SUPPORTING COMPUTER-SUPPORTED COLLABORATIVE WORK (CSCW) IN CONCEPTUAL DESIGN

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In order to gain a better understanding of online conceptual collaborative design processes this paper investigates how student designers make use of a shared virtual synchronous environment when engaged in conceptual design. The software enables users to talk to each other and share sketches when they are remotely located. The paper describes a novel methodology for observing and analysing collaborative design processes by adapting the concepts of grounded theory. Rather than concentrating on narrow aspects of the final artefacts, emerging "themes" are generated that provide a broader picture of collaborative design process and context descriptions. Findings on the themes of "grounding – mutual understanding" and "support creativity" complement findings from other research, while important themes associated with "near-synchrony" have not been emphasised in other research. From the study, a series of design recommendations are made for the development of tools to support online computer-supported collaborative work in design using a shared virtual environment.

Keywords: computer-mediated communication; Computer-supported collaborative work (CSCW); conceptual design; human-computer interface; grounding.

INTRODUCTION

As technologies for remote synchronous collaboration via the internet become more widely available, it becomes increasingly important to understand how the interfaces of shared virtual environments can support such collaboration effectively. In the field of design, there is much interest in understanding computer-supported collaborative work (CSCW), with particular recent emphasis on how teams can exploit audio conferencing facilities and shared whiteboards. Figure 1 shows a shared sketch among the student designers. Many researchers have carried out studies on collaborative design protocols e.g. (Cross 1997) and (Gabriel and Maher 1999). Some have studied the relationship between drawing and dialogue in tackling collaborative design tasks e.g. (Kvan 1999) and (Seitamaa-Hakkarainen 2001), while others have studied argumentation and constructive interaction e.g. (Baker 1999). This paper describes an

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attempt to understand online collaborative processes that occur during the "conceptual design" stage. The aim is to build a framework for observing and analysing these processes, so as to inform recommendations for the development of tools to support the learning of collaborative conceptual design.

Hence, the following research questions are raised:

"How do student designers make use of a shared virtual environment in online collaborative conceptual design?"

"What design recommendations can be made for tools to support collaborative design activity?"

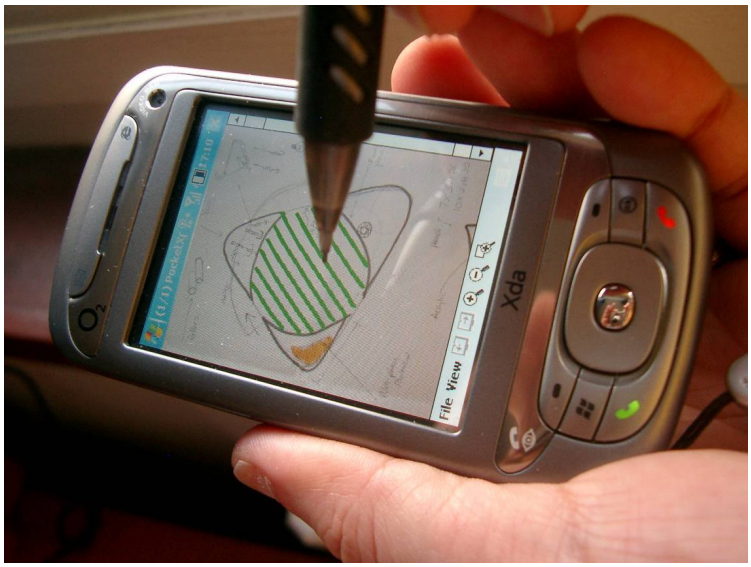

Figure 1: Student designers sketching in shared whiteboard

RATIONALE FOR QUALITATIVE DESIGN

The research applies a case study approach, adapting grounded theory (Glaser and Strauss 1967) with the use of qualitative descriptions of conceptual design activities to construct a broad picture of design practice and thus a broader understanding of how student designers make use of tools in their design processes. The rich interaction data includes graphic acts, verbal communications, idea generation expressions and verbal discussions after the tasks. An experimental approach was not appropriate to deal with rich data of multiple variables, which cannot easily be controlled. This study involves detailed qualitative descriptions and explanations of observation of realistic activities, interpretation and design recommendations.

Figure 2 shows a screenshot a share whiteboard in Elluminate.

DATA COLLECTION STRATEGIES AND PROCEDURES

The participants were mainly recruited from an Open University Third Level design and innovation course, taught at a distance. These students had a minimum of one year of degree studies. Although this course includes an introduction to Computer-aided design (CAD), the use of CAD tools is not a compulsory part of the course.

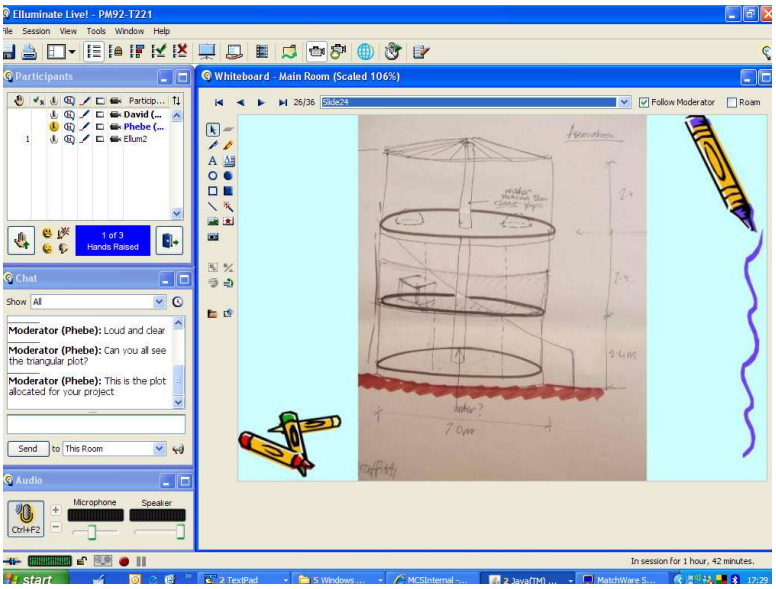

Figure 2: Screenshot of Shared Whiteboard in Elluminate

For the purpose of broadening the range of student designers, one group of participants was recruited from University College London (UCL postgraduate architecture students who had at least two years of professional degree training in the field of the built environment. The use of Computer Aided Design (CAD) tools is part of their professional training, although this consists of just one session.

The data were collected at Bartlett Faculty of Environment, School of Architecture University College London (UCL), and Open University Design and Innovation Residential Schools held at Bath University. Questionnaire data about their experience and background were collected at the beginning of the workshop.

There were twelve sessions in the study, each with groups of 3 or 4 participants located in two separate rooms. Each session was conducted in four parts. The first part was an introduction to CSCW tools. The second part consisted of hands-on structured training of 30 minutes using the shared whiteboard, text chat and audio conferencing facilities. The participants were located in two adjacent rooms so as to simulate remote collaborative design in a shared virtual environment. Each participant had access to a Tablet PC, with headphones and a microphone. Each Tablet PC has shared whiteboard and audio facilities. In the third part, the participants were given a brief to design a wine rack, and to collaborate on the task for about 40 minutes. Finally, the designers participated in a discussion of their experience of using the tools, facilitated by the researcher. This formed the semi-structured group interviews.

The data sources include a record of the interactions displayed on the shared whiteboard, audio recordings of dialogues, screen captures, and video recordings of the participants.

The data collection was designed to respect the privacy of the participants; therefore their real names were not used at any point of information collection. The data relating to participants has been presented in pseudonyms such as CSCW1, CSCW2, etc. in all verbal and written records.

DATA ANALYSIS APPROACH

An emergent themes analysis approach was used, an adaptation of “grounded theory” (Glaser and Strauss 1967).

Glaser and Strauss observed that "in discovering theory, one generates conceptual categories or their properties from evidence, then the evidence from which the category emerged is used to illustrate the concept". They see the goal of “Grounded theory” as producing a theory about some form of activity, and they regard it as enabling us to generate recommendations about how the activity could be performed better. In the case of this research, it is to generate design recommendations of interactive systems to support online conceptual collaborative design activities.

Glaser and Strauss (1967) were critical of research studies that merely verified theories instead of finding out new concepts and hypotheses. The use of grounded theory (Strauss and Corbin 1998) facilitates the interpretation of data from observations and encourages the integration of elements arising from the investigation.

Glaser and Strauss (1967) explained the constant comparative method in four stages:

1. comparing incidents applicable to each category
2. integrating categories and their properties
3. delimiting the theory
4. writing the theory

The research described here differs from most research using grounded theory in the fact that the activities are set up to be observed, rather than observing the work of designers using a shared virtual environment in their natural setting. The activities were designed to facilitate the discovery of emerging themes in collaborative conceptual design situations towards converging focuses for design recommendations.

Glaser and Strauss also suggest that when applying theoretical sampling, an iterative process of data collection, coding, analysis and planning is required for building grounded theory. For this study, theoretical sampling was adapted in a way that new cases were selected to be included as the themes emerged, not iterating in terms of collecting new data, but rather iterating in finding different incidents to support the emerging themes. This approach was along the line of what Willig (2001) refers as an 'abbreviated' approach as compared to the 'full' approach of Glaser and Strauss.

DATA ANALYSIS PROCEDURE

Figure 3 shows the Data Analysis framework, adapting an emergent themes analysis approach.

The sequential screen capture files together with their respective audio recording of the twelve collaborative design sessions were viewed in full. The semi-structured group interviews videos were also replayed in the same way. Facilitated by the software program QSR NVivo7, the data were coded in detail into “nodes” representing incidents (Figure 4) of design processes that appeared to represent concepts relevant to Human Computer Interaction (HCI) design issues.

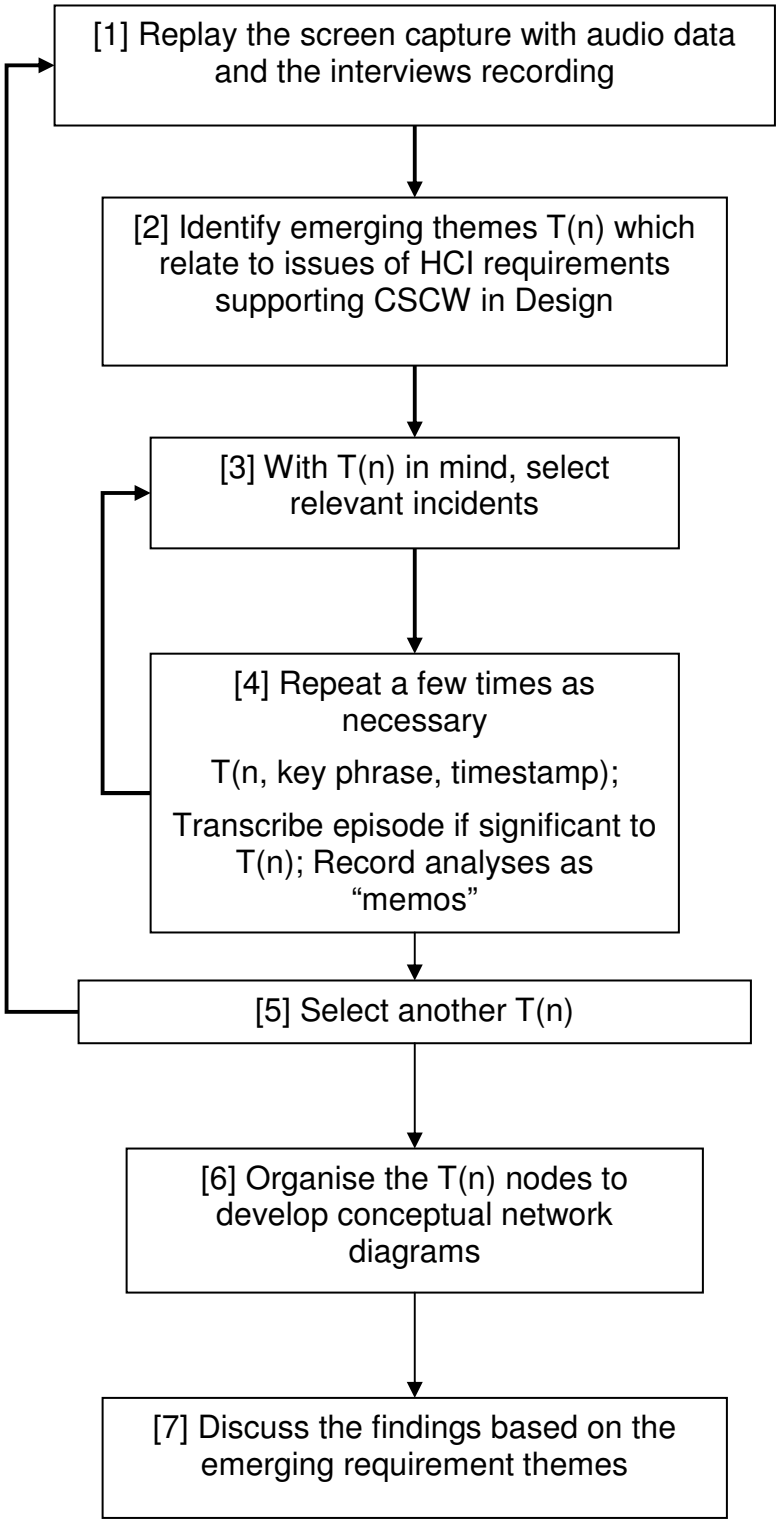

Figure3: Data Analysis Framework of Emerging Themes Analysis for CSCW in Design

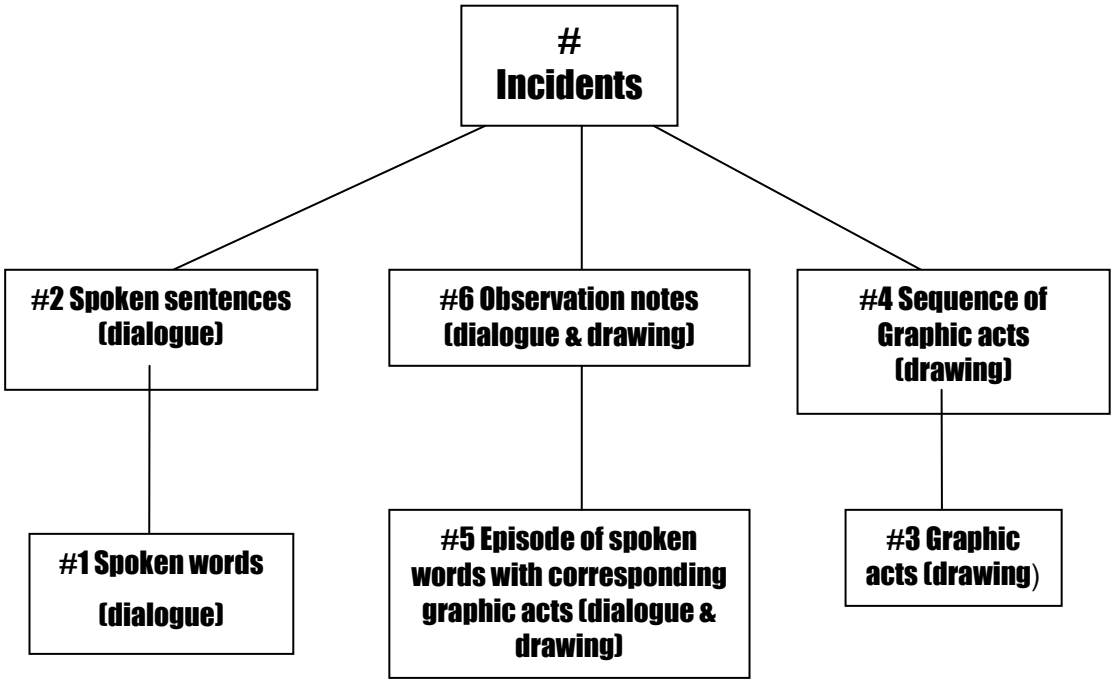

Figure 4: Illustration of "incidents" for the granularity of open coding.

As the data were coded to identify emergent themes, the connections between the themes were also recorded in conceptual network diagrams (Figure 5), which were updated iteratively during the coding stage. Hence, nodes can represent "incidents" or "themes" depending on how they are connected in the conceptual network diagrams. The nodes which represent "themes" were colour coded so as to distinguish from the nodes which represent "incidents". The connections between the themes are determined by the relationships between them.

Broad emerging themes are concepts which emerge across the observed and interview data. During the coding, they were identified, indexed and finally organised into conceptual network diagrams. These emerging themes were associated with the broad aspects of design processes which have implications on HCI design issues. The broad emerging themes were identified in several different ways. One of the approaches was to observe whether there are clusters of nodes connecting to the same key nodes. The connections derived from the evidence which suggested relationships between the nodes. Another approach was to identify the broad emerging themes from the notes taken when viewing and listening to the audio-visual data, searching for evidence from the specific emerging themes to support the broad emerging themes. A case study exploring ambulance-dispatcher decision making was analysed in a similar way using the emergent themes analysis approach by Wong and Blandford (2002).

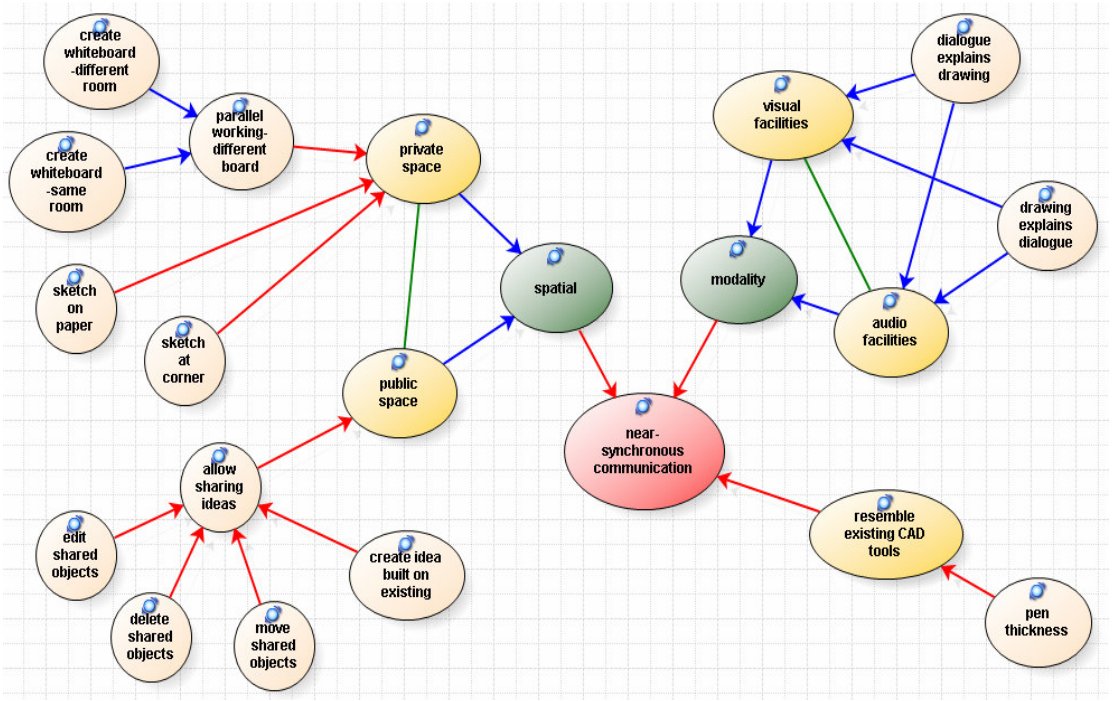

Figure5:. Partial conceptual network diagram for the broad emerging theme of near-synchronous communication in QSR NVivo7.

The interconnections between the nodes were identified on the conceptual network diagrams. Some nodes were not connected to any emerging theme; some nodes were connected to one emerging theme; and some nodes were connected to more than one emerging themes. Separate diagrams were drawn for each of the themes that emerged. Figure 5 illustrates a conceptual network diagram for the broad emerging theme of "near-synchronous communication".

TRIANGULATION

Strauss and Corbin (1998) comment that it is impossible to attain a state of complete objectivity; for every piece of research, both quantitative and qualitative, there is an element of subjectivity, and that researchers should take appropriate measures to minimise its intrusion into their analyses.

To attain a reasonable level of objectivity, triangulation was adopted from varied sources (Knafl and Breitmayer 1989). The data collected included:

- questionnaires about the participants' design background, and experience of CSCW, CAD and Tablet PCs;
- sequential screen capture and audio recording of the collaborative sessions; and
- semi-structured group interviews after the tasks.

Erzberger and Kelle (2003) recommend that 'the use of different methods to investigate a certain domain of social reality can be compared with the examination of a physical object from two different viewpoints or angles. Both viewpoints provide different pictures of this object that might not be useful to validate each other but that might yield a fuller and more complete picture of the phenomenon concerned if brought together' (p. 461). It is more appropriate in an adapted grounded theory approach to consider the coding of the independent coders as providing further information about phenomena or patterns. In this research, triangulation was regarded

as seeking complementary information rather than validation. Two architects, a software developer and a design educationist were requested to code different sets of samples of the data for triangulation purposes. The objective was to verify the fundamental logic of the inter-relationship rather than to agree on the actual categories and concepts.

DESIGN RECOMMENDATIONS TO SUPPORT COLLABORATIVE CONCEPTUAL DESIGN

In this study the participants had little access to private virtual spaces to explore and experiment with ideas. All computer-based sketch output was made on the whiteboard and thus it was in the public domain. Verbal feedback and evidence of private work on paper suggests an important need for supporting private space. Evidence from the data shows that the collaborative designers improvised their own "private space" by

- sketching at one corner of the whiteboard, as if it were a private sketch pad
- creating a new whiteboard and sketching on it without inviting others to join until they are convinced and the ideas are ready for discussion
- going to another virtual room and creating a new whiteboard and sketching on it without inviting others to until ready
- drawing on a piece of scrap paper to assist private thinking

While 'think aloud' and 'draw aloud' protocols were successfully used to generate data there were some long gaps without verbal and graphical communication. As found in other studies, the workspace tools should support the mechanisms of communication and mediate interactions between drawing and dialogue and the tools should facilitate designers' coordinating their communication. Collaborative tools should enable the sharing of a common orientation and mutual understanding, yet still allow some means of distinguishing between individuals. The data also revealed that it is important that all collaborative designers should be allowed to access shared objects, including moving, editing and grouping them. For an interactive system supporting collaborative design, the 'presence' of the participants should be represented in the tools – even where an individual is not always involved. One obvious example was that three of the participants moved to another room and continued the conversation there leaving one of them behind in the original room.

Many earlier studies of CSCW have sought to identify system requirements for the support of collaborative designing. This study suggests that those engaged in design activity may need facilities for near-synchronous communication in addition to access to conventional tools for supporting synchronous and asynchronous communication.

Near-synchronous communication presents opportunity for reflection. It allows drawings to be constructed without pressure for explanation from those viewing. It allows ideas to be recomposed. Unlike verbal dialogue the interplay between design participants using sketches to augment communication is slow. There is also a need for interpretation and reflection on outputs before a response can be made. Face-to-face collaborative design reveals considerable use of near-synchronous communication.

For student designers the use of sketching may provide an important means of supporting communication, developing a shared understanding of tasks and problems, sharing conjecture, co-constructing proposals and reflecting on achievements. As Artman & Ramberg et al (2005) confirm there is a vital role for sketching in

maintaining collaborative working. Perhaps there may be a significant need for student designers to oscillate between what they call 'different forms of design contexts'.

CONCLUSIONS

This research has explored the question of what design recommendations can be made for tools to support online collaborative conceptual design activities through the study of how student designers make use of a shared virtual environment in the activities described.

The proposed approach improves the understanding in CSCW on the themes of "grounding" (mutual understanding) and "supporting collaborative creativity" complement findings from other research. For example, Dillenbourg and Traum (2005) suggest that non-persistent media like speech would not have the persistence, and media in which it is also difficult to independently assess the attention or perception of the other would require much more acknowledgement to reach the same level of grounding. The emerging theme of the requirement of recording the design process and rationale confirms and complements their proposition. The findings of the research also confirm Clark and Brennan's (1993) proposition that grounding is essential to communication, and complement their proposition that medium and purpose interact. The findings described here also complement the design principles for tools to support creative thinking as suggested by Resnick et al (2005), especially on the aspects of sketching for creative thinking for remotely located users. The concept of private space and public space construed in this research also reinforces the benefits of extending the tabletop into physical space suggested by Rogers et al (2006).

The paper has also outlined a methodology for observing and analysing collaborative conceptual design processes. The methodology is valuable in developing process and context descriptions, and explaining patterns and phenomena. The novelty is that the emerging themes provide a "big picture" of the collaborative conceptual design process and context descriptions, rather than concentrating on narrow aspects of the final artefacts.

There were limitations with respect to the analysis and data. The analyses were carried out on a small sample of design students using a limited range of categories. However, it was felt that extensive analysis of all the dialogues was not appropriate because of the nature of the data. It was more valuable to consider the issues in wider context to understand the "Big Picture" than to study the dialogues in microscopic depth. A thematic analysis of the data was adopted to gain a view of the big picture as revealed in the observed data rather than the minutia of each interaction.

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