Understanding objects of design

Jennifer Whyte[1], Boris Ewenstein[1], Michael Hales[2] and Joe Tidd[2]

[1]Innovation Studies Centre, Tanaka Business School, Imperial College London, UK.

[2]SPRU – Science and Technology Policy Research, University of Sussex, UK.

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Introduction

We rarely stop to think about the objects that surround us. The schedules and charts, schematic layouts, bills of materials, photographs, plans and sections that form part of everyday life on projects. The whiteboard diagrams, documents, internet pages, corporate logos, business cards and address lists associated with life within the corporate office. Or the instrumentation, electronic circuitry; mechanical parts and hand-held tools of the high-tech research laboratory. In everyday work such objects become normal to us, to the extent that they become unremarkable – part of the background to our working lives. Yet there is growing understanding that these objects and artifacts play a significant role in organizational knowledge practices; and must be understood within this context.

Scholars' wider resurgence of interest in objects – the things of everyday life – has led to more precise articulation of their role within the literatures on organizational knowledge and learning (notably in Engeström and Blackler (Eds.) 2005). Across these literatures, they have been described variously as *boundary objects* (Star and Griesemer 1989; Carlile 2002) to draw attention to their role at the interface between different epistemic communities; *epistemic or trans-epistemic objects* (Knorr-Cetina, 1982; 2001; Ewenstein and Whyte, 2005) where the focus is on their role in the development of new scientific and technological knowledge; and *artifacts* (Bechky 2003; Bechky 2003); Suchman, 2005), in work that explores knowledge translation and power. When taken together these literatures improve our understanding of the mediating role of objects – in both constructive and, at times, conflicting ways (Oswick and Robertson 2005).

What is missing from these literature is a sense of how *use* of these ‘things’ is patterned across different institutional settings and across time. Every working life had its own tempo, beat, rhythm or pace. When there is excessive task conflict or disruption this can lead professionals to feel they have a ‘time famine’, lacking the adequate quantity of time to do their jobs. Perlow (1999) has shown that in some cases structuring work differently can make it possible to accomplish more in the same or less time. Interaction with objects through time plays a role in this, and this raises a number of questions. What constitutes a useful object for new product development in different industrial contexts, when and why? What different types of objects are used? And how can they be used better?

Our research addresses these questions through in-depth study of knowledge work in two cases – the design department of a capital goods manufacturer and an architectural design firm. We have a particular focus on visual representations, which we see as an important sub-set of the objects used in knowledge work. In the next section we briefly describe the methodology for the research; then in the following section we outline our observations of the use of visual representations in design within each of the contexts. The findings of our empirical research point to the role of freezing and unfreezing objects in the evolution of business knowledge, both to achieve co-ordination over time in the development of new ideas and to engage wider stakeholder groups in the approval process. After outlining the research and its findings, we conclude by discussing their implications for theory, policy and practice.

Method and Setting

In this work, we see knowledge not so much as a static substance but as part of practice (Knorr Cetina 1999; Gherardi and Nicolini 2000). It is a situated accomplishment, rooted in distinct material contexts and social relations. In order to investigate the formation and change of design knowledge in real-life contexts, we observe practice and knowledge *in action*, focusing on the interactions amongst subjects and between subjects and objects.

We studied knowledge work in two distinct industrial contexts, to enable comparative work during the analysis of empirical observations, and in order to build broader understandings of the phenomena studied. The groups of practitioners in both of the industrial contexts are involved in conceptual design work; both groups make extensive use of visual materials and both are dependent on collaborative knowledge work across boundaries for product delivery. However, the industries within which these groups are active (high-tech manufacturing; construction sector) are distinct: different markets imply vastly different business and design knowledge at work. During our research, this difference in the conditions of knowledge work gave rise to the question of how objects, especially visualisations, would be used in contrasting and consistent ways.

As a research project, the research reported in this paper involved multiple researchers and substantial research effort over more than three years. The second and third authors spent six months observing work in the architectural design firm, and the capital goods manufacturer respectively. We were involved in set-up meetings; follow-up interviews and feedback sessions with our industrial collaborators. Though as a research team we are spread across two institutions, we all met regularly to discuss emerging findings.

We studied knowledge-work within Edward Cullinan Architects, one of the leading architectural practices in the UK. The practice founded in 1965 by Edward Cullinan (commonly known as Ted), and has designed housing developments, office spaces, visitor centres, educational facilities and various mixed use buildings within the UK and internationally. There is a strong culture within the practice that puts an emphasis on the collective. During our research, the second author spent many hours shadowing staff on two projects, attending meetings, visiting the site and spending time in the single, open, office space in which all members of staff work.

We also studied knowledge-work in a capital goods manufacturer, HighTech (a pseudonym). This firm operates in an intensely competitive global market via a constantly evolving base of process-technology products (including servicing the installed base), advanced, proprietary knowledges in applied physics and engineering, and ongoing relationships with primary customers in various market segments. We signed a confidentiality agreement with the firm to get deep access into their practices. During our research, the third author examined the work practices associated with new product development in one division. These activities span the transition from exploratory research and market feedback, through engineering and product conceptualisation, to commitment of assets for prototype manufacture and release of beta-status products. Unless otherwise indicated, use of HighTech below refers to the product division being studied, rather than the entire trans-national corporate entity.

Visual Practices around ‘Fluid’ and ‘Frozen’ Materials

In both of our research contexts, the data suggest that visual materials can be treated as fluid, open and dynamic; or as frozen, and hence unavailable for change. We class the many different types of visual representations used in practices as fluid, when they are altered through the unfolding practice; or frozen, where they are referred to and talked about but themselves remain unchanged. In specific cases, their status can shift from one classification to the other, depending on the context of their use. Hence the categories 'fluid' and 'frozen' are not absolute but a matter of degree. In ongoing design processes, representations of both types are identified with respect to the local aims that practitioners pursue. They reflect two fundamental properties in the knowledge generation process, as noted by Rheinberger (1997) in relation to all objects: that they can be epistemic things – acting themselves as the objects of knowledge, evolving as knowledge is developed; or technical things – used unquestioningly as tools that facilitate certain kinds of knowledge work.

Across time, the acts of freezing and unfreezing visual representations are important in structuring social relations for delivery. Table 1 shows a number of design related practices that are characteristic for fluid and frozen visual representations in both contexts for research.

<<Insert Table 1>>

Freezing and Unfreezing in Edward Cullinan Architects

In the architectural design firm, our analysis shows that fluid visual representations are used in activities that define design problems and explore appropriate solutions.

Individual designers at work and working design team meetings are characterized by copious sketching. Through sketching, red-lining and generally marking up representations, design problems are identified and defined and corresponding solutions are tested on paper and on screen. The objects that allow such knowledge work to proceed are fluid visual representations whose status is often provisional and in flux. Representations employed in these contexts are characterized by a so-called 'unfolding ontology' (Knorr Cetina 2001). They continuously evolve. Their provisional character, however, does not mean that these visual representations are limited to hand-drawn sketches. A rapid succession of modified hardline drawings, say, can be just as fluid.

<<Insert Figure 1>>

Fluid visual representations are also mobilized when comment, input or modification is required of certain actors participating in the design process. In construction, information exchange across organizational boundaries is a key characteristic of design. Thus temporary or provisional plans, for instance, are sent from the architect to the consultant engineers so that these stakeholders can contribute their perspective to an emerging building project. Fluid representations are progressed as different professionals work on them.

Finally, our observations in the architectural design practice show that fluid visual representations are used for collective sensemaking (Weick 1995). In certain explicated respects, different stakeholders have a different understanding and

appreciation of a design project. For the services engineer, the building project might represent a tricky challenge with regard to zones of climate control, the structural engineer might have a view of the project as being centrally about walls that satisfy certain fire protection requirements whilst maximizing floor space, the quantity surveyor may view the building as a bundle of costs to minimize and so on. Elsewhere, we have studied the role of visual artifacts in mediating such trans-epistemic understandings, ranging across a wide range of expertise (Ewenstein and Whyte 2005). However, there are also shared interpretations of what the building or aspects of it are supposed to constitute. Stakeholders may have different perspectives specific to their functional responsibility, but it is equally important to foster a joint vision of a building project. Fluid, unfrozen drawings are often used in the processes of collective sensemaking. As design team members interact in face-to-face meetings, they modify and annotate fluid visual representations. Through the process of modifying drawings together a shared understanding is established.

Frozen visual representations are characterized by more certainty. This certainty is rarely absolute. Instead, it is bounded and specific to design episodes. Frozen objects in design are not available for change *now*, though they might be modified in the wider evolution of the project. But within a situated context, the knowledge expressed is far less in question than in the case of fluid representations. For this reason, frozen representations perform a number of different functions in the context of architectural design. Whilst they can also be used to achieve collective sensemaking, they are often used for accounting and record-keeping purposes; to elicit buy-in and to get sign-off; to deliver specific information to actors whose progress depends on such information, and they are used for tactical and political reasons. We will discuss these functions in turn.

Collective sensemaking can involve frozen representations. Representations that depict a given state of affairs in an accomplished or solid state approximate what Latour calls ‘immutable mobiles’ (Latour 1986). These images are imbued with power. As they circulate, they create a dominant view of the object represented across the various audiences that behold the image. They are normative and help to establish a consistent view of things precisely because their content is delivered in a largely immutable form. In the architectural work that we observed, a hardline hand-drawing produced by the founder of the practice, Ted Cullinan, serves as an example here. The completed drawing was viewed by members of the design team inside the practice as setting out a possible vision for the extension of the Herbarium at Royal Botanic Gardens in Kew, London. The immutable drawing, which would not be marked up, set out a design concept that supported a shared understanding of the project. Collective sensemaking through frozen representations also occurs in much more pragmatic terms through representations of processes in, say, organization charts or timelines (so-called Gantt charts or procurement schedules). These objects define a shared sense of how the project should unfold in time.

Whilst collective sensemaking occurs through the use of both fluid and frozen visual artifacts, frozen representations also perform a number of tasks distinct from fluid ones. In the context of everyday design work in the construction sector, frozen visual representations are used for consulting with actors and giving actionable information. In the case of detail design, for instance, highly specific information is circulated in the shape of frozen visual representations from one consultant to another to allow design work to progress. In one instance we observed, Edward Cullinan Architects circulated their design of balconies to the structural engineers so that they could finalize their structural design work in the context of a residential building project. In

other instances, we could observe how the frozen ‘shop drawings’ of manufacturers’ window, elevator or kitchen products were employed by architects to finalize their designs of the residential building.

Furthermore, frozen visual representations are also often used to circulate information to actors in a wider network of stakeholders such as planning officials or end-users. Stage reports, issued in accordance with Royal Institute of British Architects (RIBA) specifications, are generally frozen. The documents are circulated for information rather than for modification (though early drafts are often sent out for consultation). They are frozen to establish the details of the design to date and to bundle an amount of work which can be approved by and treated as a deliverable to clients. Frozen visual representations, then, are a central medium to elicit buy-in and achieve a state of ‘sign-off’. In other instances, visual representations are frozen for planning submission, in order to allow a design to be costed or assessed for standards compliance such as BREEAM (Building Research Establishment Environmental Assessment Method) specifications. Finally, frozen visual representations are used for accounting and for keeping a legitimate project record.

In the context of pursuing these and other aims, frozen visual representations are often mobilized in a subtly political way. Practitioners can mediate power relations amongst themselves and other stakeholders by managing what is and is not shown, how and when. Frozen representations can more easily steer meaning and project narrative and thereby influence the kinds of understandings different actors develop. They can become a tool for the exercise of power. In addition to mediating collaboration, they can be contested and struggled over as design decisions are taken (Bechky 2003; Bechky 2003).

Freezing and Unfreezing in HighTech

In the high-tech manufacturing context, fluid representations are equally used to define design problems and to explore solutions. However, in the case of HighTech, a distinction can be made that is not apparent to the same extent in the context of architectural design. On the one hand, designers in HighTech employ fluid visual representations to work on *engineering* design problems; on the other hand, they work on *product conceptualisation* problems. Engineering design problems relate to technological issues concerning a machine being developed by HighTech. Conceptual design problems, however, extend beyond the boundaries of the machine and its performance as a piece of equipment. Conceptual design problems can involve the performance of the machine as a product in circuits of commodity exchange. The object of design here are cost characteristics, profit margins, marketing positions and value propositions with a view to certain kinds of customers, and the timing of moves in the marketplace. In architectural design, buildings are often designed as one-off creations. They must perform against a client brief but not, as in HighTech, as investments of capital in commodities, marketed through product lines, generating a distribution of revenue over time.

<<Insert Figure 2>>

In regard to engineering design issues, fluid visual representations are used in the context of cube ‘huddles’. Huddles are gatherings of colleagues working in HighTech who crowd around a specific workstation. Here, fluid CAD representations are used to explore the 3D form of the machine being designed. Cube huddles are characterised

by talking and pointing to a 3D CAD image manipulated in virtual space by one member of the group. Furthermore, hard copies or whiteboards are occasionally used to sketch developing ideas. As in the architectural case, technological knowledge is evolved through the manipulation of visual materials that are mutable.

This applies equally to work on conceptual design problems that are not primarily about technological issues. In cross-function team meetings, verbal storytelling is used in defining issues and exploring solutions, typically in response to visual representations understood to be fluid. Narratives are generated, for example, about reducing cost and increasing gross margin, about getting and maintaining a footprint in the customer's site and about the acceptance of a given product feature (by a customer) or cost characteristic (by internal management). In distinction with our architectural case, two observations can be highlighted. Firstly, the manipulation of fluid visual materials occurs in a more controlled environment. Certain actors, often those who could be understood as the ‘authors’ or ‘owners’ of representations, are tasked with evolving the drawings. This is distinct from architectural design team meetings where prints of plans and sections are often freely modified by those attending, be they members of Edward Cullinan Architects, consultant engineers or other stakeholders such as landscape architects. Secondly, narrative plays a slightly more prominent role in the interactions with visual materials. Storytelling can be seen to precede visual manipulation, which follows in a more narrowly defined way. In architectural design, we could witness laconic dialogue and discontinuous narrative, where interaction was strongly mediated by the process of drawing or sketching; indeed, a process through which a narrative would begin to crystallize and consequently become defined. Drawing was part of the exploration and discussion, rather than the visual articulation of outcomes from a verbal discussion. This

difference in the processes of working with fluid visual materials is again expressive of different regimes of control. HighTech appears as an environment wherein visual materials are handled in a more prescribed way.

Fluid visual representations are also used to provide commentary, to offer input and for modification of existing understanding. Within teams, for instance in the cube huddles noted above, annotations on hard copy are used. In formal cross-function communication, representations created by others can be marked-up through the use of so-called 'redlining' overlays or through activating comment layers in digital documents. Email is also universally employed as a *de facto* 'comment layer' for representations enclosed or linked to on servers. As in the architectural design work observed, fluid representations are progressed as different actors work on them. This input, however, is more formally articulated through the use of multiple levels of communication such as mark-up overlays and comment functions.

In regard to the processes of collective sensemaking (Weick 1995) the use of fluid representations can be noted. Fluid 3D CAD representations are used in huddles around workstations for sensemaking regarding the form and function of the machine. In such huddles as well as in formal meetings, verbal storytelling also constitutes a key part of sensemaking regarding the business context and the desired product qualities. With regard to the architectural case, we can recall that as design team members interact in meetings, fluid visual representations are modified and annotated. Through the process of modifying drawings together a shared understanding is established. In HighTech sketching on visual representations is far less visible in this respect and verbal discussion plays a key role in collective sensemaking. Although somewhat simplified, we observe (in relation to the commonplace that ‘a picture is

worth a thousand words') that in HighTech a picture is an occasion for a thousand words, while in Edward Cullinan Architects, along with words, a picture is an occasion for another picture.

Collective sensemaking also involves many frozen representations, even informal sketches. In cube huddles or cross-function team meetings, frozen representations (very often in the form of charts) are used to construct shared contexts for problem definition and solution. In one specific example, a product launch timeline sketched by the General Manager on a whiteboard and captured as a PDF file served for several weeks to orient conceptual design and detail design. In general, frozen timelines are widely used to orient cooperation, problem definition and problem solving. They may be frozen by external negotiation (e.g. projected industry and market trajectories) or by internal authority (e.g. through senior management decisions). Other representations regarded as frozen serve similar collective orientation functions, notably financial projections and operational schedules. Elements of frozen representations (e.g. charts) are widely cannibalised in PowerPoint presentations, from publicly accessible master copies. Thus the normative content is reproduced as these 'immutable mobiles' are presented again in different contexts. As noted in the case of architectural design, power operates through the calcification of knowledge in the form of frozen visual representations.

In addition to collective sensemaking, frozen representations are used to share information and to consult with different actors throughout the design process. Representations which will be fluid in meetings are frequently circulated ahead of meetings or posted on the common-access server as unmodifiable images such as PDF or JPG files. Frozen visual materials are also used to mediate different inputs and

modifications. They characterise formal workflow handovers, when other parties take over in the design process, or formal iterative processes between actors. Iterative responses are made via separate representations, for example in the form of 'Engineering Responses' to drafts of the Marketing Requirements Specification. This creates an audit trail and enables version control. Thus, frozen visual representations are also a central component of accounting and legitimate record-keeping. Items in a legitimate audit trail are frozen, by definition.

In addition to record-keeping, accounting and information circulation, frozen visual representations are used in HighTech to elicit buy-in and to achieve sign-off. In the final sign-off of a product release across different functional groups a frozen representational medium is mandatory. A software tool linked with a central database called the business-process 'wizard' is used here to represent knowledge that is well-defined, with minimal if any ambiguities remaining. However, buy-in and sign-off can also be achieved in response to visual representations understood to be fluid. In formal meetings (notably, design reviews) representations are typically open to comment and negotiation, as distinct from hands-on modification. Agreed modifications are typically made post-meeting, by the ‘author’ or the ‘owner’ of the representation. In the architectural case observed, fluid visual representations were not characteristically used to achieve sign-off.

Finally, tactical maneuvering and political purposes are also pursued through the use of frozen visual representations. In the cross-function meeting at the launch of a new program, mandatory specifications are displayed and mandatory forms must be completed. Thereby project roles in cross-function workflows and teams are defined. In fortnightly cross-function project reviews, mandatory metrics of project

completeness are generated and displayed. In one very rare instance, a formal representation (a mandatory spreadsheet, programmed to calculate risk scores for projects) was used in fluid mode in a cross-function meeting. This was 'political' in the sense that the output value was predefined (by previous high-level agreements), requiring the participants to negotiate the realism of various sets of input values. This situation differs from more usual ‘fluid’ situations in a formal meeting setting in HighTech, by involving direct hands-on use of a fluid representation.

Discussion and Implications

The previous sections explore inter-relationships between knowledge, objects and practice in two different industrial contexts. We find that the visual practices in these two contexts involve materials that are ‘fluid’, open to change through the activities of practitioners; and ‘frozen’, held stable during the work in hand. We find this distinction to be important when looking at the evolution of knowledge in the two settings that we studied.

This analysis is not intended to suggest that visual practices are identical across the two settings. Far from it. The data shows marked contrasts in the nature and focus of visual practices in these settings. In the architectural practice, Edward Cullinan Architects, designers are engaged in the design of a complex and inaccessible product with unknown components and configuration. The visual practices are focused on understanding this one-off intangible product. As there is a high degree of novelty from one design project to another, there is a reliance on drawings to understand the configuration of the product. These visual representations are made malliable in the discussion of design across cross-functional design teams. In contrast, the capital

goods manufacturer, HighTech, is engaged in design of a complex but accessible product with known components and configuration. The visual practices used reflect the relative stability of the design across a family of products – the basic configuration is so well known to the practitioners involved in design that it has been internalised: they often do not need to draw it. There is, however, a greater reliance on drawings for mapping processes and for co-ordination – notably, representations of events in time. Within HighTech objects are fixed within the formal coordination/ negotiation meetings and unlocked only in more informal settings. Formal meetings between stakeholders are frequent in HighTech as they are employees of the same company and occupy the same building. These marked differences in the information needs and work relationships in HighTech and Edward Cullinan Architects lead to different knowledge practice and hence different patterns in the use of visual representations.

Despite these marked differences, the process of freezing and unfreezing design plays an important part in the structuring of social relations for delivery in both contexts. Over the course of a design project, representations necessarily evolve as the project is increasingly well defined. However, there are tactical and strategic instances when certain representations are frozen so as to achieve particular outcomes in the context of specific episodes within the design process.

Tactically, freezing within a design episode allows certain forms of knowledge to be held constant and in focus as other forms are worked on. The frozen representation serves as a solid tool that enables the modification of another representation that depicts more provisional design work. The frozen representation takes the form of Rheinberger's (1997) technical object while the representation that is worked on and that is evolving bears the hallmark of an epistemic thing. With Knorr Cetina (1997;

2001) we can describe the overall design for the projected building as an epistemic object, showing what is known and alluding to what is not yet known. The drawings are thus characterised by a so-called unfolding ontology, which means that it is in their nature to unfold and evolve incessantly. Overall this is accurate, yet in more focused instances the general roll of unfolding is interrupted with instances of images made static, i.e. frozen.

Strategically, representations can be made immutable and circulated to clients or planners to achieve a specific kind of interpretation of the project more amenable to the aims of the design team. The aim here is to control meaning-making processes that occur through visual representation. By presenting certain projected realities in specific ways, the immutable image seeks to elicit a particular response from its beholder.

Hence, the phenomena of freezing and unfreezing serve contrasting organizational functions: both aim to achieve co-ordination over time in the development of new ideas and to engage wider stakeholder groups in legitimation processes. This has a number of implications. Practitioners may be able to improve their working practices by monitoring their use of visual representations, in particular how they freeze and unfreeze these epistemic objects through time for co-ordination and legitimation purposes. Both for individuals and for groups awareness of the temporal patterns of freezing and unfreezing can aid the development of professional judgement through reflective practice.

Much of the current focus of research is on collating, maintaining and managing information and knowledge. Yet when considering the temporal nature of visual practices, we might want to reframe the question addressed to focus on the discarding

of information and knowledge to minimise time pressures on professionals. The study of visual practice in these two contexts raises fundamental questions about the practices of visualization that are particularly pertinent given demands for greater access to information. Further research could explore these in the context of the design of complex and safety-critical systems where there are demands to record not only the details of the product, but also formal descriptions of processes and records of the rationale for design decisions.

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[to be added]

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	Fluid representational form	Frozen representational form
Edward Cullinan Architects	• Definition of design problems; exploration of solutions • For comment, input and modification • For collective sensemaking	• For consultation/ for specific actors' information • For eliciting buy-in and getting sign-off • For collective sensemaking • For tactical and political reasons • For accounting and keeping a legitimate record
HighTech	• Definition of *engineering* design problems; exploration of solutions • *Product conceptualisation* problems; exploration of solutions • For comment, input and modification • For collective sensemaking	• Definition of design problems; exploration of solutions • For consultation/ for specific actors' information • For comment, input and modification • For eliciting buy-in and getting sign-off • For collective sensemaking • For tactical and political reasons • For accounting and keeping a legitimate record

Table 1: characteristic design practices with fluid and frozen visual representations

Figure 1: interactions with visual representations, some of which are fluid and some of which are frozen, in design work at Edward Cullinan Architects



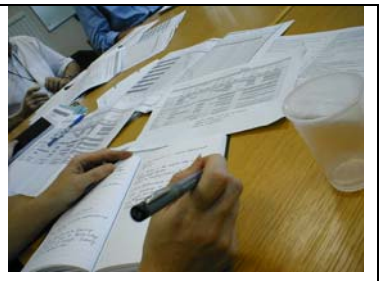

Figure 2: interactions with visual representations, some of which are fluid and some of which are frozen, in design work at HighTech