact was also used to direct the activity of others and, less successfully, to create shared understanding. Structuring artifacts are used to coordinate media and understanding but, unlike compilation artifacts, structuring artifacts are also used to establish ordering principles, establish tenor of narratives, and to direct the activity of others. Structuring artifacts can be used to promote alternative ordering principles and alternative protocols that shake the status quo.

5) Borrowed artifacts are artifacts that are taken from its creator in one community of practice and used in unanticipated ways by those in another community of practice. Designers use borrowed artifacts to augment their understanding of design problems. The practice of borrowing occurs when communities of practice are in close proximity.

Example: Brent's Physical Design Collages

In January of 2002, the fabrications coordinator, Brent, spoke to the NHM Dogs staff to ask for more specifics about the exhibits that were to comprise the final exhibition. He was concerned that he did not have enough information to allocate human resources in the upcoming months. Brent needed to know what sorts of exhibits were going to be built and how many of each type. He was not getting the type of information he needed in order to begin building the exhibition. The rest of the Dogs Groups replied to his request with pleas for patience—they would get to it soon.

Consequently, Brent decided to create a self-explanation artifact from several artifacts: two versions of the educator's narrative, the exhibition floor plan, and the concept sketches. He incorporated these three different types of documents into a self-explanation artifact without the knowledge of the producers. Using scissors, he cut pieces from the documents he had gathered and pasted them to blank sheets of paper. Each fully assembled sheet represented one exhibit.

Brent created a self-explanation artifact in much the same way that Emma created her Images and Artifacts table. However, in this case we have a borrower from one community of practice borrowing artifacts from two other communities of practice: exhibit design and education. The concept of borrowed artifacts is focused on the procurement of an artifact and not its creation. Therefore borrowed artifacts are can be used as another type of boundary negotiating artifact, sometimes being physically transformed in the process. In our example, Brent takes objects that he finds useful and adopts them for his own purposes: creating a self-explanation artifact.

The importance of borrowed artifacts is that they imply a special kind of relationship between communities of practice. The communities of practice must be in close enough proximity that they are aware of the artifacts created by other communities of practice, and while not having dual membership, is in a trusted position whereby he or she has access to those artifacts and can appropriate them for his or her own community of practice to further the goals of the project. Furthermore the community of practice that produces the artifact bears no burden for making their product intelligible or useable for the borrower's community.

Discussion of Boundary Negotiating Artifacts

Each type of artifact is entangled in a mesh of practices. The Dogs Group was relatively unaccustomed to working together and was also unaccustomed to working on a project of this size and complexity so some practices were more evolved than others.

The practices surrounding self-explanation were fairly evolved because each team member had years of specialized experience with artifacts in their own field. Each team member had years of specialized training and experience that helped them create self-explanation artifacts for recording and analyzing ideas in ways that were understandable and helpful to themselves and to those from similar backgrounds.

The practices surrounding inclusion artifacts were fairly simple: involving creating and proposing on the part of the artifact's creator; and accepting, rejecting, or reserving judgment on the part of the receivers (the other communities of practice). Including, and the related practices of accepting and rejecting, took up a great deal of time during the meetings of the Dogs Group. These practices were stable and occasionally including practices would take place without the actual creation of an inclusion artifact.

Unlike with self-explanation and inclusion artifacts, the practices surrounding compilation artifacts and structuring artifacts were not well-developed and required the development of new practices. This resulted in confusion and conflict. The curators, educators, and the exhibit designer each produced their own structuring artifacts and they each had their own expectations for how their own artifacts and those of others would be used.

Boundary negotiating artifacts are used to: record, organize, explore and share ideas; introduce concepts and techniques; create alliances; create a venue for the exchange of information; augment brokering activities; and create shared understanding about specific design problems. The taxonomy of boundary negotiating artifacts and its sub-concepts of inclusion, self-explanation, compilation, structuring, and borrowed artifacts illustrates artifacts in the context of their use.

Implications for CSCW

Boundary negotiating artifacts may be considered to be an extension of previous work on coordinative artifacts such as ordering systems, intermediary objects, and prototypes. The concepts of structuring and compilation artifacts resonate with the concepts of ordering systems (Schmidt and Wagner 2005) and intermediary objects (Boujut and Blanco 2003)—and to a lesser extent to the concept of prototypes (Subrahmanian, Monarch et al. 2003).

Simultaneously, boundary negotiating artifacts are a first step towards a theory of boundary negotiating which is a model of collaboration that: 1) does not presuppose fairly high levels of coordination, 2) does not focus on coordinative aspects of artifacts at the expense of disruptive aspects, and 3) involves artifacts that are not "standardized inscribed artifacts (Schmidt and Wagner 2005)" such as those found in ordering systems. A great deal of boundary work has to do with the discovering, testing, and pushing of boundaries. By extension collaborative work can involve discovering, making, testing, developing, and arguing over practices and how to instantiate those practices into intermediary artifacts and end products.

Strauss (1988) noted that projects could be mapped according to two axes: from routine to non-routine and from simple to complex. On these axes projects fall along a continuum. Routine projects have project paths that have been traversed frequently, with clear and anticipatable steps, experienced workers, an established division of labor, stable resources, and strategies for managing expected contingencies. Non-routine projects would have projects paths that have been traversed infrequently, with unclear steps, inexperienced workers, an unclear division of labor, etc. Complex work includes that which has many workers and many types of and levels of workers, a complicated division of labor, variable worker's commitments, possibly more than one explicit project goal, and a complex organization context for the projects. A simple project would have few

workers, few types and levels of workers, a simple division of labor, similar levels of commitments from workers, an explicit project goal and a simple organizational context. If we apply Strauss' definition, Star and Grisemer's prototypical boundary objects (1989) were part of a somewhat routine and fairly simple project because Grinell and Alexander were in the position of having stable resources, had the authority to dictate clear and anticipatable steps, had experienced workers, an established division of labor, an explicit project goal and a simple organizational context. Perhaps boundary objects are found primarily in fairly routine or fairly simple work projects. Boundary negotiating artifacts on the other hand might be more prevalent in projects that are fairly non-routine and fairly complex.

We might consider that not only do projects fall along the two dimensions Strauss described, but particular constellations of artifact types may also correspond with project location on those two axes. At each point in space, perhaps a whole taxonomy of artifacts including, but not limited to, boundary negotiating artifacts and boundary objects, may be prevalent.

The artifacts I saw in use mostly did not have a standardized format and were not devised in a collaborative process. Collaborative work can be highly contested and practices and artifacts are not always well understood. Alignments can be partial, shared understanding between groups can be spotty, and these breaks in alignment extend to understanding and use of representational and coordinative artifacts. Further research might explore more fully the relationship, or lack thereof, between boundary objects and boundary negotiating artifacts. The concept of boundary objects is important and is deserving of more research, but we must also push past the assumptions of standardization and stable boundaries between communities on which it lies. Perhaps boundary negotiating is part of a process by which methods are developed and become standardized (Remember *methods standardization* the less glamorous sibling of boundary objects?) Or perhaps, even more intriguingly, future work may find that boundary negotiating is an alternative form of collaborative work that is advantageous for certain types of circumstances (e.g. short term or highly innovative projects).

Conclusion

Since beginning this work, I was asked by someone in the CSCW community, "Isn't this just a story about people behaving badly?" The answer is no. This is a story of perfectly nice people with a common goal behaving rationally on a project that was highly complex and non-routine. Could the assumption of well-ordered and deliberate progression in the design process be clouding our vision? Might we be dismissing complex and non-routine collaborations as "people behaving badly" so that we can return to the safety of standardized artifacts and stable organizational contexts? Perhaps the artifacts and protocols found in these

situations can be most easily codified into our computational systems, but for the purposes of creating a theoretical foundation for CSCW we should try to do more.

In his work on the articulation process and project work, Strauss (1989) noted that that articulation work is but a constituent element of the articulation process. Articulation work refers to the putting together of tasks and aligning lines of work in the service of work flow. The articulation process includes articulation work, but also includes *interactional processes* such as negotiating, persuading, education, manipulating, and coercing. Furthermore, he noted that these interactional processes occur at different levels of organizations and require continual alignment. Articulation work as Strauss conceived it in occurred within an organization and within a project group that was subject to manipulation and coercion. It's not a pretty picture of collaboration, perhaps, but indeed this is much closer to the picture formed by this research.

I have attempted to document a movement within CSCW that branches out from the concept of boundary objects and forms a new constellation of theoretical constructs that lie in the considerable space between chaos and routine. Conducting additional studies of how incipient collaborations create and use artifacts to negotiate and establish boundaries, and that explore the relationship between boundary negotiating artifacts and boundary objects may prove to be fruitful for developing increasingly sophisticated theories of collaborative work.

Acknowledgments

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