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A STUDY OF INFORMATION & KNOWLEDGE GENERATED DURING ENGINEERING DESIGN MEETINGS

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ABSTRACT
During the design process, there is a wealth of information generated, and although it may not be obvious at the time, this information can be extremely useful at a later instance when it may be no longer available. Many information capture solutions utilise tools such as video and media capture, incorporating the idea that if you capture all information then you will not miss anything. However, this creates another problem. Not all the information captured will be useful, therefore how can you distinguish the information that is useful from information that is not? The challenge many organisations face is how to capture and store valuable informal information in a way that is both simple and efficient, whilst remaining unobtrusive to the designers involved and without inhibiting the design activities. Through the undertaking of a series of case studies and test scenarios, it is possible to observe, identify and evaluate the various degrees of information and knowledge being generated and passed amongst design engineering teams whilst performing design activities in meeting situations. Using multi-media recording equipment and observation techniques, insight can be gained into the decision making process design engineering teams encounter during the course of a design project, and thus it is possible to evaluate where improved techniques can be applied to enhance the recording of information for re-use.

Keywords: design information, information capture, knowledge capture, collaborative working

1 INTRODUCTION
Throughout the design process, there is a wealth of information generated, and although it may not be obvious at the time, this information can be extremely useful at a later instance when it may be no longer available. Activities such as design review meetings are prime examples of instances where valuable informal information and knowledge can be communicated through channels such as speech, body language and even gesturing, which can be extremely difficult to both recognise and record. In many cases subsequent decisions can be linked to this sometimes tacit or implicit knowledge and information, therefore much of the rationale behind these decisions are lost. Several information capture solutions such as the Ferret Browser [1] and Informedia systems [2] utilise tools such as video and media capture, incorporating the idea that if you capture all information generated during design situations then you will not miss anything. However, this creates another problem. Not all the information captured will be useful, therefore how can you distinguish the information that is useful from information that is not? Previous work by authors such as Chafe [3], Dong [4], and Huet [5] to name but a few, highlight how studies of discourse analysis on linguistics can be used to extract valuable design rationale. These works highlight close links between how designers communicate verbally and how their thoughts are sequenced.

It is essential that before any design information capture solution can capture information, it must first establish exactly what information should be captured. Information is widely regarded as being either formal or informal [6]. Where formal information can take the form of reports, finalised documents and CAD drawings, Informal information can take the form of oral communication, body language, images and sketches. Historically, formal information such as reports and specifications were widely regarded as being adequate for providing records of the design process, however, recently it has been recognised that informal design information can be extremely valuable, in some instances more so than formal information, as it reflects many important aspects of the design process that are not found in formal documentation [7]. During the design process a great deal of important informal information is generated before later being processed or recorded in documents and other formal representations, thus, potentially valuable informal information may be lost during this translation phase. On the other hand, the observation and recording of informal information and knowledge, such as the rationale, can be time consuming and to the designer, a seemingly unrewarding one. The transfer of designer's and engineer's knowledge and information to others and also the application into different contexts is termed "design reuse" [8] and is widely recognised as being extremely useful, but capturing this informal information, knowledge and decisions for reuse is notoriously difficult. The challenge many organisations face is how to capture and store this valuable informal information in a way that is both simple and efficient, whilst remaining unobtrusive to the designers involved and without inhibiting the undertaking of the design activities.

2 BACKGROUND

Information can be categorised as being either formal or informal. Formal information is defined as having a recognised form ensuring validity [9]; it is explicit and definite and can take the form of reports, finalised documents, CAD drawings, and any other information communicated in a predefined form. Informal information therefore can be defined as not having a recognised or prescribed form [9] and can take the form of oral communication, images and sketches. Various methods have been developed to categorise and record both formal and informal information. However, before the information and knowledge can be captured it must be first identified and it is this capture and categorisation activity which presents the significant challenge. Interesting work performed by Badke-Schaub et al [10] analysed design team situations in an attempt to distinguish the critical situations from the otherwise routine work, and in the process developed useful categorisations of information. Other notable developments include the coding scheme developed by Huet [5] during his PhD studies, an extremely useful aid for the transcription of design meetings. It is these important developments which the research within this paper builds upon.

2.1 Formal and informal information

Recent work performed on the capture of formal and informal design information include the integration of capture tools within Computer Aided Design (CAD) systems and the use of Smart Drawings [11], Interdisciplinary Communication Medium (ICM) and design information infrastructure [12]. However, these systems rely on traditional CAD representations of information as a base, linking informal information about a design to parts of the CAD model using databases and other information management tools. In general these tools are effective in capturing formal design information as it resides in structured and defined forms; however they do not possess mechanisms for capturing informal information and it is widely acknowledged that informal information such as rationale can be extremely useful if captured in a form which allows it to be revisited over time.

Design rationale is the reasoning behind or explanation of why an artefact, or some part of an artefact was designed the way it was [13]. Design rationale draws on the designer's experiences, background knowledge and assumptions and encompasses the reasoning, trade-offs and decisions made throughout the development of the design. The difficulty with design rationale capture lies with developing methods and tools which allow the capture of it effectively and easily. There is some ambiguity as to where exactly the split occurs between formal and informal information and how to identify the relevant information types. In an attempt to clarify the relationship between formal and informal information, Yang et al [6] proposed the Formality Spectrum of Design Information (figure 1) highlighting their definition of the split.

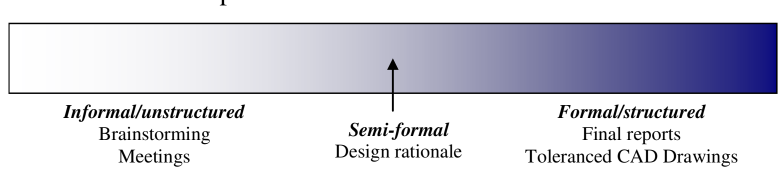

Figure 1. The Formality Spectrum of Design Information [6]

Yang et al propose highly structured, detailed documents, such as final reports, patents, and CAD drawings reside at the formal end of the spectrum, while at the informal end they present unstructured, fragmentary documents, such as those captured in meetings and brainstorming sessions. Within their model Yang et al see semiformal information (informal information with a limited amount of structure [6]) such as design rationale systems or case studies, residing somewhere in the middle of the spectrum. Yang et al's formality spectrum can be useful as a platform for which to demonstrate this area of research. The aim of the research is to investigate methods of capturing the informal and semi-formal information, effectively making it explicit and thus can be stored for re-use. Figure 2 (below) highlights this aim; to unobtrusively capture and store informal and semi-formal information and by doing so, effectively pushing them towards the formal end of the design information spectrum and thus making this information easier to store and to reuse.

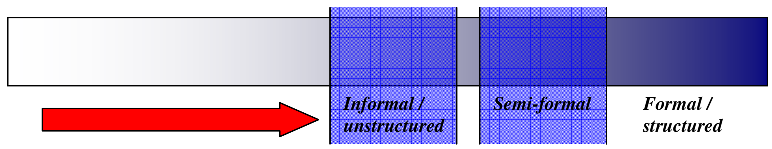

Figure 2. Adapted Formality Spectrum of Design Information capture activity

The various types of information can be further categorised into three groups which crossover with informal and formal design information (figure 3). Tacit information is information which is unspoken or not communicated [9] and usually resides within the designer's head. Tacit design information is entirely informal and encompasses design capacity, expertise, intuitive understanding and professional insight formed as a result of design experience. Throughout the life cycle of a design project, the designer can rely heavily on tacit design information and knowledge to support design decisions. Implicit information is implied though not plainly expressed [9]; information which is capable of being inferred from something else. Implicit information can take the form of sketches and also oral communication and generally implicit information can be expressed through either informal or formal information. Explicit information encompasses all data and information recorded in a clear and unambiguous format.

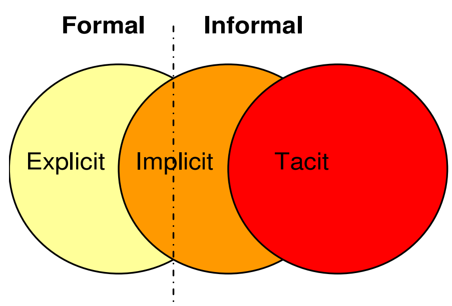

Figure 3. Design information space: relationship between tacit, implicit and explicit information

Explicit information can take the form of completed layout drawings, CAD models and any information medium, which prescribes to a pre-defined form. In essence explicit information is formal in nature. Within the research presented in this paper, tacit information and knowledge is regarded as being entirely informal and located within the head of the designer, this means that when this information and knowledge is communicated via any medium it can no longer be classed as tacit, but instead it will be either implicit or explicit. The relationship and crossover between tacit, implicit, explicit information with regards to the informal and formal nature of information is demonstrated in figure 3 above.

2.2 Critical situations in design

A 'critical situation' in the context of design scenarios can be defined as any situation which impacts directly or indirectly upon the direction or development of the design activity being undertaken [10]. Previous work performed by Badke-Schaub et al has focused on distinguishing the 'critical situations' from what they term 'routine work' performed during the design activity. The idea of distinguishing critical instances is by no means a new phenomenon with similar work performed on 'novel design decisions' by Akin and Lin [14] 'Critical Decision Method and Team Cognitive Task Analysis' by Klein et al [15], and work on 'Critical Incidents' by Flanagan [16]. However, Badke-Schaub et al's work on critical situations is of particular relevance to the design activity and thus this work, as they proposed identifying criteria based upon the general problem solving process as shown in figure 4.

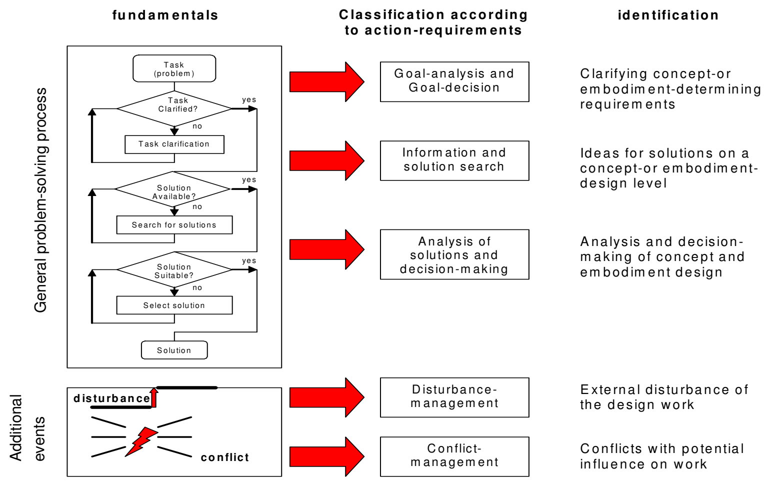

Figure 4. Division of 'critical situations' according to the general problem-solving process [10]

Badke-Schaub et al's work stems from two methods of data compilation, direct and indirect. They determine direct compilation as being "the continuous non-participating observation of the design work" [10] in which they employed two independent observers to observe the design process, a mechanical engineer to monitor the technical aspects of the design process and a psychologist to monitor the social and collaborative aspects of the design work. They also employed methods such as video recording, audio recording and the like to ensure that all interactions were observed. The indirect data compilation methods were post-experiment analysis through the distribution of diary sheets, questionnaires and also post experiment interviews. Through a combination of the indirect and direct data compilation, Badke-Schaub et al gained a comprehensive record of the design process from which they could use to distinguish the critical situations from the routine work. Figure 4 shows the protocol used to identify the critical situations. Badke-Schaub et al categorise critical situations into 5 variations: goal analysis, solution analysis, solution search, and additionally disturbing or conflict management [10]. From this analysis of the design activities they were able to model the design process dependencies based on the identified critical situations. Badke-Schaub et al's work is of particular relevance to this work as the study focuses on the examination of engineering design teams engaged in social design activities.

2.3 The Transcript Coding Scheme

Within recent work performed during his PhD studies, Gregg Huet [5] produced several transcripts of industrial based design meetings conducted within a large multinational organisation. Through analysis of the audio recordings taken at the time of the meeting, Huet developed a coding scheme (figure 5), which was used to codify the transcripts of these meetings. The aim was to provide not only information on which meeting participant commented on certain topic but also allows the classification of information type (product, process, resource or external factor) artefact type (drawings, calculation, component, testing etc.) and the relevant topic / description.

The Transcript Coding Scheme (TCS) created by Huet is an extremely useful tool for analysing the interactions between designers in design situations. For example, the codification of the information exchanges coupled with the codification of supporting artefacts give the reader an overwhelming quantity of information some of which may be deemed critical and which may not have been possible to record through traditional minuting techniques. However, although extremely detailed records were generated, the time and effort required to process and interpret the information is vast (through experimentation within this paper it was found that it requires approximately 10 hours to accurately transcribe and codify 30 mins of footage).

MEETING TRANSCRIPT — CODING SCHEME

ID (1)	TRANSCRIPT (2)	TIME (3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
GH	We used 3 sections // and optimised the path through the pylon	00:10:03	S	INF	Prod.	Slide #1	Co	Systems design	Design of the fuel line between the fuselage interface and the engine interface	P
SJC	/Good/ I see you used standard fittings to join all the elements	00:10:06	S							
CAM	What about the pressure loss? Did you do any calculations?	00:10:08	Q	CLA	Proc.					
[GH]	[ ]= audio not understood	00:10:11	A							
CAM	Ah! OK, sorry … so can you explain how you achieved this?	00:10:16	Q			Slide #2	Co			

LEGEND

1. IDENTITY OF THE SPEAKER (initials);
2. TEXT TRANSCRIBING SPEECH;
3. TIME WHEN THE INTERVENTION ENDED (hours:minutes:seconds);
4. INTERVENTION TYPE (statement (S), question (Q), answer (A), or feeling/emotion (F));
5. EXCHANGE ROLE (informing (INF), exploring (EXP), resolving problems (RES), managing (MAN), evaluating (EVA), debating (DEB), digressing (DIG), clarifying (CLA), or decision making (DEC)
6. INFORMATION TYPE (product (Prod.), process (Proc.) resources (Res.), or external factors (Ext.));
7. SUPPORTING ARTEFACT;
8. ATREFACT TYPE (Office (O), Drawing (D), Activity management (AM), Information management (IM), Calculation (Ca), Communication (Co), Component (C), Testing (T));
9. TOPIC / DOMAIN OF COMPETENCE (structures design, systems design, manufacturing & procurement, aircraft configuration & architecture, certification & testing, project management & business, production, in-service etc.);
10. TOPIC / DESCRIPTION;
11. TOPIC / ORIGIN (predetermined (P), derived (D), or unexpected (U)).

Figure 5. Huet's Transcript Coding Scheme [5]

3 OBJECTIVE

The objective of the research presented in this paper was to analyse collaborative design meeting scenarios to gain an insight into the various types of information and knowledge which are typically generated and communicated within social situations. The overall aim of the research was to identify where improvements could be made in the recording of this sometimes tacit and implicit information and knowledge. The hypothesis was that current methods of recording these collaborative and social situations are not efficient in capturing the necessary information and knowledge quickly and in forms which can be scrutinised at later dates. Using video and audio recordings of meeting are satisfactory at capturing all interactions and informal and formal information and knowledge exchanges as they happen, however these method result in large quantities of data being stored, much of which can be dismissed as being unimportant routine work or 'noise'. In contrast, traditional meeting records compromising of minutes taken during the meeting fail to capture all of the critical situations as they occur as they may not be obvious at the time and thus many decision made during these instances may be lost.

4 METHODOLOGY

Through a combination of the techniques discussed in section 2.2 and 2.3 the critical situations were captured and retrospectively identified within various design meeting scenarios, subsequently identifying the critical decision points in the design processes and proposing techniques to improve the information and knowledge capture process. This analysis was based on a series of experiments conducted in controlled environments. The aim was to study and examine two basic elements of information activity within the design process:

1. What information is generated
2. What information is stored

By knowing what information is generated and what is actually stored it is possible to build a view of what should have been stored but wasn't (i.e. lessons learnt). A combination of an adapted version of Greg Huet's Transcript Coding scheme [5] to document the interactions within meeting scenarios and Badke-Schaub et al's Critical Situation work [10] to interpret the results were used.

In the first instance, face-to-face meeting scenarios were created whereby a group of 5 participants were given a simple design exercise and asked to complete the task within a limited time (30 mins). Only four of the participants were actively participating in the design process and comprise the design team, the fifth participant was nominated as chairperson and given an agenda which was to serve as the main driving force behind the meeting whilst also doubling as a document for which meeting record can be documented. The design meeting scenarios were filmed using two digital video cameras; a table camera which monitored the face to face interactions between the group, and an overhead camera which monitored the hand movements and gestures of the group during the meeting. This set up (figure 6) gave complete coverage of the meeting and allowed unobtrusive monitoring of the meeting as is shown in figure 7.

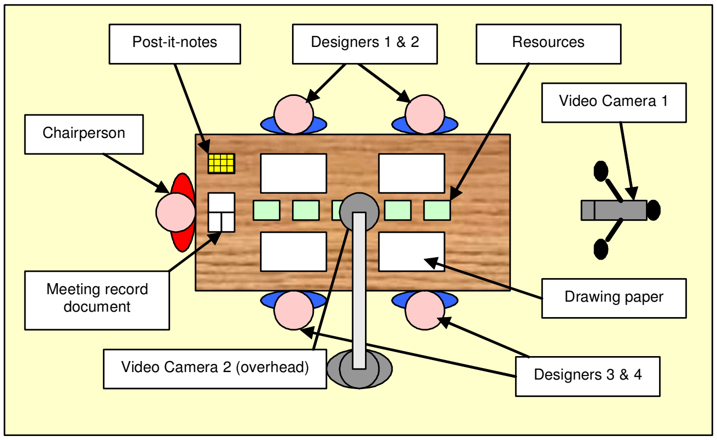

Figure 6. Experiment set up

Figure 7. Camera Views

The audio from the meetings were transcribed and a modified version of Huet's Transcript Coding Scheme (TCS) applied. The basic structure of the TCS was kept the same as many of the categories developed by Huet were applicable to the analysis; however, additional categories were added to identify the critical situations. Through the application of the critical situation criteria proposed by Badke-Schaub et al [10] to the transcript of the meeting, it became possible to identify the critical situations as they occurred throughout the meeting transcript, and subsequently it was possible to identify the critical decision points within these situations as is shown in figure 8.

ID	Transcript	Time	Type	Role	IT	Item	Crit. Sit.	Crit. Dec.
LH	Maybe something that you slip down	28:22	S	DEB	PROD	2	2	
JH	Its like a lid thing	28:24	S					
MS	So you've decide that your making it as a modular design?	28:25	Q	CLA	PROC			
KM	yeah	28:27	A	DEC				
MS	A modular design	28:28	S	INF				

Legend

ID	Identity of the speaker (initials);
Transcript	Text transcribing speech;
Time	Time when the intervention ended (minutes: seconds);
Type	Intervention type (statement (S), question (Q), answer (A), or feeling/emotion (F));
Role	Exchange role (informing (INF), exploring (EXP), resolving problems (RES), managing (MAN), evaluating (EVA), debating (DEB), digressing (DIG), clarifying (CLA), or decision making (DEC));
IT	Information type (product (PROD.), process (PROC.) Resources (RES.), or external factors (EXT));
Item	Agenda Item
Crit. Sit.	Critical situations; 1 - Goal analysis and goal decision, 2 – Information and solution search, 3 – Analysis of solutions and decision-making, 4- Disturbance management, 5 - Conflict management
Crit Dec.	Critical decisions;

Text conventions
Words in *italics* are approximately transcribed
… In the text marks a pause of 10 seconds or less
(…) In the text marks a pause of more than 10 seconds
[…] In the text marks a pause of more than 30 seconds
Underlined words are those which overlap with the transcript following

Specific speaker conventions
[ID] some or part of the intervention from this speaker was not transcribed and the reason given in the transcript encased in [ ]
ID = X, the identity of the speaker was not recognised

Figure 8. Modified Transcript Coding Scheme (TCS)

5 EXPERIMENTATION

Experiments were undertaken within the department of Design Manufacture and Engineering Management at the University of Strathclyde and focused on participants who had experience in design or engineering related problem solving. A design brief was created specifically for the experiments and this brief asked the participants to undertake the concept design and evaluation of a paper-based coffee cup holder. The design brief was loosely based on a class design project undertaken by 3rd year undergraduate Product Design Engineering students within the department. It was felt that the level of difficulty of this task was such that it would not present any significant problems for the participants to complete within a short time-frame, whilst replicating a valid design exercise. Using this student project as a base also allowed the introduction of resources to the scenario such as existing concept sketches and models developed by the students as it was felt these resources would normally be present in real-life scenarios. Within the brief, it was made clear that there were three points which had to be covered within the time frame:

1. Identify the Unique Selling point of the design
2. Generate, concepts, combine and select three to take forward
3. Identify the final design

These three points provided an identifiable structure for the meeting and subsequently were incorporated as agenda items that the chairperson was instructed to conduct the meeting around.

5.1 Phase 1 Experiments

Initially two experiments were undertaken. A group of five people, each with a design or engineering background, were given a simple design task to perform within a design meeting setting. A design brief was provided to each member of the team and the chairperson given sheets of paper with the three specified agenda items that the meeting was expected to cover within the 30 minutes.

5.1.1 Analysis

The audio from both meetings was analysed using the modified TCS and compared with the minutes taken during the meetings. The results were unsurprising in that the depth of information contained in the minutes differed significantly from that of the transcript. From the evaluation of the data from the first meeting it was observed that there were ten instances which, according to the TCS came under the banner of a critical decision but which were not identified within the meeting minutes. From the analysis of the second meeting data set it was observed that there were eleven instances where critical decisions were highlighted by the TCS but failed to be recorded in the meeting minutes. A general observation was that in some cases the decision was recorded; however there was no rationale or background to which would give an indication of how the decision was reached. The following table summarises the results.

	Minutes of meeting		Transcript Coding Scheme (TCS)	
	Decisions	**Critical Decisions**	**Decisions**	**Critical Decisions**
Experiment 1	**5**	**5**	**22**	**15**
Experiment 2	**17**	**9**	**34**	**21**

Table 1. Initial Experimentation Results

5.1.2 Conclusions

Overall, the conclusion drawn from the initial experiments were that traditional minute taking activities are not sufficient to provide a rich history on the decisions made throughout design activities, especially if the intention is to reuse the information within the minutes at a later stage in the design process. It was also observed from the video footage that many decisions stemmed from informal information sources such as gestures and resources available in the meeting, thereby another problem was identified; how can these physical gestures and interactions with resources be recorded in a way which would help provide detailed information on the decision points? In fact it was observed that to adequately record what was happening in the scenarios, certain key pieces of information should be recorded for each decision point:

- Background – what the decision was in relation to, where did the decision stem from?
- Decision – what was the action taken or the decision made?
- Reasoning – why was this decision taken? What was the rationale or reasoning behind it?

It was proposed that these key pieces of information, if recorded, would provide a richer history of information on the decisions relating to both product and also the process information. The identification of these key pieces of information led to the development of a modified method of minute taking. From the evaluation of the traditional minutes it was observed that not enough information on the decisions was being recorded. It was felt that to solve this issue the chairperson or minute taker should employ an enhanced method of minute taking which would record not only the decisions taken during the meeting but also the key information which related to the rationale and background. If at the instance when the minute is being recorded, the minute taker was able to document not only what the decision or minute was but also where it stemmed from i.e. if a decision was made based on a drawing which was made or even centred on the resources being used in the meeting then these interactions would be considered valuable as it provides rationale behind the decision. This enhanced method of minute taking would be a step closer to achieving a richer information history.

5.2 Phase 2 Experiments

Building upon the analysis and conclusions from the initial set of experiments and to evaluate the concept of an enhanced minute, the design meeting experiments were repeated, this time with a different method of minute taking. The chairperson was given three sets of colour-coded Post-It® notes, each colour representing a different resource (Yellow – Resources provided to the teams, Green – Sketches created within the meeting, Blue – Physical interactions and gestures between the design team). As well as documenting the decisions and actions as they arose from each member of the design team, the chairperson was responsible for adding the Post-It® notes to the written document, indicating the background to the decision i.e. where the decision stemmed from. This was done by attaching the appropriately coloured Post-It® note to the relevant point in the meeting minutes, as the minutes were being taken (figure 10). To aid post meeting analysis, the resources which were made available in the meeting set-up were clearly labelled as is shown in figure 11 and the chairperson asked to note the identifier of the resource on the Post-It® notes. Labelling the resources was also considered useful for the identification of the resources when analysing the videos retrospectively. To adequately identify and represent the user interactions with the resources, the previously used TCS document was modified. An additional column was added which documented the use of media such as the resources, the drawing paper (i.e. conveying ideas through sketching), text based communication and also physical gestures.

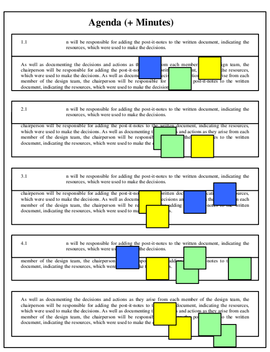

Figure 10. Enhanced Minute Concept

Figure 11. Labelled Resources

5.2.1 Analysis

As with the initial experiments, the audio from both the third and fourth meeting scenarios was transcribed and analysed within the TCS document. The TCS was then compared with the minutes taken during the meetings (figure 12) to identify any differences in the number of decisions and critical decisions recorded by the chairperson.

	Minutes of meeting		Transcript Coding Scheme (TCS)	
	Decisions	Critical Decisions	Decisions	Critical Decisions
Experiment 1	5	5	22	15
Experiment 2	17	9	34	21
Experiment 3	9	5	26	21
Experiment 4	16	7	39	24

Table 2. Experimentation Results Summary

As can be seen in table 2 above, the results for experiment 3 and 4 again highlight a significant difference in the number of critical decisions identified through post meeting analysis compared with those identified within the minutes of the meeting. This further strengthens the argument that traditional minute taking techniques are not sufficient to capture all important decisions as they are made. Based on these results, it can be said that the concept of the enhanced minute failed to aid the chairperson in increasing the number of decisions recorded; in fact it would appear that the introduction of the concept neither enhanced nor hindered the recording of critical decisions. However, the use of the enhanced minute concept and the addition of coded Post-It® notes provided not only a record of the decisions but also gives indication of the rationale and the background to these decisions, something not present in traditional minute taking techniques.

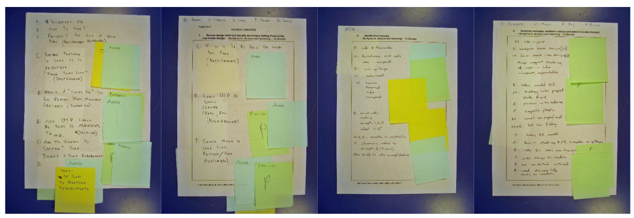

Figure 12. Meeting Minutes - 3rd and 4th Experiments

5.2.2 Conclusions

From analysis of the Transcript Coding Schemes and minutes from the initial two experiments and the third and fourth experiments, it is apparent that although the enhanced minute concept does not actively aid the chairperson in recording design decisions, it does enhance the overall meeting record. The addition of the Post-It® notes provide some of the much sought after rationale which traditional minutes fail to record. Decisions which stem from sketches and the user's interactions with resources are made explicit through the addition of the Post-It® notes, ensuring that a more complete view of the meeting is achieved. These additions can improve the process of identifying the influencing factors on which many design decisions were undertaken and in many cases why. The overall gain achieved by enhancing the meeting record is such that readers who were not present at the time can gain a more accurate perspective of the meeting and better understand the outcomes compared to traditional minuting techniques.

6 FUTURE WORK

This study and analysis of design meetings has focused very much on the early design stages of the product development cycle and on one particular design scenario. The foundations laid down by this work however, possess the necessary attributes to be applied to many different scenarios and modes of working. Although the recording of critical user interactions through the enhanced minute concept and the post-scenario analysis using the TCS were developed for use in meeting scenarios, there appears to be no reason why they cannot be adapted to suit individual working and other design tasks such as design development or prototype testing. It is in this area where future work is being directed. The work presented in this paper is currently being extended to encompass working in the latter stages of the design process and discussions are ongoing on the possibility of performing combined experiments with other academic institutions. The overall vision for this work is the development of a computational based enhanced minuting system which will allow the rapid and simple capture of not only critical design decisions as they happen but also extended rationale and reasoning for these decisions. The rising popularity of distributed design activities has been recognised as an area where the need for information and knowledge capture technologies is particularly pertinent and the long term vision for this work is to develop a system which can address the needs of not only co-located engineering design teams but also globally dispersed design teams.

7 CONCLUDING REMARKS

Through a combination of evaluating previous work and undertaking a series of experiments, this study has observed, identified and evaluated critical instances of information and knowledge generation amongst engineering design teams whilst performing conceptual design activities within meeting situations. Using unobtrusive multi-media recording equipment and observation techniques, it is possible to gain an insight into the decision making processes which engineering design teams typically follow during the course of a design exercise. The work presented in this paper highlights through experimentation that traditional minuting techniques fail to capture all decisions made throughout the course of design development. It was also found that many of these decisions stem from informal information sources and therefore the rationale and intent becomes difficult to identify and subsequently capture.

Overall, the undertaking of this study has provided a useful insight upon which further work can build. From analysis of the conceptual methods presented in this paper, it becomes clear that the development of enhanced minuting systems complimented with multi-media such as audio and video has the potential to improve the recording of informal information for re-use at latter instances. The aim is to assist design engineers to record more information than traditionally documented, providing a much richer product history and allowing the design process to be revisited at a later instance. If design engineers are to capture information and knowledge with a view to re-use at later stages in the product lifecycle then the focus must be on developing a rapid, effective method of capturing formal and informal information at the point at which it is generated rather than through retrospective analysis.

8 ACKNOWLEDGEMENTS

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