Storytelling and the development of discourse in the engineering design process

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Engineering design is often perceived as a mainly technical activity yet within the engineering design organisation it really only coheres as a social activity. This paper describes a study of engineering design as *a social activity in a small design and manufacturing organisation, using the social scientific method of ethnography. Ethnography is characterised by detailed observation of social groupings and close attention to empirical, and mainly qualitative, data. The paper explains how social experience is acquired and used in the design process through the mechanism of storytelling, and concludes that ethnography can provide considerable insight into behaviours that are usually 'taken for granted'. Storytelling appears to be a central mechanism in the development of a common language in design teams. Something that is often thought to be a useful indicator of good design.*

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There is a prima facie argument for considering engineering design as a purely technical activity, albeit one requiring considerable artfulness. The proliferation of writings and systems that promote a view of engineering design as 'simply' one of technical optimisation is a view that has logical consequences in the ability of technology to design for us in absentia[1,2]. Yet engineering design really only coheres as a social activity in a collective context. Most engineering designs are the products of organised effort that transform a set of requirements into a reality. Brunel himself was famous for encouraging and effectively communicating with the engineers who worked around him[3]. If the 'technical' view applies anywhere it is much more likely to apply in disciplines of industrial design or architecture where designs are much more attributable to individual cognitive effort. So it is a curious anomaly that the enduring image of the

1 Zavbi, R and Duhovnik, J 'The analytic hierarchy process and functional appropriateness of components of technical systems' *Journal of Engineering Design* Vol 7 (1997) pp 313–330
2 Harrison, K and Wilson, C C 'Evaluating configuration complexity in machines' *Journal of Engineering Design* Vol 8 (1997) pp 165–174
3 Pugsley, A (ed.) *The Works of Isambard Kingdom Brunel: An Engineering Appreciation* Institution of Civil Engineers, London (1976)

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engineering design process should be of a technical, 'mechanical', even in some respects anti-social, process. Correspondingly, although many articles recognise the primacy of social interaction in the design process, there have been few studies of engineering design *as* a social activity, Bucciarelli's studies on the subject perhaps being the best known[4,5].

Normative models of the engineering design process reinforce the technical aspects of engineering, claiming design to be a well-defined procedure that starts with a concept and steadily progresses through detail to manufacture[6]. This view is trivialised here to make a point. There are surely aspects of normative models that are important, but a normative model, by definition, does not cover the social reality of any particular design process. This reality is necessarily more complicated. It is, then, the purpose of this paper to outline the methods of ethnography, which can elucidate this social complexity through the 'rigorous understanding of the shared schemes of reference and accounting practices through which organisational members construct and comprehend the social orders of which they are a part'[7]. In effect ethnography provides a way to problematize normative engineering models by questioning how they affect, and can be contrasted with, engineering design practice.

1 *The ethnographic approach to organisational complexity*

Ethnography is an inclusive term that encompasses a wide range of approaches to the study of foreign cultures. Initially for ethnography these *really were* foreign cultures[8,9] but more recently 'culture' has tended to mean sub-cultural groupings[10], and most recently organisational culture[11–14]. Correspondingly the 'pure' ethnography characterised by years of observation—literally living in foreign cultures—has mutated into various types of 'quick and dirty' approaches[15,16] where a number of weeks are thought sufficient to understand the working practices of an organisation. What is constant is the general attitude to data adopted by the ethnographer; an emphasis on staying close to what is actually said and observed, when explaining social mechanisms, and a willingness to forgo specific hypotheses and consider virtually anything one sees and hears as data, in an emergent understanding of a culture.

This raises the question of how the ethnographer *does* explain social mechanisms and cultural behaviour. Clearly some degree of translation has to take place, and one of the key features in an ethnographic explanation is making the unfamiliar familiar by drawing analogies between cultures. This is, in effect, saying: 'this practice *x* that we observed is really quite like this practice *y* that we commonly understand'. There are theoretical issues

4 **Bucciarelli, L L** 'An ethnographic perspective on engineering design' *Design Studies* Vol 9 (1988) pp 159–168

5 **Bucciarelli, L L** *Designing Engineers* MIT Press, Cambridge, MA (1994)

6 **Pahl, G and Beitz, W** *Engineering Design* The Design Council, London (1984)

7 **Fischer, M D and Finkelstein, A** 'Social knowledge representation: a case study', in *Using Computers in Qualitative Research*, **Fielding, N G and Lee, R M** (eds), Sage, London, UK (1991) pp 119-135

8 **Mead, M** *Coming of age in Somoa: A Psychological Study of Primitive Youth for Western Civilization* William Morrow and Co, New York (1988)

9 **Descola, P** *The Spears of Twilight: Life and Death in the Amazon Jungle* HarperCollins, London (1996)

10 **Garfinkel, H** *Studies in Ethnomethodology* Prentice-Hall, Englewood Cliffs, NJ (1967)

11 **Gregory, K L** 'Native-view paradigms: multiple cultures and culture conflicts in organizations' *Administrative Science Quarterly* Vol 28 (1983) pp 359–376

12 **Kamata, S** *Japan in the Passing Lane: An Insider's Account of Life in a Japanese Auto Factory* George Allen and Unwin, London, UK (1983)

13 **Wilkins, A L and Ouchi, WG** 'Efficient cultures: exploring the relationship between culture and organizational performance' *Administrative Science Quarterly* Vol 28 (1983) pp 468–481

14 **Lloyd, P and Deasley, P** 'Ethnographic description of design networks' *Journal of Automation in Construction* Vol 7 (1998) pp 101–110

15 **Hughes, J, Somerville, I and Bentley, R** 'Designing with ethnography: making work visible' *Interacting with Computers* Vol 5 (1993) pp 239–253

16 **Randall, D, Hughes, J, and Shapiro, D** 'Systems development—the fourth dimension: perspectives on the social organization of work', in **Quintas, P** (ed) *Social Dimensions of Systems Engineering: People, Processes, Policies and Software Development* Ellis Horwood, Hemel Hempstead, UK (1992) pp 197-214

here beyond the scope of the paper but suffice to say this is a rigorous activity. Before one even attempts an explanation one has to organise and group data, classify in manifold ways, make connections of content or time, etc. The manipulation of qualitative data is perhaps something worth emphasising here, and computer tools have helped considerably in the management of the huge volumes of qualitative data one typically gets from ethnographic study.

Coupled with these developments in ethnography are the changing motivations for the parties involved in a study. Initially the sole reason for ethnographic study was for the researcher to understand a foreign culture and communicate this understanding to a wider audience. The ethnographer was a kind of specialist journalist, a documenter of how things actually were. The culture that was being 'understood' often had no knowledge of the purpose of such a study—or even any concept of what a 'study' was—and would not specifically consent to the study taking place. The ethnographer would turn up, ingratiate themselves, stay for a period, and then leave. Clearly organisations are more demanding and participation is often based on some idea of organisational improvement or change. To this end ethnographic study has effectively revealed working practices that have then been supported by new software systems[15,17,18]. Ethnographic studies have also been used to develop a complex understanding of environments as a basis for revealing 'cultural' product requirements[19]. However, without an obvious use there is pressure on the ethnographer to demonstrate improvement in a more reflexive way during the period of actual study. This is perhaps best illustrated with an analogy. In an ethnography of the Achuar, a South American 'head hunting' tribe, Descola[9] describes how the tribesman 'use' the ethnographer to help secure competitive or social 'advantage' over other tribes, for the procurement of weapons for example, or by 'showing off' the ethnographer as a highly regarded guest.

Notwithstanding the foregoing it is probably more accurate to describe the current study of a design and manufacturing organisation as a qualitative study conducted with an ethnographic attitude—in the spirit of ethnography—rather than an ethnographic study *per se*. This is for two reasons. Firstly, the length of the study was only two weeks—hardly enough time to become fully acquainted with the complexity of the organisation. Secondly, the general engineering design sub-culture was one that was familiar to the author. Although the second reason tends to justify the first, it also tends to make the ethnographer's explanation of foreign practice by analogy less significant. With a greater degree of understanding at the outset of the study a more critical approach was taken in the subsequent analysis.

17 **Heath, C and Luff, P** 'Collaborative activity and technological design: task co-ordination in London underground control rooms', in *European Conference on CSCW*, Amsterdam, The Netherlands (1991)

18 **Jagodzinski, P, Parsons, R, Burningham, C** *et al*., 'A socio-technical system for the support of the management and control of engineering design projects' in *First International Engineering Design Debate*, Glasgow (1996) pp 77-108

19 **Rayner, B** 'Now hear this! The black magic of product development' in *Electronic Business Today*, pp http://www.eb-mag.com (1997)

This paper, then, is a qualitative study looking at some of the social mechanisms manifest in a small engineering design and manufacturing organisation. It is structured by firstly giving an overview of the particular method that was followed in the period of observation and the subsequent analysis; and secondly, describing a particular social mechanism of how language was observed to be used in the design process, what will be termed 'storytelling'. To do this three types of experiences in the design process are distinguished—individual, social, and organisational—and the assertion is made that storytelling is a valuable mechanism for encoding social experience. The discussion returns to issues surrounding ethnography and its 'use', particularly the idea that ethnography is a reason giving, and critical activity, rather than the more deductive, and reductive, activity of the conventional scientific paradigm. The paper concludes that ethnography can provide valuable insight into aspects of engineering design that are largely 'taken for granted' in the contemporary literature.

2 *Cirrus Technologies, March 1995–January 1996*

Cirrus Technologies is a design and manufacturing organisation near Birmingham in the UK, employing approximately 100 people and producing bespoke automotive testing systems for customers such as Rover, Vauxhall, Ford, and Nissan. These test systems form part of the customer's automotive assembly line so that when, for example, an airbag is added to the car currently being assembled, it can be tested *in situ* for correct operation. There are thus a number of testing 'stations' that appear at regular intervals on the production line—fascia test, automatic brake test, engine management test, to name a few. Cirrus is responsible for the design, manufacture, and maintenance of these test systems.

The fieldwork for the study took place over a two week period and consisted of two researchers (one of them the author) observing different organisational departments, travelling to customer sites with Cirrus personnel, tape recording and taking notes of: situations, activity, and conversations; and conducting informal interviews. Although video recording was considered as a possible option for data collection, pilot studies showed it to be too indiscreet and uncomprehensive. As much data as possible was tape recorded and subsequently transcribed and, generally speaking, the data was of four types.

- *Interviews* were either semi-structured or *ad hoc*: semi-structured interviews were used to gain an overview of a person's formal role in the organisation, *ad hoc* interviews were used to follow up a particular issue, after a telephone call for example.
- *Field notes* attempted to capture the essence of what was occurring;

key phrases, environmental descriptions, who was talking to whom, subject matter of conversations, etc.

- *Taped segments* of work activity were obtained by leaving an audio recorder running during conversational periods in the office.
- *Corporate artifacts*—quality procedures, newsletters, product information—are all valuable in understanding both the technical and procedural basis on which the organisation rests and how the organisation represents itself.

During the study 30 hours of audio taped material were produced, including 19 interviews and 10 taped segments of work activity. 52 A4 pages of field notes were also recorded. The transcription of the data took a total of four and a half months and yielded 300 pages of text (195,000 words). This data was entered into computer analysis software in the form of 24 documents.

Once classified and coded a general picture of work activity was built up by *asking questions of the data collected*. This is very different from having specific hypotheses as a basis for the whole study and in this respect it is useful to think of the data as text. By asking questions of the text, in much the same way as one might systematically analyse a novel, it is possible to achieve rigorous interpretations supported by textual evidence. One might focus on the efficiency of information transfer between design and manufacture for example, or how the design process of software engineers compares with that of mechanical engineers. These specific questions are issues, certainly, but issues that have a wider context. By intentionally *not* discriminating at the data collection stage it is possible to preserve this wider context for understanding. With this method one builds a general 'picture' of an organisation before raising specific issues.

2.1 Method of analysis

To illustrate how the raw data, or text, is categorised and leads to an interpretation, several examples can be used to show how data is (1) generalised according to content, (2) related to other data, and (3) how a complex view of an issue builds up. Consider the following fragment of text that talks about the vague design specifications that are received by the engineering design manager from the sales department:

'. . . I mean what I've just started last week, for every new project that comes in I'm going to put a requirement for a variance document. The reason I'm doing that is because the orders come in so open—the one pitch quote. What I'm going to get the design engineers to do is, everything that they feel possibly might be an extra, doesn't have to be, but they think "well I'm not really sure, because of the [sales specification]".'

This fragment, one text unit (the lowest unit of meaning in our study), might first be categorised as *design specification*, because this is the ostensible content of the fragment. The text unit also reveals an attitude. The manager clearly feels that the design specifications received from sales are too 'open', so the text unit might also be categorised under *design specification/problems*. Finally in the text unit, the manager (category: *talk—of—manager*) explains his way around the problem by 'getting the design engineers to [list any possible extras]', and this means the text unit would also be categorised under *design specification/solutions*. One might find other things of note in the text unit, and perhaps introduce more categories at a later date.

Another text unit relating to the design specification, this time from the perspective of a software designer:

> 'I can show you some specifications from sales, it tells you generally what the project, works order number is, and who are members of the team, and there's generally the name of the project as well. There is very rarely anything more than that . . . And then you have to start, you know, get on the telephone, or go and talk to the people involved to find out what in fact is really required, to get some idea of, you know, to try and summarise it in some kind of simple way.'

In this text unit the designer outlines what he thinks is usually contained in a sales quote, again he seems to imply that there is not enough information ('there is very rarely anything more than that . . .'), so again a category of *design specification/problems*. He then outlines his way around the incomplete specification ('I'd get on the telephone or go and talk to the people involved . . .') again a category of *design specification/solutions*, though this time from a designer (category: *talk—of—designer*).

From these categories a tree structure emerges. Figure 1 shows how the design process can be broken down into a number of sub-processes and issues. Categories are not mutually exclusive and often overlap—for example the text referenced in *specification* might equally be referenced as something to do with *quality*.

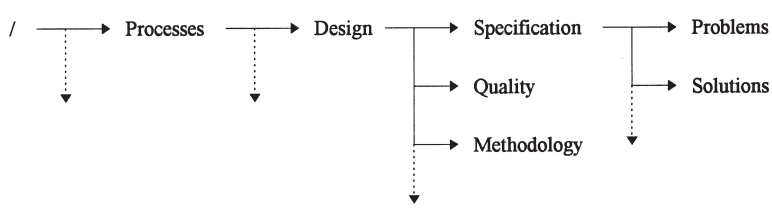

Figure 1 Sub-tree of the Design Process. *Dotted lines indicate connections to other parts of the tree, '/' indicates the tree 'root'. Each 'node' is a pointer to all the textual fragments about the subject of the node, so 'specification' relates to everything that was said, by all categories of person, about design specifications. In this figure the issues furthest to the right are thus a breakdown of the design process as understood by the employees.*

It is in this way that all these data—interviews, field notes, taped segments of work activity, and corporate artifacts—are divided into basic text units, and then categorised. In our study 4011 meaningful text units were produced. The analysis of the data yielded 89 categories covering approximately 75% of the complete data set.

Once a complete categorisation had been made it was then possible to relate similar categories. For example both fragments quoted above are about the design specification, and if one is interested in finding out how the design specification relates to other mechanisms for distributing information in the company, then all the categories (and hence text units) relating to the design specification can be gathered, compared, and an understanding reached. The key to this analytical process lies in the many different perspectives informing an issue that, when taken together, provide a 'rich' account of what is happening within the workplace.

Software called NUDIST (non-numerical, unstructured, data, indexing, searching, and theorising) was used to build an understanding of the data collected. NUDIST allows issues that arise from the data to be categorised and linked as described above. It also allows the subsequent investigation of issues arising from the data. To a large extent, the linking of the data, and the particular breakdown of issues is a choice made by the researcher. Other equally valid interpretations are possible. The main criterion is that any interpretation of the data is supported by text units, and must show *how* and *why* a particular interpretation has been made.

With a complete data structure it is possible to formulate questions based on the categories produced. A simple question might simply be to ask how many text fragments are categorised as both *specification* and *quality*. The 'answer' might indicate how, or even whether, people understand the relationship between product specification and product quality. If the 'answer' consisted in many text fragments being retrieved, one might then go on to split the results by department (*talk—of—x*). The question might then become 'how do different departments understand the relationship between product specification and product quality?' In this way it is possible to construct a sophisticated understanding of issues that may be unclear if one were simply to read the data 'text' from beginning to end.

3 *Engineering design as social experience*

Having established an understanding of a text there are many issues that could be pursued and elaborated. In an ethnographic report for Cirrus Technologies many issues were covered and subsequently discussed. The paper

now, however, focuses on the issue posed in the introductory section: the differences between the common understanding of engineering design as a technical and rational process and engineering design as a social, lived, process. This is done by proceeding from a premise that is held to be self-evident: that designing is largely a matter of using, and building on, previous experience. There are three types of design experience to be distinguished here:

- *individual experience* of specific projects and practices, generally what is cognitively constructed;
- *social experience* because commercial constraints necessarily motivate the need to communicate with clients, suppliers, users, legislators, team-members, mentors, etc. Social experience is experience of particular situations, discussions, and agreements, generally what is socially constructed;
- *organisational experience* of documented procedures, product histories, evolutions, and genealogies, generally what is organisationally constructed.

There are clearly fluid relations between these three types of experience and a suggestion of differing ontologies. Individual experience once vocalised to another might become social experience for example, and documented social experience might become organisational experience. As an ethnographer one is interested in the second of these types of experiences—social experience—and the questions that follow in the context of the design organisation: how is social experience acquired? how does it exist? how does it change? how is it used from one design project to the next?

3.1 *Narrative as a way of social explaining*

In most reasonably large design and manufacturing organisations there are procedures and models which prescribe a certain way of doing things, a type of organisational experience. British Standard (BS) 5750 is a ubiquitous example but larger organisations have developed their own 'product introduction methodologies'. These are slightly more wide ranging and company specific versions of the design methodologies of, for example, Pahl and Beitz[6]. This prescribed way of doing things brings with it a certain way of explaining and this often results in an awkwardness to interactions where the procedures are used *as a way of* explaining what is being done in terms of designing. In the following excerpt a software designer, phoned by his customer, is asked to outline how far through the design he is. He tries to explain this by making direct reference to the customer's methodology of the design process:

[phone rings]

Designer Hello Blair

Customer [how are you?]

Designer Fine thanks, and you?

Customer [How are you getting on with the design?]

Designer All I've said to various people . . . only time to finish it off if you like, but that's all . . . I've got to the, how do you put it, 'the requirements from other people for information' at the moment . . .

Now clearly the reference to the customer's process model—'the requirements from other people for information'—raises a further question. Both conversants understand what stage the design process is at in the terms of the model, but in terms of the meaning of 'the requirements from other people for information' what has actually been done, i.e. the evidence for, or experience of, having reached that stage is not spoken of. One might imagine the conversation continuing along the lines of:

Customer [OK, but what does that mean?]

Designer Well I did *x*, then I did *y*, then I did *z* . . .

And here the reference to the model would be explained with a kind of story, a time-based narrative of events. In fact the conversation continues with:

Customer [. . .]

Designer No, I've, well going from a previous conversation where you said 'it's all done on the same machine . . .'

So a common narrative thread is picked up with a reference to a shared experience and the conversation continues more comfortably.

Similarly, a meeting between a customer and a designer, to discuss progress on the installation of a new piece of equipment, goes through a list of requirements that *should* have been met. Stopping at the requirement stating that the supplier must use a software design methodology the customer

says: 'you *have* used a software methodology haven't you?', 'I don't know . . .' comes the reply, the designer not having written the actual program code himself. The customer goes on: 'you use Yourdon[20] don't you?', the designer answers: 'yes we do'.

Again the interaction rings false. There is an ambiguity to the discussion—it is not clear whether Yourdon *was* actually used on *this* particular design. The only satisfactory way of resolving this issue is with an account that recalls the experience of using Yourdon on this particular design. As it is no such account is forthcoming, the checkbox is ticked, and the next requirement is 'discussed'.

The engineering design process model is an appeal to the general not the particular. As such it is a normative appeal. In terms of design this provides a tension between what a designer thinks they *should* do, and what, in actual fact, they do. A narrative, or story, provides a way in which a designer can explain what they actually do, *specifically*. This is not to say that models of the design process are divisive. It is just to say that as an explanation for design or, to be more accurate, how the designer explains their design process to other designers, they are insufficient. Rather a model provides a rhetorical structure; a story evidences personal experience.

As an example of this relationship between model and story, Louis Bucciarelli, in his book *Designing Engineers*[5], describes how a team of designers, faced with a design problem and a number of potential solutions, use Pugh's method of concept selection from his book *Total Design*[21]. This method 'prescribes a sequence of steps to follow in order to evaluate possible options against criteria established by members of [a] design team'. From the point of view of evaluating potential solutions the meeting is a disaster, there is constant argument over 'fixing' performance specifications, even over setting a datum design from which to measure other designs. What does slowly emerge however is a shared vocabulary for talking about the design; designers with different interests in the design negotiate, and discover, a new language capable of describing aspects of the evolving design.

3.2 *Constructing stories*

Storytelling introduces a narrative element into designing, a description of related events which link people over time. Storytelling in this technical sense comes equipped with added terminology, a story can be interpreted or 'read', different narrative 'viewpoints' might be included, there is a sense of 'closure' in a story, a definite ending, and a 'name' might be invented that references the complex of action.

20 **Yourdan, E** *Managing the System Life Cycle: A Software Development Methodology Overview* Prentice Hall, New Jersey (1988)
21 **Pugh, S** *Total Design* Addison-Wesley, Wokingham, UK (1991)

We explain why John the chief designer did not turn up for work on time by describing how he had to travel to see a client the previous day, and missed a train connection on the way home. That is why the supplier, who'd arranged to see him the next morning to discuss his latest line of products, had to wait around for two hours before being told that everyone was too busy to see him. The 'supplier waiting in reception' story is born, it enters the experience of the designers, *those* words refer to *that* story which then becomes an instrument to add to, or measure, other story experiences.

The following excerpt is taken from a meeting to discus a new 'rolling road' being commissioned at a motor manufacturer's site. The problem was that the rollers rotating the front wheels of the car, and the rollers rotating the rear wheels of the car were rising at different rates. This had caused the customer to complain to the designers that the rolling road was not working properly. The service engineer Phil outlines the problem to the designers Ian, John and Tony:

Phil The next problem is the balancing of the lift edge, which I had a look at . . . the problem is that the front lift is a lot longer than the rear lift. If both valves are actuated at the same time, the same valves obviously respond a lot slower, so what happens is you get the rear of the car coming up [before the front of the car] . . . the only thing I would suggest we could do is possibly to put a timer on it . . .

Ian In other words delay the rear coming up?

Phil There's no other way, John would probably back me up on that . . .

Ian [to John] is this reasonable?

Tony Does it make any difference if the back of the car comes up first?

Phil No, but it's something they're going to pick up on . . .

Ian Unless there's a mechanical way that we can get over that then, it's down to me to do it electrically . . .

Initially Phil explains the problem of the rolling road by making his experience of it explicit. This is, in effect, his *story*, his version of events. Ian

tries to make sense of this story, firstly by summarising: 'in other words . . .', and secondly by asking John, who has more experience of this problem, if he thinks the story makes sense: 'is this reasonable?' Tony queries the wider implications of the story by asking if it makes any difference, Phil counters by adding to his initial account, saying that, regardless of whether it makes any difference, it is something that the customer is 'going to pick up on'. Ian, having understood Phil's story, suggests that he, an electrical designer, try to solve the problem.

What is constructed over the course of this discussion is a common understanding of a situation, and the way that that situation is initially described is by telling a story. Later in the meeting the problem was referred to as 'the lift edge problem', these words now referring to this commonly agreed story.

There is an economy of language here. Complex social and technical scenarios are deconstructed, understood socially, and then reconstructed into a word or phrase. Experience is encapsulated, the story no longer needs to be retold. The implications of this become apparent when Phil generalises the 'lift edge problem':

Phil You know that's a problem that we have on every rig we build

In any future meetings, the 'lift edge problem' can be used as a 'story index', a pointer to a common discussion. Any new design can take account of the 'lift edge problem'.

Conversation in the engineering design organisation is peppered with such words and phrases: the 'Edwards fiasco' refers to a design project for a company called Edwards Triasto that went seriously wrong. When a project manager visits a designer and says only: 'mini airbags' the designer knows exactly that he is referring to the current state of the corpus of information built up in a project that has lasted several months. Similarly three letter abbreviations would seem to have this economising and indexical function. Reference to 'ABS systems' or 'ECUs' need not be explained, they are the agreed units that form part of the ongoing and larger stories within the design project and design organisation.

To the designer within the organisation, specialist 'story' words and phrases have *particular* meaning. They encapsulate personal experience and contribute to a larger narrative at either team, project, departmental, or organisational level. For the researcher entering the organisation the

same words leave 'narrative gaps'. It is simply impossible to understand what is being talked about without further explanation. This means that, in effect, a new language has to be learned. This dual function of story words—that they are simultaneously inclusive and exclusive—has a direct relationship with team, group, departmental, and organisational culture. The more specialist one gets the more inclusive the sub-culture becomes.

3.3 *Deconstructing stories*

The previous examples have shown that particular words—'Spikes', 'CB40', 'Floflex', ECU, ABS system—have a commonly agreed meaning which is negotiated through a particular narrative discourse. There are, however, more familiar words—'product specification', 'callout', 'shop-floor', 'quality', 'engineering drawings'—which intersect everyone's experience in the design organisation. There is a certain ambiguity to these types of words which allows appropriation into different, and often conflicting, stories. In terms of *individual* experience these appropriated meanings might be explained with Bucciarelli's term 'object world'[5]. In this view the designer literally constructs a 'world' of meaning in designing. What is of interest in social terms, however, is the way in which different organisational functions appropriate a commonly existing 'object' to build a narrative that reflects its own sub-culture.

As an example of this social appropriation from our study the 'product specification' was an object of some disagreement, particularly between salesman and designers. The disagreement was not about the existence of the product specification, but about what it actually meant. Designers claimed that specifications were 'vague', 'underspecified', 'one-pitch' and 'open'. Salesman on the other hand explained the significance of the design specification in a different way:

'it's a balance between giving the customer sufficient information to give him confidence . . . and not dotting i's and crossing t's'.

The specification for the salesman is something to inspire confidence in the customer, not something to functionally detail a working design, which is how the engineering designer understands it:

'we [should] provide a sufficiently detailed specification so that if the customer places the order on that basis, we can say "look! this is what you've paid for"'!

The different departments have incorporated the product specification into different explanations—stories—of their work. The word 'sufficient' in both quotes suggests that the common object, the product specification, has (at least) two necessary purposes. To the salesman a 'sufficient' product specification is one that sells the design project with minimum effort: 'if

you do ten quotations and get two orders, you've probably not done too bad'. Why 'overspecify' when you might not get the order anyway? To the salesman there is a reason for leaving out information. The 'story' of the salesman is of efficient selling, and this explanation fits this narrative. The designer, on the other hand, understands the specification as providing information: '[you need] to find out what is *really* required'. To the designer the specification should be a succinct summary of 'what the customer wants'; a well-defined starting point for the design.

The point here is not the validity of either claim, but that there *are* two different claims, two different understandings, and hence two different narratives that use the same object. And similarly with quality procedures, with engineering drawings, and with the design object itself. There are competing narratives trying to appropriate the object as their own, to tell the definitive story, to locate a permanent meaning to a set of words. The design vocabulary might in this instance, then, be defined as much by common disagreement as by common agreement.

The engineering designer's assertion that a design specification should tell him 'what is *really* required' (author's italics) brings us back to where we started from—the commonly understood normative model of design: specification, to concept, to detail, to manufacture. By suggesting that it *is* possible that a complete product specification can be detailed prior to work starting on design, 'what is *really* required' invokes the normative model to challenge the explanation of the salesman's story. The normative model is being used rhetorically in a social context.

4 *Discussion*

This paper has claimed that engineering designing is based on three types of experience. Individual experience, social experience, and organisational experience. The second type, social experience, appears to be a neglected area of study and by using a rigorous, ethnographically informed, qualitative method some insight has been provided into engineering design *as* social experience.

Engineering design as a social activity consists in the construction of social agreements. We have observed storytelling to be a mechanism that aids this construction. The consequences of this are that, for any particular product, a language is 'invented' which allows a description of the ongoing experience of that product and design process. In other words the product is constructed in words as it is constructed in reality. As the process develops, discourses—in effect meta-conversations—start to emerge surrounding the product and accordingly the product begins to assume some sort of identity.

This identity is based on the stories that are told about it, stories that are then condensed into words or phrases: 'unreliable', 'elegant', 'smooth', 'complicated', 'easy to use', 'all singing, all dancing'. These are commonly held agreements, some permanent, many only transitory.

In the continual telling and re-telling of experience a language is built up which can be used to negotiate the factors influencing the final design. In our study we noted discourses about: the end-users of the product, about supposedly 'cut and dried' technical calculations, about what the customer 'really wanted'. What emerged from the study was the idea that a design process is as much about key social points—a particular meeting, a talk with the customer, a chat among several engineers—as about key technical points—what the cycle time of the machine is, the thickness of a coating layer, the torque that a motor needs to generate. It was also of note that activities which are often thought of as individual—drawing, sketching, listing requirements, etc.—add to the narrative of a particular design project by producing objects *for* communication and discussion, and these objects contribute to the ongoing discourse. There can be very few parts of an engineering design process that are not socially explored.

There is also an evaluative aspect to the development of discourse in this fashion. Something that is often noted in the literature is that good design teams do tend to have a well-defined common language to communicate, a language which expresses experience and creates an identity for a particular product[22]. What 'well-defined' might mean in this context is not clear, although the mechanism of storytelling would seem to provide some sort of foundation from which to explore this issue. If one was to agree that the quality of different products do vary, then might there be a corresponding variation in the quality of a related common language? This is tantamount to saying that, in terms of designing, some experiences are better expressed and re-expressed through words than others. Frankenberger and Badke-Schaub[23] describe 'critical situations' in the design process, and it just might be that these 'experiences' are worth holding on to in words. In short there seems an intervention that it is possible to make that would improve communication in the design process by developing and making explicit the opportunity to converse about experiences that were previously private. This would be an intervention of 'making social', akin to helping a design team to 'reflect in action'[24].

22 **Lloyd, P A, Lawson, B R and Scott, P J** 'Can concurrent verbalization reveal design cognition?' *Design Studies* Vol 16 (1995) pp 237–259

23 **Frankenberger, E and Badke-Schaub, P** 'Modelling design processes in industry—empirical investigations of design work in practice' *Journal of Automation in Construction* Vol 7 (1998) pp 139–155

24 **Schön, D A** *The Reflective Practitioner* Temple Smith, London (1983)

4.1 Design and the particular

One word that has been used consistently throughout this paper is *particular*: the particular product, the particular design process, the particular designer, particular meaning. This is an underlying theme perhaps worth

emphasising as it is a conscious approach to design study. It is very clear studying a design and manufacturing organisation that different designs *are* different. That is to say that every product brings with it in the design process a set of contingencies that make it unique. These contingencies might well be social in nature, but the point is that there is value to be had in looking at any particular design process, before trying to generalise to other design processes. This kind of inductive, case approach to the study of design denies immutable design 'laws' and brings to mind Wittgenstein's famous aphorism 'the world is everything that is the case'. In this respect stories, *particular* narratives of experience, account well for the differences between design processes. It is also no accident that the ethnographic method is a way of looking at particulars and is (particularly) suited to design study.

A discussion of the merits of the ethnography adopted in the study is perhaps apposite here. The data set obtained at Cirrus Technologies was considered as a kind of text. On to this text were overlaid systematic codes, categories, and explanations from which followed interpretations. The analogy of analysing a novel was briefly introduced earlier, and in many ways this approach to the analysis of data *is* critical, i.e. involves sifting data, making comparisons and contrasts, finding evidence for, and evidence against a particular point of view. One looks to emphasise certain features of the text, using as much direct quotation as possible, in order to make inferences and interpretations about that text (and by extension the organisation under study). This type of 'critical' ethnography is therefore a 'reason-giving' method—it recognises certain features and attempts to explain them—rather than seeking to establish causal reasons for relationships. By giving reasons one is encouraging others to recognise such interpretations in other (particular) cases.

There are drawbacks with an ethnographic approach. The time required for study, transcription, and rigorous analysis is considerable and, when balanced against the direct uses of the ethnographic account, begins to look disproportionate. An account with no direct application in terms of the organisation studied usually has to be justified on the grounds that it promotes a different way of thinking about social situations. This has been our experience in feeding back ethnographic information to employees at Cirrus Technologies. It is also questionable how relevant this type of study is to other design and manufacturing organisations. There are two replies here. The first is to assert that the degree of relevance is determined by the degree of similarity. So, for example, a low volume design and manufacturing organisation employing a few hundred people might find the ethnographic account of Cirrus Technologies enlightening. A larger, high vol-

ume producer would find less of relevance. Secondly, it should be pointed out that ethnographic research is meant to be read critically[25]. One is not meant to look for a set of 'key' results but actively engage in the reading process and question interpretations. Ethnographic research promotes a questioning attitude to empirical data and this brings with it a corresponding way of viewing the world. This is beneficial to both researchers and organisations.

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25 Hammersley, M *Reading Ethnographic Research* Longman, London, UK (1990)