Capturing and analysing own design activity

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A discourse on the selection of tools for capturing and analysing own design activity is presented. Issues including design activity as data and the validity of self-reportage/analysis are discussed. Candidate data collection tools are compared, with participant observation, action research and diaries as preferred choices. The empirical development of a diary to capture industrial design practice is presented. The diary is found to be effective in eliciting specific elements of own design activity amenable to verbal articulation (e.g. materials and manufacturing) and its suitability to practice-led research is demonstrated.

Keywords: design activity, research methods, industrial design, reflective practice, practice-led research

The context of this paper is practice-led research in design, which has also been termed 'research *through* design' (Archer, 1999). Practice-led research is a mode of enquiry in which design practice is used to create an evidence base for something demonstrated or found out. It involves a researcher undertaking a design project subservient to stated research aims and objectives. Thus, the main motivation of practice-led researchers is to elicit and communicate new knowledge and theory originating from their own design practices. Its pursuance of course requires that the researcher is also a skilled designer and is prepared to combine the two roles of scholar and designer: something that is known to be intellectually challenging (Hales, 1987; Archer, 2004a).

The integration of personal design projects within research is rare but not new. It has been promoted in recent years as especially pertinent to staff and students of higher education art and design institutions, where new research cultures are being cultivated. Practice-led research has significance because it empowers academically competent designers to utilise their design expertise and assert ownership on design research. This is commendable not least because it promises contributions that complement those from researchers who do not profess to be designers. However, because of lack of examples and an absence of critical analysis of the benefits of practice-led research, a debate over its academic credibility has persisted. Research reviews are gathering

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momentum towards defining good practice and persuading sceptics (AHRC – Arts and Humanities Research Council, 2007), whilst models of how to successfully integrate design projects within academic research have now been developed (Pedgley and Wormald, in press). In each of these models, the inclusion of a design project constitutes an empirical enquiry from which designing (as activity) and designs (as outcomes) are sources of research data.

- Model-1. Find out about current design practices (e.g., pursue a design project to help uncover decision-making processes and social responsibilities).
- Model-2. Devise improvements in design methods (e.g., pursue a design project to help conceive and develop new design procedures, information, priorities, and tools).
- Model-3. Make improvements to designed artefacts (e.g., pursue a design project to help contribute to how a type of product can or ought to be designed, how it can be improved, and to demonstrate benefits).

The purpose of this paper is to identify and discuss the principal methodological considerations for creating a convincing research evidence base from own design practice. It centres on the need for systematic and objective tools for capturing and analysing design activity, with the intention of achieving the rigour associated with studies of other people's designing (Cross et al., 1996; Bayazit, 2004).

One of the chief characteristics of practice-led research is that it is highly personal, being centred on the creative practices of the self. Practice-led researchers must subscribe to the goal of making public one's private design discourses. There can be no place for seeking to uphold an inexplicable 'black box' account of art and design practice (Fallman, 2003) or a reluctance to be candid about own creative processes (Hockey and Allen-Collinson, 2000). Nor can the artefacts arising from design projects be relied upon to communicate aspects of their conception, development or research relevance (Rust et al., 2000). The consensus amongst researchers is that practice-led research must include substantial reflection, analysis and theorising on one's design activity and design outcomes if the work is to be differentiated from routine design practice (Frayling, 1997; Friedman, 1997; Cross, 1998; in press).

A useful complementary description of practice-led research is that it is an autobiographical research methodology, or 'ethnomethodology' (Baird et al., 2000). It requires researchers to become 'adjunct ethnographers of their own circumstances' (Zimmerman and Wieder, 1977), fulfilling multiple roles of self-observer, self-analyst and self-reporter. The intertwined nature of autobiographical enquiry brings a heightened responsibility on researchers to provide methodological clarity, particularly regarding data validity, reproducibility,

effectiveness, and the degree of generalisation that can be safely associated with data.

1 Origins of the research

Much of the work reported in this paper is built upon the author's practice-led PhD in industrial design (Pedgley, 1999). The doctorate responded to calls from the design research community for (a) more case studies and greater investigation into the processes of designing, and (b) development of new tools for capturing and analysing design activity. The specialist subject of the doctorate was an examination of the forms of knowledge and other kinds of resources industrial designers use to influence choices of materials and manufacturing routes for new products. This had been identified as an underdeveloped area of understanding within higher education. The doctorate followed model-1 practice-led research. In order to corroborate and generalise sections of the data, nine industrial designers at consultancies and manufacturing companies were interviewed about their design practices.

The design project for the practice-led research was a new generation of polymer acoustic guitar, a concept with much potential that had been commercialised in the 1950s by Mario Maccaferri, but which failed in the marketplace. Technology and markets had advanced significantly in the intervening decades, and it was very reasonable to be optimistic about achieving innovation and creating a working instrument. The 'guitar project' was completed with success, evolving into a present-day business and continues to receive worldwide media coverage (Cool Acoustics, 2007).

Good methodological reasons existed for choosing the guitar project, in addition to the project personnel being musicians. It was well known that traditional guitar-making draws upon know-how and intuition. It had also been established that technologists and engineers were unable to advise on the selection of 'musical polymers' or on polymer instrument design. However, a successful guitar would undoubtedly rely on effective materials and manufacturing choices. For these reasons the project made for a particularly engaging study on materials and manufacturing decision-making, where forms of knowledge other than derived from science would probably dominate. Knowing that the guitar project could likely result in commercial intellectual property, it was selected by Loughborough University as a case study for intellectual property generation and was accordingly pursued in a confidential manner. Patents and registered designs for the guitar were secured prior to examination and public release of the doctoral thesis.

2 Design activity as a data source

Design activity encompasses cerebral activities including thinking, imaging and decision-making as well as practical and externally perceptible activities such as information gathering, drawing and model-making. Externally

perceptible activities can be observed, recorded, archived for analysis and so on, whereas externally imperceptible activities are far harder to capture. Their elicitation requires more complex tools, which will be examined later. That said, even externally perceptible activities can have limited standalone value. Outputs of design modelling (e.g. sketches, prototypes, CAD visualisations) rarely provide a clear account of design thinking. Sketches, for example, are often intelligible and of intended use only to the originating designer (Lawson, 1990). Thus, a basic but key point to note is that only by eliciting an account of designing from the originator can the nature of design activity from the originator's perspective be revealed (Pedgley, 1997).

In considering design activity as a data source, the term *capture* is used because ordinarily design activity is highly transient and becomes lost in time. Only exceptionally conscientious designers archive accounts of their decision making (Mackinder and Marvin, 1982), whilst commissioned designers are rarely obliged or able to, owing to confidentiality. Lack of necessity and practice are also important factors: designers are not used to accounting for what they know or do. They tend to just get on with their designing. Furthermore, irrespective of designers' *choices* over whether to disclose or archive their design activity, it is well known that sometimes they will be *unable to* because their work is performed within an ineffable domain (Ryle, 1963; Polanyi, 1967; Daley, 1982). In such circumstances, designers draw upon tacit knowing and intuitive decision-making, such that they know or do something but cannot say what they know or do.

The capture of design activity has crossovers with the 'design rationale' movement of the 1990s, concerned with eliciting the 'why of designing… issues in the methods, documentation and communication of design thinking' (Moran and Carroll, 1996). Proponents of design rationale include project managers seeking to create records of design practices for corporate reasons, such as reuse and efficiency gains in subsequent projects, detecting and correcting errors, increasing design accountability, and retaining expertise after the departure of expert staff (Marsh, 1997). Design rationale differs from the present debate because its motivation is not to satisfy an academic research agenda. Rather than seeking an exposé of the design act, design rationale is concerned with eliciting the reasoning behind product specifications: a subtle distinction between a 'messy' personal/social focus and a 'rationalised' process/outcome focus. Nonetheless, the principle of design rationale 'options' (from 'questions, options and criteria notion') is directly relevant to design activity reportage, being concerned with design possibilities that are entertained but for some reason not implemented.

Allied to the practical problems of design activity reportage are complicating factors that derive from the nature of the design act itself. Designing is an intensely personal pursuit, in which designers are orchestrators of their own

design processes. Notions of neutrality, objectivity or universality in design reasoning are ill-founded in this context (Biggs, 2000). No assurance can be made that a design task undertaken on one occasion will be repeated in the same manner by the same person on a different occasion. This is further complicated by the proposition that the ability to self-capture design activity is a dynamic phenomenon affected by one's state of mind, demanding a 'level of consciousness beyond that required for routine office practice' (Dias et al., 1999). Accounts of designing must therefore be expected to have variation in intensity and detail from day to day.

Design researchers are humbled to accept that the reproducibility of data, a tenet of research in the natural sciences, cannot apply for studies of design activity. Instead, these studies fit better into what has become known as 'sciences of the artificial' (Simon, 1981), acknowledging that human conditioning from fact, judgement, opinion and perception must all be expected to influence the design act. Accordingly, phenomenological approaches to research are frequently used to capture the intricacies and natural flow of design activity, which is '…pursued through action in and on the real world, in all its complexity' (Archer, 2004b). Whilst phenomenological enquiry is essential for upholding the authenticity of the design act, its consequence is to intensify the intellectual conception and logistical execution necessary for practice-led research.

3 *Macroscopic and microscopic analyses*

A principal reference when seeking to capture design activity is a timeframe. Largely because of a need to make research practicable, the majority of empirical studies of design activity have centred on time-restricted periods of other people's designing. These studies have been well suited to *microscopic* analyses of design activity:

- Associated with short-term goals;
- Contained within short episodes of activity (e.g. seconds, minutes, hours);
- Concerned with the structure of decision-making (e.g. trains of thought, reasoning, modelling);
- Revealing of the nature of expertise and information use.

It has been argued that a comprehensive understanding of design decision making cannot be formed solely from time-restricted studies and the un-naturalistic interactions that they involve (Dorst, 1995). Thus, naturalistic longitudinal design activity, of the kind likely to feature in practice-led research, provides the opportunity to develop complementary *macroscopic* analyses:

- Associated with long-term goals;
- Contained within long instalments of activity outside of individual episodes (e.g. days, weeks, months);

- Concerned with creativity and the evolution of decisions across project phases (e.g. dead-ends, u-turns, path from brief to final outcome);
- Revealing of operational constraints and opportunities across project phases.

Tools for capturing design activity vary in their capacity to generate data suitable for microscopic and macroscopic analyses. An important factor in the selection of data collection tools is therefore the interest that the practice-led researcher has in performing either (or both) levels of analysis. This will be determined by the nature of the gap in understanding that the researcher seeks to bridge.

4 *Data collection issues*

Several very useful articles providing advice on how to go about capturing and analysing design activity were published in the relatively early days of design research (Bessant, 1979; Yeomans, 1982; Magee, 1987). More recently, Bayazit (1993) has offered a three-stage process well suited to achieving the methodological transparency needed for capturing own design activity. The process is built around the classic research model of data collection, transcription, codification, analysis, results, discussion and conclusions.

1. Knowledge elicitation. Collect data on designers' thinking and archive this in an unstructured and unanalysed form.
2. Interpretation of knowledge. Analyse data by a hierarchical procedure.
3. Structuring of knowledge. Present findings and discuss their wider validity and implications.

A crucial matter to consider at stage 1 is that all data collection tools have a presence that will to some extent interfere with the very phenomenon for which they are being used. In the study of design activity, interference effects can occur when designers are asked to supplement their normal (predominantly non-verbal) working practices with reportage. The effects can be viewed as potentially constructive, e.g. improving self-learning and awareness (Walker, 1985; Moran and Carroll, 1996; Moon, 1999) and augmenting/altering design thinking (Dias et al., 1999; Jagodzinski et al., 2000), or potentially destructive, e.g. upsetting the natural rhythms of activity: '…like golfers, designers might come to lose their swing if they think too much about what it is they actually do when they design.' (Fallman, 2003).

The major work on the use of verbal reports of human behaviour as data (Ericsson and Simon, 1993) campaigns for the deployment of data collection tools that are as 'close' as possible to behaviours and activities taking place. The main approach advocated is concurrent verbalisation (thinking aloud whilst doing) to capture in real-time a person's 'inner voice' as trains of verbalised thought. However, it is acknowledged that not all circumstances are suited

to concurrent verbalisation and that retrospective reports may be used as an alternative. Their advice in this regard is to minimise the presence of any post-event rationalisation by:

- Generating reports as soon as practicable after events occurring;
- Providing reports of specific events rather than general experiences;
- Corroborating and contextualising the reports with the help of cues ('stimulus material') arising from the specific events;
- Briefing and training the reporter to be alert to generating 'general descriptions of his own cognitive processes'.

Post-event rationalisation in reportage, involving speculation, inference and streamlining, is a well known phenomenon that can occur when people are asked to provide eye-witness accounts. People can be adamant that they tackle a task in one way when in reality they do it quite differently. People can also be dishonest to show themselves in a good light, either by modifying their behaviour or by fabricating self-reports of their behaviour. Unfortunately, there is no simple solution to detect or remedy post-event rationalisation in retrospective reports, except to triangulate against other sources, leaving researchers to persuade their audiences that on balance a good level of internal authenticity and validity in data has been achieved. Ericsson's and Simon's (1993) advice for retrospective reports provides a good reference for such persuasion.

5 *Tools for capturing own design activity*

Aside from the crucial matter of eliciting accounts of design activity from the designer's perspective, candidate data collection tools for practice-led research must also satisfy four additional criteria: solo effort, endurance, subject delimitation, and mobility.

- *Solo effort*. Opportunities to employ a second researcher to fulfil a data collector or analyzer role may not exist. Data collection must therefore be executable as a solo effort.
- *Endurance*. Data collection must be compatible with a longitudinal design project, spanning months if not years.
- *Subject delimitation*. Without subject delimitation, literally all aspects of design activity are candidates for capture. This would result either in data overload and researcher fatigue or data dilution, caused by too much breadth and too little depth. Data collection must therefore be carefully directed towards the specialist subject of the research.
- *Mobility*. Data collection must allow designing to be carried out in multiple locations, such as a studio, workshop and home, as is normal for a longitudinal project.

Table 1 provides a matrix of compliance of potential tools against the stated criteria.

Table 1 Suitability of data collection tools for capturing own design activity

Data collection tool	Brief description	Criteria				
		DA	SE	EN	SD	MO
Project archiving	Designer systematically collects and archives outputs of modelling, minutes of meetings and suchlike	×	✓	✓	×	✓
Project report	Varied and detailed factual account of project by designer, created at project end	✓	✓	✓	✓	✓
Interview	Spoken exchanges between designer (interviewee) and researcher (interviewer)	✓	×	✓	✓	✓
Questionnaire	Printed document prepared by researcher, completed by designer, ranging from 'tick box' to 'write about' requests	✓	×	✓	✓	✓
Survey	Variation of interviews and questionnaires administered on large scale to gain statistically strong generalised results	✓	×	✓	✓	✓
Observation	Researcher (observer) takes notes on designer's (participant's) externally perceptible activities	×	×	✓	✓	✓
Participant observation	Designer observes and takes notes on dynamics of social situations including own behaviour and activities	✓	✓	✓	✓	✓
Action research	Extension of participant observation: designer initiates/evaluates effects of planned intervention on social situation	✓	✓	✓	✓	✓
Diary	Reportage on designing given at regular intervals with emphasis on personal experiences and perceptions	✓	✓	✓	✓	✓
Protocol analysis	Real-time audio (concurrent verbalisation) and visual (video recorded) 'protocols' to reveal cognitive activity	✓	✓	×	×	×
Replication protocol analysis	Researcher (replicator) deduces designer's apparent line of thinking given only design brief and final proposal	×	×	✓	✓	✓
Reflective conversation	Variation of interview in which designer uses reflection in/on action to verbalise thinking during/after design episodes	✓	×	✓	✓	✓

DA = designer's account of designing, SE = solo effort, EN = endurance, SD = subject delimitation, MO = mobility.

Only four tools from the list satisfy all the criteria. 'Participant observation' and 'action research' require social interactions that for solo practice-led researchers will not always be relevant or present. These specialist data collection tools and techniques have widespread use across academic research and their application to design research is already quite well articulated (Allen, 2002; Archer, 2004b). A 'project report' is created too distant from activities occurring to be given credence as research evidence, leaving the 'diary' as the only remaining candidate.

6 *Rethinking the design diary*

Diaries are used widely in social sciences to gather ethnographic data. One of the attractions of a diary as a data collection tool is that it requires no

oral-to-text transcription, so a great deal of time and effort can be avoided during data preparation. Nonetheless, the use of diaries as a design research tool is rare, most probably because diaries are associated with longitudinal design activity and macroscopic analyses, which have tended not to be the focus of researchers. Almost without exception, where diaries have been used they have been for studying other people's longitudinal designing rather than to account for own design practices. For example, Jagodzinski et al. (2000) used a written log as a repository for the results of interviews held weekly with design engineers across a 40-week project. Ball et al. (1994) managed diary studies of seven electrical and electronic engineering student projects. Mackinder and Marvin (1982) compiled diary studies of architects' intended and actual activities over a weeklong project. The only known previous work combining longitudinal own design practice with a diary is Hales (1987), who used a daily journal to log details of meetings and work done across a three-year engineering design project, recording a total of 1373 'project interchanges'.

It was apparent that the full potential of design diaries as a data collection tool had yet to be realised. A major objective of this present work was therefore to trial and evaluate a new form of design diary, devised especially to capture own design activity in the context of practice-led research. In response to weaknesses identified by Hales (1987), emphasis was placed on increasing the level of personal conscience and accountability communicated in the diary, augmenting plain logs of 'time spent and work done'. The new diary was required to extend beyond the specification-oriented investigation and inspiration typically found in a fieldwork diary, to contain more insightful accounts of decision making. As well as facts, diaries traditionally reveal emotional responses towards circumstances, along with moments of serendipity and comments on perceived roles within social situations (Duncan, 1993; Moon, 1999). These were the kinds of entries that were sought, characterised especially well by Brett (1987).

A diary very rarely has the polish of professional writing… but the occasional roughness is part of the charm. A diary entry should glow with the immediacy of reaction (even if the diarist subsequently revises his opinion of what he has written).

Returning to Table 1, 'reflective conversation' was included as a candidate data collection tool, but it was rejected because it required a conversational interview with a 'facilitator'. However, reflective conversation has its origins not as an empirical data collection tool but rather as an explanation of the silent cognitive processes that drive professional expertise, known as 'reflective practice' (Schön, 1983). Reflective practice is said to comprise *reflection-in-action* (the mechanism for 'thinking-on-one's-feet') and *reflection-on-action* (the mechanism for retrospective 'stock-taking') (Moon, 1999). In the context of design practice, reflection-on-action involves a deliberate pause

in designing to make critical comment on the period of activities that has passed, in order to orient subsequent designing in a desired direction. The reflection is made using the outputs of design modelling as stimulus material, revealing for example a 'conversation with materials conducted in the medium of drawings' (Schön and Wiggins, 1992).

Hatton and Smith (1995) identify three types of written report arising from reflection-on-action: descriptive reflection (a factual account of an event), dialogic reflection ('stepping back' to give account of personal involvement and influence on an event) and critical reflection (exploring reasons for an event in a broader social, ethical, moral or historical context). Reflection-on-action has obvious parallels to the retrospective accounting required for diary writing. It was thus adopted as the main mechanism for creating diary content, performed as a self-conversation with one's inner voice.

7 *Diary formats and implementation*

The decision to write diary entries concurrently (at the time of designing) or retrospectively (at some point after designing) was made after trialling both approaches. The trials allowed testing of different diary formats, and exploration of the kinds of data that could be reasonably captured in the process of diary writing. Table 2 lists the open-ended diary instructions devised from social sciences briefing methods (Zimmerman and Wieder, 1977; Bourque and Back, 1982), intended to elicit both macroscopic and microscopic levels of attention. The overall aim was to capture the objectives within design episodes and, on any given day, what obstacles were encountered, how they were overcome, and what it was actually like to design. Good practice in diary writing (Table 3) emerged during the trials.

Printed versions of the instructions and good practice were always at hand during diary writing and were eventually memorized. Once written, the day's diary was archived and left untouched in readiness for analysis.

The 'concurrent format' involved diary writing as a side activity, immediately after an episode of designing connected to the specialist subject (materials and manufacturing) had occurred. Strictly speaking, the concurrent format was retrospective but administered as close as possible to events occurring. Designing was paused and a diary entry was made. Entries typically consisted of a series of annotated sketches and brief lines of text. Two systems were used to refer to artwork. Simple artwork was redrawn as part of the diary entry, whereas complex artwork was marked-up with a letter on the original (e.g. 'X'), with the corresponding diary entry referring to artwork 'X'. Video recordings were made to gather evidence on the duration and frequency of diary writing. The duration ranged from less than 1 to 5 min. The median time gap between entries was 9 min, with a range of between 1 and 90 min.

Table 2 Diary instructions

Instruction	Details
Strategy	If you have a plan for how you are addressing materials and manufacturing issues, explain it. If your plan changes, give details of how and why.
Outputs of modelling	Refer to sketch sheets, log books, models and suchlike to remind you of how and why decisions were taken. What have you considered regarding materials and manufacturing processes? How have you gone about it (what knowledge have you applied?) and why have you looked at it this particular way?
Information sources	Give details of all information sources you have made use of to help address materials and manufacturing issues. Did the information help? How?

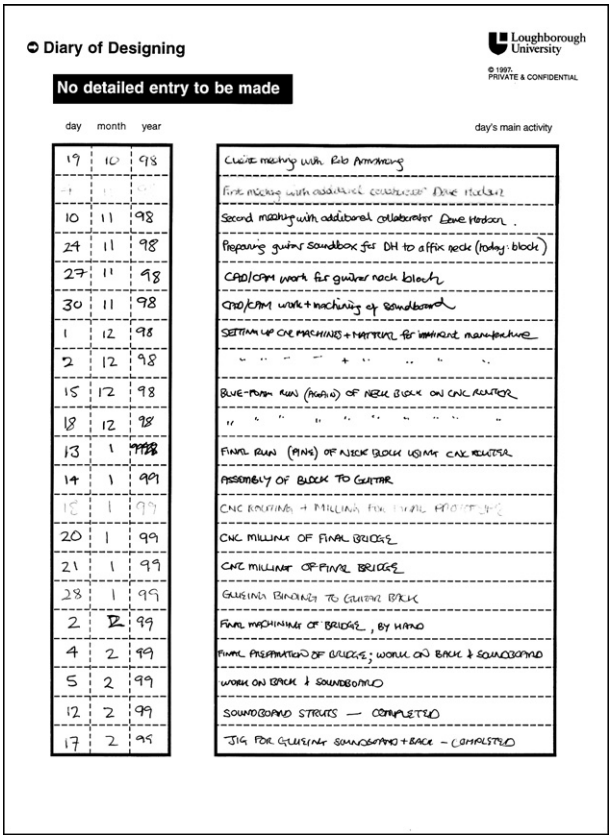
The concurrent format was used for the first 24 days (10%) of the guitar project, after which time it became apparent that an alternative format, completed at the end of the day, would be more effective and less tiresome to write. It would remove the stop–start disruption, and no longer compete with the activity under study. In any given day, the quantity of data relating to materials and manufacturing was not vast, and experience had shown that the crux of a day's work remained fresh in the mind at the day's end. The replacement 'end-of-the-day format' was considered neither too close to the activity so as to intrude upon it and reduce authenticity, nor so distant to risk excessive post-event rationalisation and misremembered information. Furthermore, by allowing for a grace period, comments on the worth of design episodes could be made. Coupled with these observations was a desire to improve the system of referencing to sketch sheets, which were implicated in many periods of designing involving attention to materials and manufacturing. Accordingly, the following three types of *pro forma* stationery were developed for the end-of-the-day diary.

Table 3 Good practice in diary writing

Good practice	Details
Chronology	Describe work in the same sequence that it occurred, ideally as bullet-points
Clarity	Keep entries intelligible, insightful and honest
Focus	Keep entries succinct: they should not be a crafted essay
Record images	Record still and moving images of developing and completed physical models
Out of hours	Account for instances of 'out of hours' designing in the next day's diary
Diary admin	Ensure that all diary sheets are numbered and dated
Modelling admin	Ensure that all modelling outputs are numbered and dated to aid cross-referencing (e.g. 'LB1:22' refers to log book 1, page 22)

- 'No detailed entry' A4 stationery (Figure 1). This acted as a record of the main activity carried out each day of the project. Its purpose was to track the specialist subject within a broader project context.
- 'Standard' A4 stationery (Figure 2). This provided blank space to contain general diary entries. Its purpose was to allow freedom of expression in any textual or graphical style. It was used on 47% of project days.
- 'Tracing' A3 stationery (Figure 3A, B). This was a sheet of tracing paper used as an overlay on sketch sheets. Its purpose was to expose concerns for materials and manufacturing embedded within graphical modelling. Pertinent sketches were circled on the tracing sheet and accompanied by a diary entry, thereby eliminating the need to redraw artwork. It was used on 9% of project days.

The end-of-the-day diary was used to gather data for the remaining 203 days (90%) of the guitar project. The time required to write each day's diary varied from around 45 min for the few very intensive days to around 10 s when only the 'no detailed entry' stationery was used. Typically, it took around 15 min. In total, 408 detailed diary entries were made.


Diary of Designing

Loughborough University

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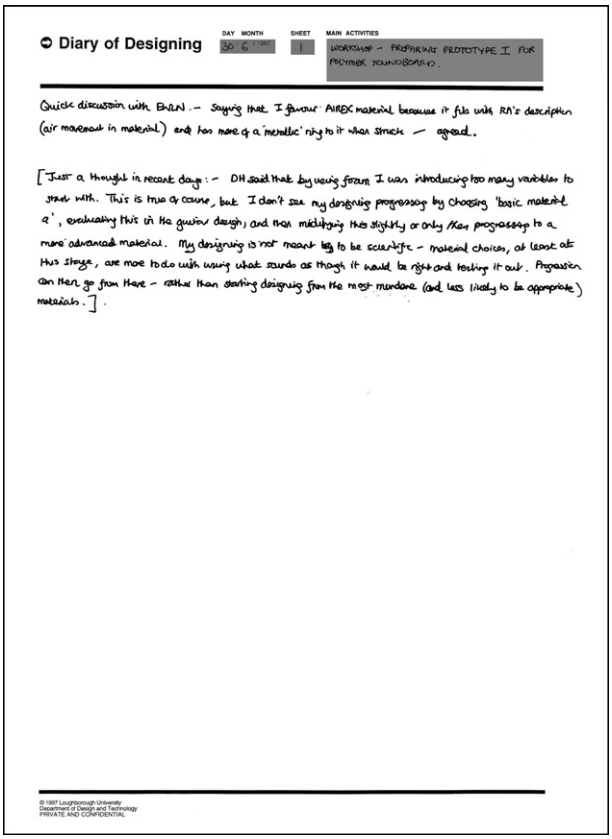
No detailed entry to be made

day	month	year	day's main activity
19	10	98	Cluster meeting with Rob Armstrong
[illegible]			First meeting with additional collaborator Dave Hodson
10	11	98	Second meeting with additional collaborator Dave Hodson.
24	11	98	Preparing guitar soundbox for DH to affix neck (today: block)
27	11	98	CAD/CAM work for guitar neck block
30	11	98	CAD/CAM work + machining of soundboard
1	12	98	SETTING UP CNC MACHINES + MATERIAL FOR VARIOUS MANUFACTURE
2	12	98	" " " " + " " " "
15	12	98	BLUE-FOAM RUN (AGAIN) OF NECK BLOCK ON CNC ROUTER
18	12	98	" " " " " " " " "
13	1	9988	FINAL RUN (PINE) OF NECK BLOCK USING CNC ROUTER
14	1	991	ASSEMBLY OF BLOCK TO GUITAR
15	1	99	CNC ROUTING + MILLING FOR FINAL PROTOTYPE
20	1	99	CNC MILLING OF FINAL BRIDGE
21	1	99	CNC MILLING OF FINAL BRIDGE
28	1	99	GLUEING BINDING TO GUITAR BACK
2	12	99	FINAL MACHINING OF BRIDGE, BY HAND
4	2	99	FINAL PREPARATION OF BRIDGE; WORK ON BACK & SOUNDBOARD
5	2	99	WORK ON BACK & SOUNDBOARD
12	2	99	SOUNDBOARD STRUTS — COMPLETED
17	2	99	JIG FOR GLUEING SOUNDBOARD + BACK — COMPLETED

Figure 1 Completed 'no detailed entry' stationery


Diary of Designing

DAY MONTH 30 6 SHEET 1 MAIN ACTIVITIES WORKSHOP – PREPARING PROTOTYPE I FOR POLYMER SOUNDBOARD.

Quick discussion with BALN. – Saying that I favour AIREX material because it fits with RA's description (air movement in material) and has more of a 'metallic' ring to it when struck – agreed.

[Just a thought in recent days: – DH said that by using foams I was introducing too many variables to start with. This is true of course, but I don't see my designing progressing by choosing 'basic material a', evaluating this in the guitar design, and then modifying this slightly or only /Key progressing to a more advanced material. My designing is not meant to be scientific – material choices, at least at this stage, are more to do with using what sounds as though it would be right and testing it out. Progression can then go from there – rather than starting designing from the most mundane (and less likely to be appropriate) materials.].

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Figure 2 Completed 'standard' stationery

8 *Data preparation and analysis*

Impartiality and transparency of method were striven for in the data preparation and analysis. Self-analysis inevitably draws attention to one's weaknesses and reservations over how tasks have been completed. It was tempting to question and criticise the designing as captured by the diary, but introspection in this manner had to be strictly avoided. The following hierarchical procedure was used to process the diary data.

8.1 *Step 1 – initial review*

On multiple advice (Zimmerman and Wieder, 1977; Burgess, 1981; Ball et al., 1994) an initial review was held to verify if any retrospectively 'critical events' appearing within the project archives (log books, sketch sheets, models, etc.) had failed to be entered into the diary. Only three were identified: (i) the knuckle wrapping of material samples to assess acoustic qualities, (ii) the origin of the idea that soundboard materials should be aerated, and (iii) the negative acoustic effect of painting polymer sheet. Diary entries that were off-topic or which described prototyping procedures with no impact on product design were purged at this step.

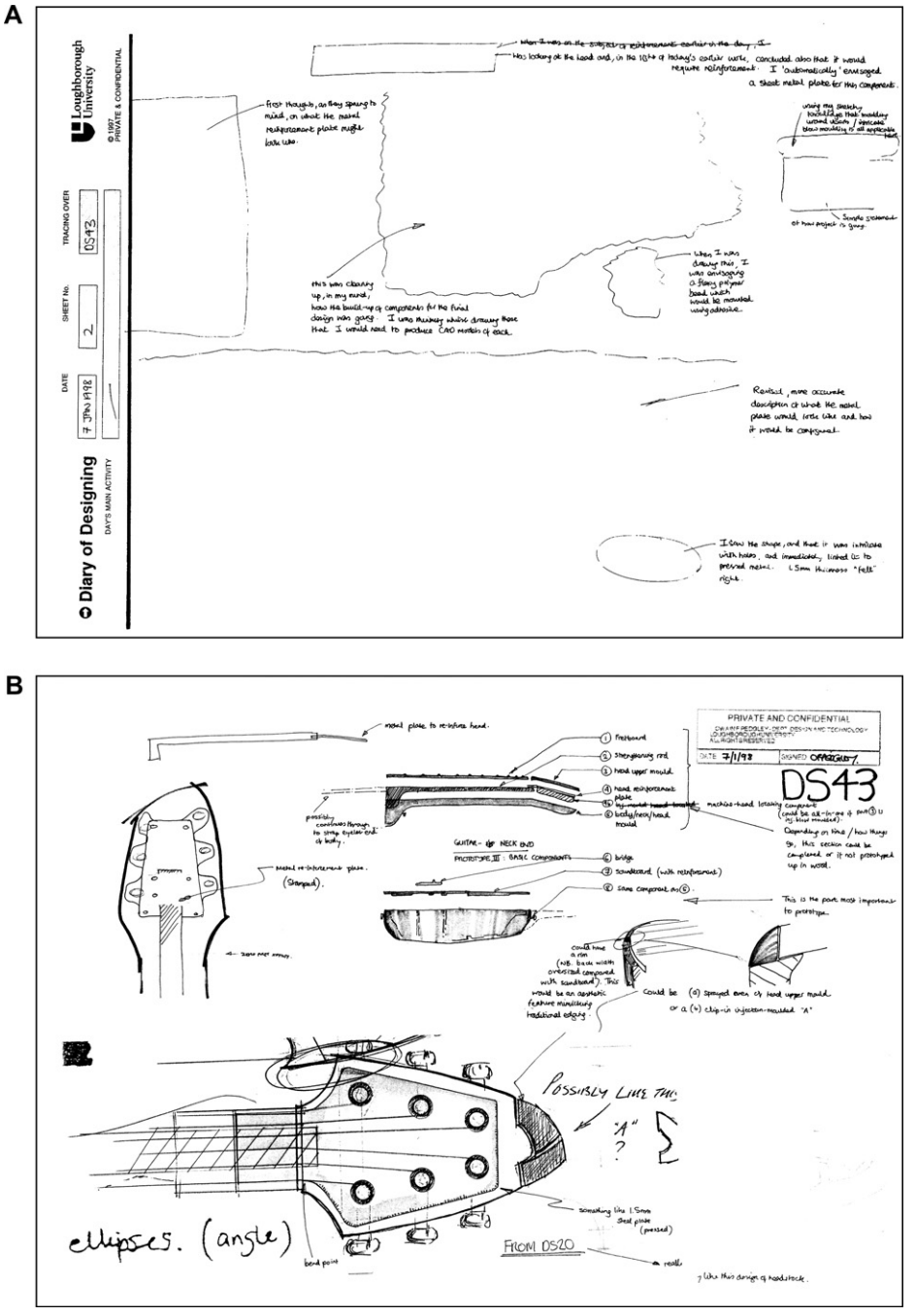

Figure 3 (A) Completed 'tracing' stationery. (B) Corresponding sketch sheet for (A)

8.2 Step 2 – encoding

In keeping with common qualitative research procedures, the data were organised using a conventional a priori content analysis. Individual diary entries were assigned codes decided upon in advance following literature reviews and postulation around the specialist subjects of materials and manufacturing and the nature of design activity. For the latter, an analytical framework promoted by Norman (1998) was adopted, in which the interaction of knowledge, skills, and values comprises the technology (i.e. the required expertise) to practise design. The encoding was thus made from a developed theoretical position. It involved identifying connections between the data and the pool of available codes, relying (as is usual) on the researcher's own knowledge of the subject domain. A strength of practice-led research is the familiarisation that the researcher can draw upon in creating these connections, both for the designing being analysed and the specialist subject being probed. In cases where no predefined codes fitted a diary entry, a new 'emergent' code was defined. All diary entries were therefore assigned either single or multiple codes. A pool of nine codes was used in total, shown in Table 4.

The vast majority of diary entries were clear in their content and meaning. On the few occasions where there was ambiguity, a note was included in the coding process stating what had been inferred.

8.3 Step 3 – detailed catalogue

A chronologically correct detailed catalogue of diary entries (Excel spreadsheet) was made, containing the following headings: 'date', 'entry number', 'artwork reference', 'content (verbatim)' and 'codes'. Internal consistency of English (e.g. names, conventions, literal and figurative forms) was imposed at this step.

8.4 Step 4 – summary catalogue

A chronologically correct summary catalogue (Excel spreadsheet) was made, listing each day's main activity under the following headings: 'date', 'project

Table 4 Content analysis encoding

Code	Shorthand	Description
2D	2D	2D modelling
COGNITIVE	Cg	Cognitive modelling
CONSTRAINTS	Cn	Constraints on choice of manufacturing route
FUNCTIONS	Fn	Functions materials and processes satisfy within industrial design
INFO	In	Use of information
KNOW/VALUE	Kn	Knowledge and values
LEVEL	Lv	Level of detail reached
TASK	Ts	Non-modelling tasks for deciding on materials and processes
WHEN	Wn	Timing and sequence of attention

day', 'no detailed entry day?', 'figure', 'day's main activity (verbatim)', 'day's main activity (translated)' and 'work classification'. The translation was performed to explain the use of jargon and to impose English consistency. The 'work classification' reduced the data to a set of eleven design activity descriptions based partially on established new product development phases (in alphabetical order): CAD, concept development, detail design, information gathering, meeting, planning, report writing, system-level design, testing and refinement, unclassified, and work on registered design rights.

8.5 Step 5 – glossary of terms

A glossary of terms was created to explain all shorthand, abbreviations and acronyms within the diary.

8.6 Step 6 – digital scanning of artwork

All artwork referenced in the diary was digitally scanned and stored as an archive for use in presenting the research results.

8.7 Step 7 – detailed analysis

Reasoned and logical argument was used to describe and explain the captured design activity code-by-code, showing awareness to criteria such as durations, expectations, frequencies, intensities, latencies, occurrences, omissions, peculiarities, sequences, surprises and trends, from which models and theory were constructed.

9 Example results

The analysis resulted in rich explanations of how materials and manufacturing were woven into the guitar project, from the drafting of the project brief to the delivery of the finalised prototype. On a microscopic level, the diary data exposed epistemological issues including forms of knowledge, information use and modelling. On a macroscopic level, the diary data exposed pragmatic issues including critical design discoveries and operational constraints and opportunities.

The microscopic level analysis resulted largely in written discourse with extensive references to modelling output. For example, the diary entry for the artwork in Figure 4 (a close-up from Figure 3B) was: '(Entry 197) I saw the shape (of the head reinforcement member), and that it was intricate with holes, and immediately linked it to pressed metal. 1.5 mm thickness ''felt'' right'. By collating similar examples, the role of graphical sketching for initiating cognitive modelling on materials and manufacturing, and for revealing ways of knowing, could be presented. Another significant outcome of the microscopic level analysis was timeline charts such as Figure 5, similar to tracking charts created from previous empirical studies of design activity. The macroscopic level analysis led to the creation of material and manufacturing consideration maps and to improved understanding of the nature of creativity in the area.

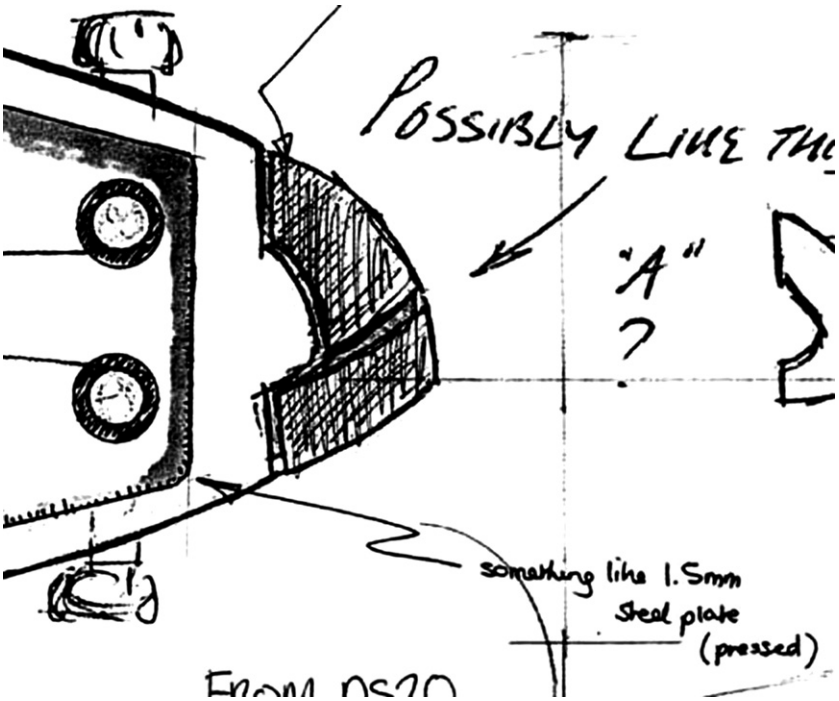

Figure 4 Sketch associated with attention to materials and manufacturing

10 Diary evaluation

End-of-the-day diary writing was experienced as a secretarial layer on top of the guitar project. It required meticulous organisation, whilst a quiet location without interruptions was found to be beneficial. Perseverance towards the task was solid because the award of an academic degree was at stake. Even so, as would be expected over such a longitudinal project, motivation for diary writing occasionally waned. An awareness to write diary entries was omnipresent and was felt to raise the level of alertness to own design activity, easing the grasping of some design issues and aiding decision-making. Regrettably, the degree of deviation away from 'normal practice' caused by such interference effects is impossible to ascertain, but the lasting impression having completed the diary is that the effects had a positive influence. On a few occasions, the prospect of design activity rich in attention to materials and manufacturing fuelled an excitement that strong diary entries would result. With regard to data validity, the diary entries showed extensive correlation to modelling outputs throughout the guitar project: evidence that can allay concerns over honesty and post-event rationalisation.

The effectiveness of the diary has been established. Of the 408 detailed diary entries, only 24% were purged during the data preparation process. This

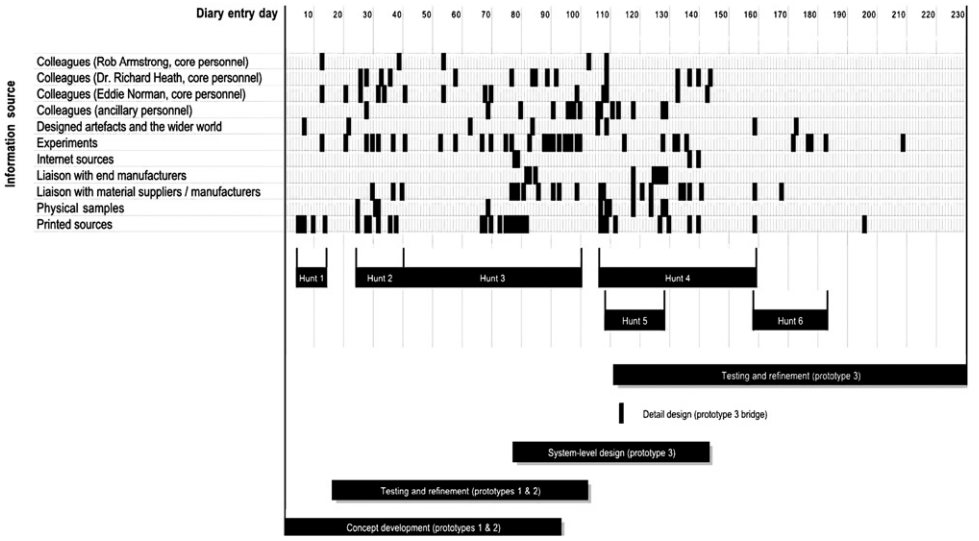

Figure 5 Timeline chart showing information sources and hunts across project phases

was considered a low rejection rate given that it was the first diary study of its kind and the first design diary created by the author. An element of learning how to create diary entries was inevitably involved. Later diary entries were generally more detailed and revealing than earlier ones. The diary was well suited to forming explanations of design activity on a macroscopic level and for examining epistemological issues with reference to elapsed time and phases of work. As a retrospective data collection tool, diaries had been predicted to be ineffective for revealing trains of thought in discrete design episodes (Ericsson and Simon, 1993). This prediction could not be tested since data of this type had not been sought, but experience suggests that it would indeed be the major limitation of diaries.

11 Conclusions

This paper has argued for systematic and effective methods for capturing and analysing own design activity, so that the resultant data may be used as a credible evidence base for practice-led research in design. The autobiographical nature of practice-led research, involving self-accounting and self-analysis coupled to inherently personal design processes, demands that special attention is paid to achieving methodological transparency. Articulation of these issues has formed the main thrust of this paper.

Three data collection tools and methodologies have been identified as suitable for recording longitudinal own design activity: participant observation, action research and diaries allied to reflective practice. For solo practice-led researchers, the use of a design diary is posited as an underused but valuable approach, as demonstrated by a worked example from the author's doctoral

guitar design project. Future research should be directed at providing (i) evidence of the suitability of diaries across the spectrum of design specialties from art to engineering; (ii) evidence of the effectiveness of diaries for illuminating a range of specialist subjects, from those that are more amenable to articulation (e.g. design drivers, influences on decision-making, modelling strategies) to those that are less so (e.g. creativity, discovery, imaging); and (iii) guidance on the management of diary studies within model-2 and model-3 practice-led research.

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