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Mocking Up:

Strategies to engage expert users in designerly thinking

Saiful Hasley Ramli

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Content

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Abstract

This research investigated methods to enhance creative collaboration between designers and expert users, in this case surgeons. I adopted a practice led approach in which I acted both as researcher and designer. In the pilot studies, I explored methods and issues using a variety of expert users as proxies for the surgeons. In the main study, I used two live projects to explore and evaluate strategies identified in the pilot studies. Design methods developed from this research enable expert users to employ designerly strategies in design collaboration. These strategies include co-evolution of problem and solution, problem reframing and exploring the solution through making, in this case, sketching and making mock-ups.

The design methods evaluated through the practical work are:

- *Contextual Immersion* by the designer. This is a process to help designers to understand user's context through a form of 'apprenticeship'.
- *Mocking Up*. It is a co-creation of mock-ups, between expert user and designer as a framework for creative collaboration.

Through the research, data were collected in the form of interviews and video recordings on co-design sessions allowing analysis by expert reviewers as well by myself. The analysis of these workshops demonstrated that these collaboration strategies can enable the expert users to mobilize their professional experiences and knowledge in a designerly collaboration.

The outcome of this research is a description of a co-design approach which I called Mocking Up, which designers or expert users may use to facilitate collaboration between them. Another outcome from this research was a design artefact, a 'Fistula model' to be used by surgeons and radiologist as a visual and physical reconstruction aid of fistula-in-ano cases.

Chapter 1: Background, aim and objectives

This is a report of a research project, undertaken through design practice, in a collaborative setting. The research is an exploration of methods of designing which may be of value for practitioners who design for professional contexts. In this chapter, I will describe my experience as a practical designer and the shift to becoming a design researcher. This will be followed by a discussion of my previous MA project which led to the interest in exploring design research in the surgical domain. Then, I will discuss the projects I undertook in this research. Finally, I will discuss the aim and objectives of my research.

1.1 Experience that led to my PhD

After I graduated with my first degree in industrial design, I practiced for five years in manufacturing in two manufacturing companies. I was responsible for developing a range of products from furniture to display settings. The knowledge and skills gained from academic study were then developed further in the professional world.

In 2005, I started working as a tutor at Universiti Putra Malaysia, Malaysia. At that time, my understanding of my responsibilities as a design academician was to pass on professional knowledge and experience in design to the students. While planning my MA study, I met a proctology surgeon who was working at Kuala Lumpur General Hospital in Kuala Lumpur, Malaysia. He explained the difficulties he had encountered in the operating room regarding the use of the

current anal speculum. I assumed, by knowing me as a designer, he was taking the opportunity to propose a collaboration of working together and a chance for him to innovate.

As an experienced designer, this was an opportunity for me to work in collaboration and in a clinical setting which was new and interesting. I was also invited to be present during real surgery at his work place, so he could show me the problems encountered while performing the surgical procedure. I was also given permission to do a video recording of the surgery for observation. While recording, he explained the use of the current instrument while doing the operation. In addition, he expressed his needs for an instrument that may help him to better perform future operations. Even without any medical (or biology) background, I could clearly understand his problems and needs by watching and listening to the surgeon.

We had only cooperated briefly when I pursued my MA in the UK. Still, taking into consideration the surgeon's concerns, I brought this issue as my MA project at Sheffield Hallam University. Without further advice from clinical experts, I studied the video recording as a method of understanding the context of the problem mentioned by the surgeon. I undertook this inquiry by referring to existing specula and other related instruments on the market, and by reviewing relevant scientific publications.

Doing my MA gave me the opportunity to get valuable advice from a tutor who was experienced in design for health. This also led me to become acquainted with some producers of medical instruments in Sheffield and I took my instrument design proposal to be evaluated by them. This exposure gave me an understanding of current design development practiced by these stakeholders e.g. they appreciated digital 3D modelling compared to paper sketches.

1.2 Outcomes of the MA Project

I developed a new design of an anal speculum and developed a product for use (Fig.1.01). I received input from related manufacturers and I had the chance to take the design to the surgeons to be evaluated. It achieved a positive response

e.g. it was suggested that I should patent the design as they found it usable and original.

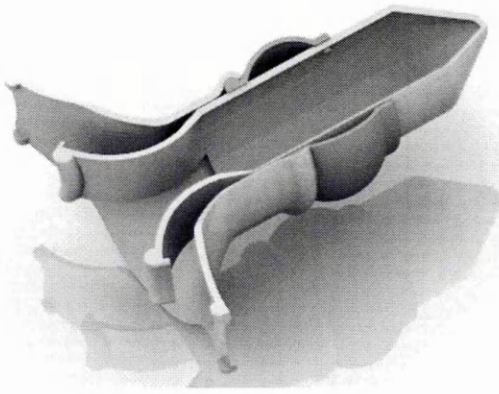

***Figure 1.01**.SRAS.Self-retaining Anal Speculum.*

Developing the speculum and its positive international recognition (e.g. patent and medals from design exhibitions) allowed me to develop my skills with regard to design in the surgical domain and also to see that it is worth the effort.

Referring to this past design project, the surgeon was only involved at the early stages and at the end of the process (Fig.1.02). Without the presence of the user in designing a critical product, such as a surgical tool, the designer may have limited information, or the wrong target use of the product as my understanding about the user context maybe based only on certain resources distant from user's involvement.

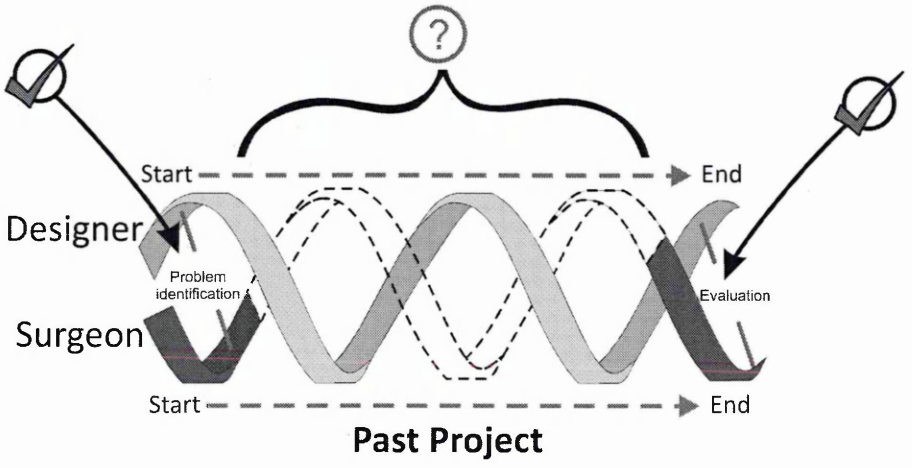

***Figure 1.02**.Diagram of my previous MA design process.*

In such collaboration as this, it is important for a designer to know the context of the domain involved. Rasoulifar et al. (2008), who undertook design

collaboration with surgeons, suggests that designers can barely be representative of the users when designing in such a domain. To design with a user, one needs to understand the world of the user (Muller et al. 1993). Having seen the importance of having expert input, I believe that user participation is important from the start to the finish of a particular product design. So, I suggest that to have user collaboration throughout the project seems to be significant in designing in the medical domain.

To participate in collaboration, it is useful to refer to user-centred design methodology. This offers several approaches that can be chosen depending on the nature and suitability of the project. Steen et al. (2007) made a useful review of six methods and suggested their use according to the project's goal. From this review, I found participatory design (Schuler and Namioka 1992; Muller et al. 1993) of interest for investigation.

This is because in a participatory design approach, users become partners in the design process, while most other user-centred design approaches take users as a subject of study (not to say participatory design does not do this as it also involves study of the user). Schuler and Namioka (1993) and Muller et al. (1993) describe how this methodology provides the participant with a voice in the process of design, evaluation and implementation of the system which they will use.

I explored two particular methods from participatory design which were 'contextual inquiry' (Holzblatt and Jones 1992) and 'mock-up' (Ehn & Kyng 1991). Contextual inquiry offers a suitable concept of how to learn a user's context while mock-up shows that users can be actively involved in design activity by using 3 dimensional artefacts.

From my initial review of participatory design, I found a significant number of examples in the medical domain. A small number of researchers discuss participatory techniques for designing surgical instruments (Rasoulifar et al. 2007, 2008; Hisarciklilar et al. 2009; Thoman 2009). A greater number have investigated human-centred design for electronic medical devices (Bieman 1991; Lin et al. 1991; Sjoberg 1998; Berguer 1998; Gennari and Reddy 2000;

Kristensen 2006; Weng et al. 2006). These suggested that user participation cannot be detached from the design process in the medical domain (this includes surgical and healthcare).

1.3 The research project

Meeting surgeons to evaluate my MA project in early 2009 led to a further design project. A consultant surgeon, working at the Northern General Hospital in Sheffield, proposed working together as a partner on a project of designing important surgical instruments used in the surgery of *intestinal anastomosis*[1] – a surgery of the union of parts (especially tubular parts) of the body. This practical project was seen as a potential vehicle for this doctoral study (Rectal clamp project).

A second project was undertaken with another colorectal surgeon who was working in the same hospital. During this doctoral research we collaborated in designing a fistula model to aid the radiologists and surgeons in understanding complicated MRI reports on *fistula in ano*[2](Fistula project).

Both surgeons came to me with their propositions which seemed genuine and they also appeared motivated to collaborate in the design projects. Von Hippel (1976, 1986) characterised such people as 'lead users'. These are people who experience needs earlier than other users and are motivated to innovate because they can benefit from it, and surgeons are widely respected as innovators of surgical instruments (Kirkup 2006; Bennion 1979).

So, it is interesting to explore the interaction between surgeon-innovators (that may be lead users) and designers in design collaboration. This collaboration may suit co-design as defined by Sanders and Stappers (2008). They describe co-design is the creativity between designers and non-designers, or people who are not trained as designers, collaborating in the design development process and enabling latent creativity within these users. Sanders and Steppers co-design is

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[1]Surgery procedure in lower gastrointestinal where patient intestinal were separated into 2 section by incision and sutured together.

[2]An anorectal disorder where there are appearance of unusual connections between the lower bowel system (anal canal) and perianal area (anus outer surface).

growing in take up within participatory design, so their concept was suitable for my study which was based on investigating a participatory design approach.

1.4 Aim and objectives

As previously mentioned, collaborative design work with surgeons is worth exploring. The professional practice in this research may not be considered novel because interaction between designers and users is widely practiced and known as design consultation in the market. However, documenting and evaluating these collaborations may provide a reliable and generalizable approach to such collaborations which does not depend only on the individual experience of the designer.

Sanders and Stappers (2008) suggested that users are also creative at some level. So, this research has shown how a user's creativity can be integrated with a designer's knowledge and skills, and how this can lead them to design new and effective surgical tools that are reliable to use and perhaps have the potential to be a marketable product. Collaborative and creative activities could be the key of missing part in the design process.

Thus, as a researcher, I have set out to develop an approach that may be useful for designers or surgeons in designing effective surgical tools in a collaborative setting. So, the focus of the research is a method for co-design. As a designer, I hoped to help the surgeons to develop their ideas into designs that can assist them in their professional work. The research has required me undertake different roles (designer and researcher) simultaneously. This was a challenge as I was very experienced as a designer and practiced this for quite some time, but was a novice researcher. Two live design projects were undertaken in this research as the vehicles to address the main and supporting research question as follows;

> To what extent can a participatory design approach aid the development of surgical tools and improve their effectiveness? And what are the techniques for improving designer–user interaction, which may include lead user involvement, during the design process in surgical-tool development?

The overall objectives guiding the research were:

1. To investigate current professional practice in developing surgical tools.
2. To investigate participatory design methods that will become the base line for developing my own approach in a co-design setting.
3. To investigate how a surgeon's creativity can be employed in design collaboration.
4. To explore and establish a co-design framework that may suitable in designer – surgeon collaboration.
5. To evaluate the validity of the co-design approach developed in the research.

As mentioned above, the novelty of this research is the documentation and evaluation of design collaboration between designer and surgeons. The second novelty of this research is the use of process of making mock-ups in a presence of expert users as a tool to understand the user's context as well as designing. This also makes the second novelty of the research that is the contribution to design knowledge through the use of 'making' as a shared responsibility between designers and expert users.

Chapter 2: Exploring design research methodology

In seeking a starting point for my research methods, considering my experience as a professional designer, I encountered a number of suggestions that action research is a useful model for inquiry by design practitioners

Bruce Archer (1995), in a very wide ranging review of the nature of research, suggested Action Research as an appropriate methodology to investigate practitioner action. He defined Action Research as "systematic enquiry conducted through the medium of practical action; calculated to devise or test new, or newly imported, information, ideas, forms or procedures and generate communicable knowledge"(ibid). He indicated clearly that the practical action in this case includes design practice.

Investigators in Action Research undertake their action in real situation in order to "test or develop or shed light on something" (ibid). Archer points out that action research is "situation specific" because it is undertaken in a real and complex world and findings apply to the circumstances (place, time, and person) where the action took place. Swann (2002) made a deeper exploration where he proposed how action research can be executed in a design setting.

2.1 Action research for design research

Swann (2002) explored research approaches for design and found that action research is a useful methodology for design research. He suggested that designers often present the product they designed to inform the general community about creative design activity. However this approach cannot reveal 'design in action' which he claims is necessary if a wider audience or collaborator is to understand and respect the relevance of design.

He explained that design deals with the interaction between people, artefacts and situations whereas engineering and physical sciences are more focused on what he described as the "quantifiable certainties" of the physical world. Design research may be interpretive and a form of qualitative research which is suitable to investigate human action. Visual forms of design outcome may be 'read' by an informed audience but may not offer understanding to a wider population. For this it is important for design to be interpreted into other communication forms often written, rather than represent itself simply through products.

Swann stated that design is likely to initiate synthesis as a way for designers to develop their understanding of a problem.

> *"The act of designing is a problem solving performance that is not necessarily the same as research and analysis" (ibid)*

So, to recognize some design action as research activity, Swann proposed that action research methodology offers some important components. He described action research as requiring three conditions (after Kember and Kelly 1993).

> *"First, its subject matter normally is situated in a social practice that needs to be changed; second, it is a participatory activity where the researchers work in equitable collaboration; and third, the project proceeds through a spiral of cycles of planning, acting, observing, and reflecting in a systematic and documented study".*(Swann 2002)

So, he suggested that as action research and the action of designing are very similar, it seems that action research may be applicable as a research methodology for designers to investigate design practice. As participant

observers, they are able to observe and control their practice very closely, providing different research opportunities to those available to 'outsiders'. By 'outsiders' he means researchers who are not designers, looking at the nature of design or designers.

Lee (2008) also discussed insiders and outsiders in research into design and user involvement. Following Mitchell (1993), he described a gap between "scientific" design researches by researchers who are not designers and "creative" design practice. He suggested that new insights might come from professional designers who engaged with research.

Two researchers, who I categorise as outsiders, can be taken as examples here. Eric Von Hippel (1986), who has been based in innovation research, analysed existing case studies to look into how designers or engineers can make use of lead users in the innovation process. Another instance is Arlene Oak (2008), who investigated interactive aspects of design particularly in designers' communication and negotiation from the social psychology perspective. Both of these studied the interaction between designers and users in design, with aims similar to my research.

Von Hippel studied past cases to conclude that lead users are useful in innovation while Oak observed and analysed conversations in design processes to understand her subject more directly, but neither were able to intervene in the design process in an experimental way. Non-designers' provide a valuable outside perspective on design. However, it is arguable that other insights may be available if designers study their own work, and action research offers a platform to do this.

Swann (ibid) suggested also that participation and collaboration in action research should empower stakeholders who were not designers. He suggested that users should be genuine collaborators, not merely commenting or evaluating design work, but working concurrently together with the designer/s.

Action research requires systematic documentation of the research although such documentation may be difficult due to the 'messy' nature of design practice. For this reason, action research has methodologies for documentation suitable for

design e.g. CRASP (after Zuber and Skerritt 1992) and this led Swann to describe his own action research model for design.

> *Data gathering by the participants*
>
> *Participation and power-sharing in decision-making*
>
> *Collaboration as a critical community*
>
> *Self-reflection, self-evaluation, and self-management*
>
> *Learning progressively by doing and making (mistakes) in a "self-reflective cycle"*
>
> *Reflection and communication to the broader community*
>
> (Swann 2002)

Swann suggested that, such research being reflective and grounded in a particular situation, will contribute a comparative case study for other designers. He claims that such documented practice has been very rare. This systematically documented professional practice can then enrich design theory, documenting practice as well as exemplar products.

Koskinen et al. (2011) discussing design research through practice, has given an example of design research using an action research approach. This research work, which was led by Ezio Manzini and Anna Meroni at Politecnico di Milano, studied the local value chain of the food business and at the same time created a new service prototype. Koskinen gave this as an example to illustrate the significance of fieldwork and how design activity, in this case service design, might become action research.

Another instance, which sheds some light on differences between action research and practice-led research by designers, can be taken from Nicola Wood's research (Wood etal.2009; Wood 2009, 2010) where she investigated how craftsmanship skills can be transferred through multimedia learning resources. She spent more than 7 years exploring methods for how designers can elicit crafts people's knowledge and embed it into materials for learning. She worked closely with master craftsmen, interviewed and took videos of them during the making

process e.g. knife making. She claimed that her research is similar to action research that might be carried out to explore educational strategies, but is distinct in the continuous and fluid way that designers evolve their work, compared to Kurt Lewin's 'action research spiral' which involves cycles of planning, action and fact finding about the result of the action (Wood et al. 2009).

2.2 Research through design

William Gaver (1999; 2012) is recognized for innovation in design research methods, for example his development of "cultural probes". Gaver's (1999) "cultural probe" provides a good example of how designers can gain direct insight into participants as opposed to gathering data for analysis, which would be more normal in observational research. A cultural probe is a pack which may contains materials for the user to complete a number of tasks, recording aspects of their lives, e.g. by photographing something they value or dislike or writing a description of some experience or object. When returned to the designer/researcher the probes may provide rich insights into participants' lives, which may influence directly the designs that are produced.

The packs are designed not to be 'highly finished' allowing participants freedom to change the materials. Cultural probes are used to document the cultural situation, combating distance as well as closing any generational gap between researchers and participants. Nevertheless, it does not lead directly to new designs, instead being a tool for familiarizing oneself with the current culture of the site.

In my research, it was important for me to understand the culture of surgery and surgeons in order for me to collaborate with them. Referring to scientific and clinical sources often only offered me a superficial understanding. Immersion in the user's context seems to be crucial in collaborative designing (e.g. Holzblatt and Jones 1992; Burns et al. 1999). For this, an approach related to cultural probes, for example providing participants with materials that they may manipulate, may be used within the designer's 'contextual immersion' (as described in 4.1).

Gaver (2012) suggested that the main focus for research through design is the finished product (he cites Dieter Rams' work for Braun and Vitsoe) where these companies annotated the design methods developed from the product. This is obviously in contrast with my research. As a designer, it is true I have a focus to develop a product with the surgeons. However, my research was focused on developing a method of designing in effective collaboration with a surgeon which may be used for other expert users.

Gaver (2012) and Zimmerman et al. (2010) agreed that having artefacts as a result is general and common when undertaking research through design. Therefore this convergence between design practice and theory building may become methodology in this kind of research (Gaver 2012). Although the products of my research are methods for practice, which refer to the role of advanced research as a process of creating theory, the impact of the research will depend on the work leading to convincing products or prototypes.

Zimmerman et al. (2010) discussed the formalization of methods in research through design by undertaking interviews with experienced researchers in the HCI domain. They suggested that researchers in HCI attempt to distinguish research through design from design practice in that the research allowed the designer to ignore commercial concerns in order to focus on new understanding of technology. This split between "theoretical" research and commercial practice may not always be true especially in the medical field. Karel Van der Waarde, who did his PhD on drug packaging design, including user engagement in design process, successfully commercialized his design approach because pharmaceutical companies needed the "scientific" validation that his research could provide (Rust 2012)[3].

But on the other hand, do designers care to adopt design methods developed in research through design?

Gaver (2012) suggested that designers tend to design by referring to design techniques and orientating concepts as well as existing design examples to inform

[3]Conversation between C.Rust and Karel Van Der Vaarde 2009, reported to the author, November 2012.

their own practice. This is because theory (design method) is conditional while design artefacts are explicit. So he suggested that by including and showing design work (portfolio), together with annotation, this may persuade designers to refer to design methods developed from research through design.

2.3 Design activities as research data

If design activity is an important part of the research activity, then it is necessary to understand what kind of data come from such research and how they can be documented.

Owain Pedgley's (2007a, 2007b) work is a useful resource because he provides a precise method for his research including design activities and their documentation.

He used a written diary technique to capture his own design activities, together with a review process involving experts with strong tacit knowledge in the particular context (guitars). His documentation covered "visible acts" (macroscopic) as well as "near to invisible acts" (microscopic). He listed four criteria he must have in the tool for capturing the design activities in his particular research; solo effort, endurance, subject delimitation and mobility. These criteria were not employed in my research however; I am looking at actions in the collaboration between designer and user.

Pedgley noted that similar criteria can be found in action research, but he did not regard his work as action research which requires social interaction while his research studied his own solo practice.

Diary writing did not play a big part in my research as I focused on video recording and review. Nevertheless, Pedgley's list of good practice in diary writing (Fig.2.01) provides some ideas when considering methods for recording design work and the interactions between the designer and the surgeons:

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)

***Figure 2.01**.Pedgley's list of good practice in diary writing.*

My own methods for using video recording and review, following work by Wood (2012) are described in detail in (5.5) below.

2.4 Characterising my research

Based on the discussion above, action research techniques have played an important role in my research. Descriptions of action research by Archer (1995) and Swann (2002) indicate that the nature of my research has some characteristics of action research.

As described above (2.1), Swann suggested that subject matter in this research is 'situated in a social practice that needs to be changed'. This was indicated in my research where the designer and surgeons collaborated in a design project with the aim of developing and investigating ways to improve both the collaboration and the surgeon's ability to engage in "designerly" thinking (4.6). This was also indicated Swann's second feature of action research which is fair collaboration. In fact, my research investigated the method of working in partnership with expert users, in this case surgeons.

Archer described action research as a 'systematic enquiry undertaken through the medium of practical action' and Swann elaborated that these enquiries "proceed through a spiral cycle of planning, observing and reflecting in a systematic and documented study". I undertook this approach in my research through semi-structured interviews, video observation and transcription as well as undertaking post hoc expert reviews (described in detail on chapter 5).

The intended result of the research is a design method or conceptual framework for a researcher or a designer to employ in their own enquiry or practice which Gaver (1999; 2012) and Zimmerman (2010) both describe as a characteristic of research through design.

During the course of the research some of the original design aims were put aside when the expert user identified more interesting opportunities arising from the design process (8.2.5). This has allowed documentation of a form of 'Wicked Problem' thinking (Rittell & Webber, Buchanan) which is not easily visible in post-hoc descriptions.

To carry out the research in this way it is necessary to work intensely with a very small sample of users. Clearly this provides a different kind of result to work that is able to survey a wider population. I have considered how such work can be both valid and useful in (6.4) below. Briefly, the success of the research depends on both the depth of experience of the expert users and their ability to represent their wider professional body.

Chapter 3: Contextual review

In this contextual review, I investigated surgeons and their involvement with surgical tool innovation. For this I drew on medical history literature and interviews with surgeons and surgical tool manufacturers seeking to understand surgical tools innovation. This is important for me as a designer, to understand the user's context and as a researcher, to explore the proposition of surgeons as innovators. The chapter ends by discussing the current challenges in developing surgical tools which I drew from the interviews.

3.1 Surgeons, tools and innovation

Many of my sources come from the history of modern surgery in Europe (e.g. Porter 2006). However, there is also relevant information about innovation by medieval surgeons, particularly Avicenna and Abucacis (Bekraki et al. 2000 and Tschanz 2003), and Kirkup (1982, 2006) have provided evidence of prehistoric surgery and surgical instruments.

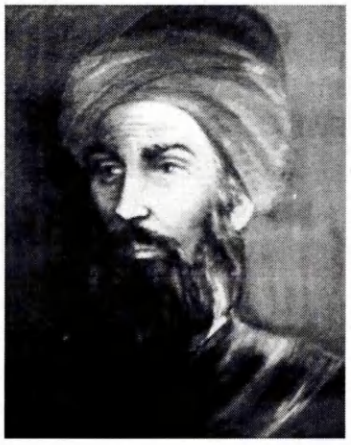
Other useful material has included Wilbur's (1987) catalogue of surgical instruments from the enlightenment era which he termed "antique". Bennion (1979) also listed 'antique' surgical instruments and discussed the early era of

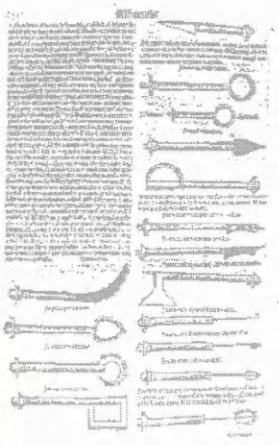
surgery as a profession. Bekraki et al. (2000) and Tschanz (2003) provided continuity through their description of medical developments from medieval Islamic times to the modern surgical world.

In Medieval Europe, 'cutting' was the job of a butcher. An expert butcher assisted a medical practitioner or 'healer' (early doctor) to make a major incision in an operation (at that time, operations were mainly to cut off an infected body part), while in the medieval Islamic world, medical experts carried out operations themselves.

Medieval medical experts formed a bridge between ancient Greek and 'enlightenment' medical practice, as well as innovating in their own right. IbnSina (known in Latin as Avicenna) introduced the use of alcohol as disinfectant in medicine and explained methods to perform a cataract removal operation (Porter 2006). Al Zahrawi (known in Latin as Abucacis) (Fig. 3.01) is known as the father of operative surgery, and he listed 200 surgical instruments in his book Al Tasrif (Fig. 3.02) (Bekraki et al. 2000). Most of these tools appear similar to later devices but with fewer examples of specialist tools for specific procedures.

At that time, medicine was centred on 'bimaristans', or clinics, where a wide variety of medical techniques were practiced, including surgery (Tschanz 2003, Porter 2006 pp182).





Left, ***Figure 3.01***
Portrait of Al Zahrawi

Right, ***Figure 3.02***
A Latin translation from the book Al Tasrif.

Avicenna wrote '*The Canon of Medicine*' which was a key reference of medical scholars until the European Renaissance. In the early Ottoman period, a medical scientist named Serefudin Sabuncoglu wrote a book about medical and surgical

techniques in Turkish (Bekraki et al. 2000). His special interest was in anal diseases and proctology, and he designed his own equipment (as well as inheriting tools from the AlZahrawi period). He recorded this in illustrations that he drew himself (Fig.3.03).

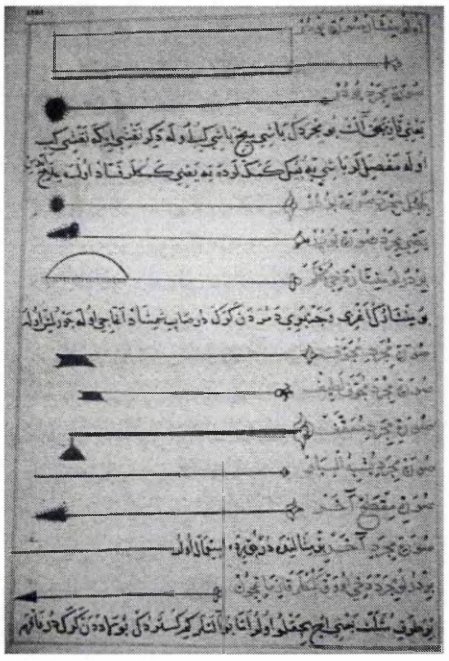


Figure 3.03.*Illustration of surgical tools made by Serefudin Sabuncoglu. Bekraki et al. (2000).*

The early practitioners, IbnSina, Al Zahrawi and Sabuncoglu show the inventiveness that can be found among surgeons. From my experience as a designer looking at this historical account, it appears that these surgeons were able to design surgical instruments as well as document them in drawings. A few centuries later, the European Renaissance accelerated new discoveries in medicine and surgery. For example, Ambroise Paré (c. 1510 – 20 December 1590) invented surgical procedures for amputation as well as limb prosthesis in his time (Porter 2006 pp192).

In the European enlightenment, specialist barber surgeons appeared in place of butchers. Their skills in knife cutting work were well known but criticized as a manual skill which was learned by apprenticeship. Surgeons were subordinate to doctors (Porter 2006 pp189). They assisted the doctors in certain cases which needed incision and suture works. Then, in the 18th century, surgery rose in quality and status and became an academic discipline taught in colleges. For instance, the Royal College of Surgeons in Edinburgh in 1778, offered a Diploma

in surgery to the public to be undertaken as a professional course (ibid pp194). The innovation of anaesthesia and asepsis in 1840 allowed surgeons to explore new techniques in surgery (Pickstone 1992 pp17-46).

3.2 Surgical tools

There are varieties of tools known as surgical instruments such as scissors, clamps, scalpel etc. There is a rich history of such devices, for example the medieval instruments shown in Fig.2.02 and 2.02a as well as the modern ones shown below in Fig. 3.04. Kirkup (1982,2006), Wilbur (1987) and Bennion (1979) have described a great variety of tools with functions of cutting, suturing, grasping, clamping and retracting to be used by surgeons directly to perform surgical procedures.

Figure 3.04.*Basic surgical instrument itinerary.*

A second term, 'surgical device' refers to machines used in surgery e.g. oxygen pump, patient monitoring device (Fries 2000). Researchers from various areas in design and innovation e.g. Glen et al.(1996), Genmariet al.(2000), Liljegren(2006), Lettlet al.(2006), Lin et al.(1998) use the same term to explain

electronic equipment and other machines used in the hospital in their research, although some of them refer it as medical equipment.

There is a further 'tool' that surgeons and other medical staff use in their work known as simulators. Simulators are used in training and demonstrating procedures and sometimes preparing for procedures within the broad areas of the medical and surgical domain.

In this research, I use the term 'surgical tools' to refer to all of these devices that support the surgeons in their work including surgical instruments, equipment and simulators. This research is not focused on designing a certain surgical instrument or device but the outcomes may apply to designing any tools in a surgical domain. In fact, this project started with a proposal to design a surgical instrument, but in the end both collaborations with surgeons have resulted in devices for simulation.

Surgeons depend on their tools. "With the right tools, they become the master of the operating theatre" (Porter 2006). Surgical instruments have always been designed based on two factors; the need of and for surgery and the development of technology and they contributed to each other (Kirkup 2006 pp9-18). In the early innovation of surgical instruments, they were designed and tailored for specific surgeons.

In other words, every surgeon had different designs and different sets of instruments. As the techniques in operations became generalized through training and the growth of surgery as a respected profession, surgical instrument design also became standardized. Most tools started as modifications of tools from other crafts for example the bone saw (Fig.3.05) was originally a modification of a small handsaw used by carpenters (ibid pp5).

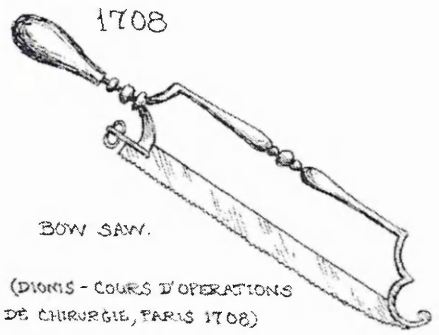


Figure 3.05
An antique bone saw.
Kirkup (2006)

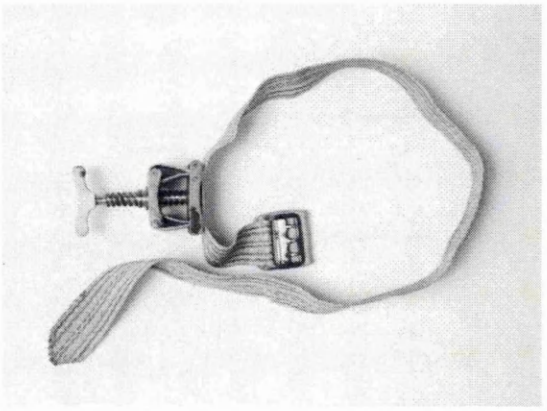


Figure 3.06 *– Petit tourniquet. London Science Museum website.*

A great deal of innovation in surgery techniques and instruments followed the development of explosive weapons which produced very complex injuries, inducing compound complicated fractures, wound contamination, gangrene and frequent death (ibid pp10). This generated new instruments in the 15th century for probing and bullet extraction. War led to a new viewpoint on urgent amputation as a means of saving life. For example, Jean-Louis Petit 1674 – 1750, a military surgeon who developed a new practice with amputations at the thigh, invented an effective tourniquet (Fig.3.06) that controlled blood flow while the surgeon carried out ligatures (Porter pp192).

In the mid 19th century, anaesthesia led to rapid growth of surgery which brought along the development of surgical instruments. J. Marion Sims (1813-1883) (Fig.3.07), a surgeon and pioneer gynaecologist in America, introduced silver wire repair, novel instruments and a speculum (Fig.3.08) (Kirkup 2006 pp15). Another example, a Polish master surgeon, Jan MikuliczRadecki (1850-1905) extended the range of surgical instruments with haemostatic forceps (Fig.3.09),

known later by his name (Popiela 2004). Although surgeons designed their own instruments they did so with the assistance of craft makers, blacksmiths and manufacturers (Kirkup 2006 pp30).

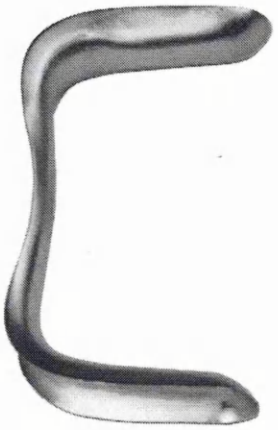


Figure 3.07*. Top left, Portrait of James Marion Sims.*
Source : Kirkup (2006)

Figure 3.08*.Top right, Sims speculum.*
Source: www.midmeds.co.uk/rocialle-sims-speculum-double-ended-medium-p-2519.html

Figure 3.09*.Left.Mikulicz's forceps.*
Source:www.accringtonsurgical.co.uk/p/2222/mikulicz-peritoneum-fcps

From the mid eighteen century, some makers of cutlery (cutlers) started to specialize in the making of surgical instruments (Kirkup 2006 pp30). In 1912, stainless steel was introduced by Brearley of Sheffield to substitute for crucible steel as the main material for surgical instruments (ibid pp17). Sheffield was and still is one of the cities with many surgical instrument makers based there e.g. Swann Morton, a leading surgical scalpel blade manufacturer and Aesculap Surgical Instruments, which produces a wide range of surgical itineraries (kits) for broad surgical domains.

In surgical instrument development, established instruments tend to remain unchanged[4]. Innovation in instruments tends to emerge with new surgical techniques and new technologies (Kirkup 2006, Bennion 2006, Riskinet al.2006, Garde et al.2008). For example the development of laparoscopic surgery, which is also known as keyhole surgery, drove the growth of new instruments in the market.

Riskin et al. (2006) placed surgical instrument innovations into a few categories to define their level of innovativeness e.g. simple modification, revolutionizing tools and revolutionizing technology or science. He was also a surgeon, and illustrated the field of surgical innovation from the historical review and applied new findings from the study of technological innovation. He found that surgeons rarely looked into critical innovation due to their current responsibilities. The current innovations in their domain were inconsistently supported despite the impressive developments thus far.

The increasing wide range of specialisms in surgery has led to a very diverse range of needs which may require the involvement of industrial designers. For example, the emergence of new techniques in colorectal surgery was one of the influencing factors behind this research project[5].

As discussed above, 'surgical tool' also includes simulators. In medical and healthcare practice, many simulators have been developed to assist clinical training for medical staff (doctors, nurses, health carers) such as shown in the images below (Fig.3.10;11;12)

[4]A visit to the Science Museum London indicated that some of the instruments remained in their original form from medieval to the era of the early industrial revolution.

[5]A surgeon from one of the major hospitals in Dublin showed interest in incorporating the author's speculum (1.1.1) novel features into their new surgical tools for their innovative procedure in colorectal endoscopic surgery which can be referred to Hompes et al. (2012).

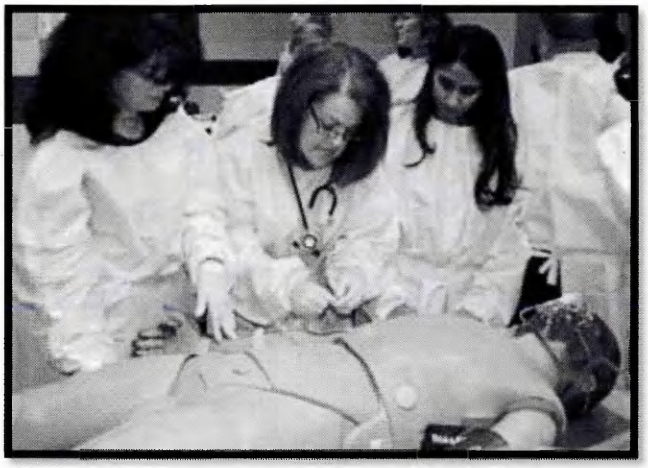


Figure 3.10
Patient care, emergency simulator manikin.

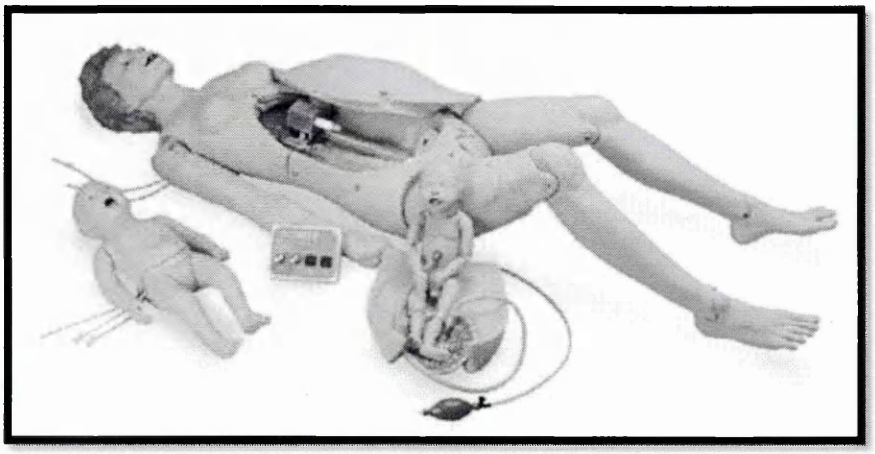


Figure 3.11*, second top*
Birthing simulation training manikin.

Figure 3.12*, left*
Wound dressing training manikin.

Simulators or medical models are not only used for training purposes but are also designed for testing new surgical instruments. Trejo et al. (2005) used this method in their project to develop a new handle for a laparoscopic surgical instrument. They employed surgeon-centred design principles that shared the

same principles as user centred design focusing on the user's needs and practices. They invited 38 experts in laparoscopic surgery and asked them to demonstrate their laparoscopic skill on a simulated silicon organ and torso (Fig.3.13). They found that an effective surgical tool can be designed through looking at the task the surgeon performed rather than modifying an existing surgical instrument. This illustrated that the use of simulator may help in the development of surgical tools.

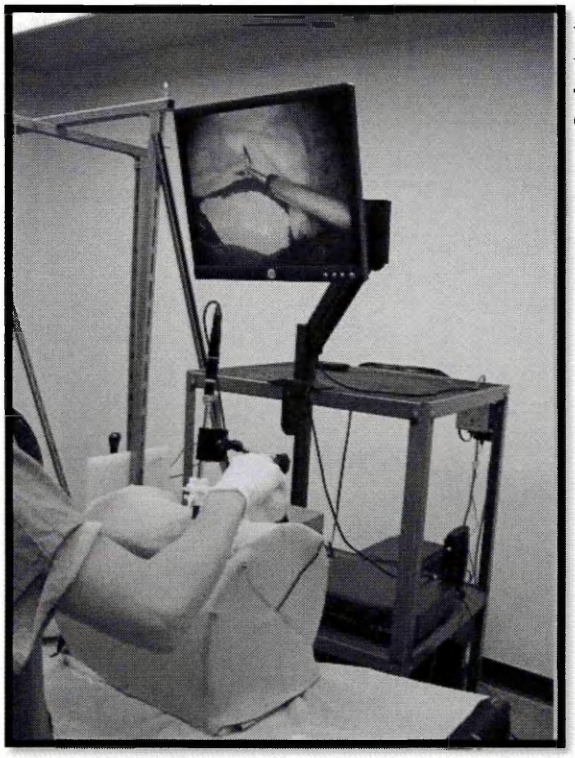


Figure 3.13
Plastic torso was used as a simulator for Trejo's design project.

3.3 Surgeons as innovators

Surgeons receive the same basic medical education as doctors, which covers biology and medical sciences. Broadly speaking, doctors treat patients using medicine and drugs whilst surgeons use operations. They shared the same methods of learning i.e. hands on clinical tasks in apprenticeship with a senior medical officer. "See one, do one, teach one" has been a guideline at medical school to this day (Groopman 2007).

During an operation, some surgeons undertook innovative actions under pressure. Martine Christie (2004), a consultant neurosurgeon illustrated this in her

description of *heroic surgery* on a woman who had been stabbed with a spear. She and a colleague undertook the operation even though on that day, their senior surgeon was away and there was nothing they could find in the manual as a reference for the particular problem.

Dr Christie learned that when a situation looks desperate, a surgeon sometimes needs to take radical action in order to save a patient's life. Another instance, a paediatric surgeon, James Beaney, performed a non-amputation surgery which turned into a heroic surgery as he faced a complication during the operation and he published this in detail as a pioneering conservative (non-amputation) approach to the orthopaedic and surgical management (Pearn 2004).

> *"On dissecting it out, it broke off by the neck, presenting a vermiculated appearance, from ulceration and interstitial absorption. The disease part readily turned outwards and the bone sawn through immediately below the trochanters . .. the acetabulum was healthy, and very little blood was lost during the operation. The edges of the wound were brought together and the patient placed in bed" Dr. James George Beaney, (1859)*

According to Ross (1956) '*a surgeon may on occasion have various qualities attributed to him. He may be regarded as somewhat of a scientist, something perhaps of an artist, but certainly if he is any good, he is a craftsman'.*

Ross (ibid) discussed the surgical craftsmanship in his lecture presented in the memorial of a master surgeon Sir William Mitchell Banks. He put surgeons as craftsmen by referring to the Mitchell Banks' work undertaken and became an example to other later master surgeons. He added,

> *"The craft of the surgery is to the art much as tactics is to strategy; and while the art may develop with the increasing of knowledge into an applied science, surgery without craftsmanship is as dead as faith without works" (ibid)*

He described surgery as knowledge that transferred through apprenticeship and it is an exciting opportunity for a surgeon to watch and learn as another surgeon

performed an operation. Surgeons draw together science, knowledge and craft work to lessen humans' suffering and multiply their happiness (ibid).

Popiela (2004), Moore (1985) and Soh (1998) followed Ross in calling surgeons craftsmen although they must also understand human biology and physiology. They are also pictured as people who combine art and science in their work. Kwok (undated) explained, there are three questions that surgeons need to ask which can equally well be made by craftsmen.

What is the best way? How well do I do it? What will be the expected result?

The surgeon Norman Capener (1956) made a study of the hand of the surgeon in the context of how surgeons use their hands in surgery. His study was influenced by the sculptor Barbara Hepworth's drawings of surgeon's hands in action (Fig.3.14). He showed that there are similarities in the way the hands are used between craftsman (sculptor and potter) and surgeon. He did this by analysing x-rays of his colleagues and his hands holding crafting tools and surgery tools. He suggested that hands in action are reflections of intellect and character and furthermore are instruments of sensibility and of expression.

Figure 3.14*.Study of surgeon's hands by Barbara Hepworth.(Carpener 1956).*

In this paper, he also described an alteration he made to a surgical retractor as he found it important to have a longer handle and grip made of fibre for more precise control (Fig.3.15). He criticised surgeons for failing to learn from good practice in other crafts e.g. in the design of surgical instruments:

> *"It surprises me that we 'invent' new tools to perform jobs that craftsman in other materials have done adequately for countless generations" (ibid).*

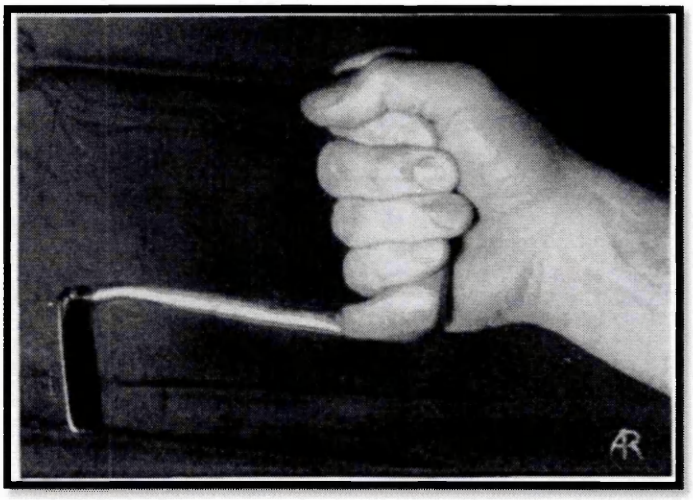


***Figure 3.15**. Surgical retractor redesigned by Capener and his colleague. (Caperner 1956).*

Some surgeons are active innovators. Von Hippel (1976) noted that scientific instruments are usually designed by the users of the instruments, so that innovations are brought about in direct response to practical needs. Luthjeet al. (2004) reviewed studies of user-innovators and found that 22 per cent of the examples reported were innovations by surgeons. A historical review by Kirkup (2006) and Bennion (1979) showed that a significant number of surgeons designed and invented surgical instruments (3.2).

In support of this, I observed that, of the two surgeons who took part in this research, one (Mr Brown) had previously taken part in innovation projects. Two of their colleagues encountered during the project were active innovators, one designing instruments for liver surgery and another being a founder of an instrument manufacturer.

The innovations of surgeons arise from their need for new tools that can help them to perform better during operations. The surgeons I worked with each had a specific problem and suggested possible solutions.

Soh (1998) suggested that to assess and evaluate a surgeon for appraisal, they should perform as a passionate scientist and researcher. They should be enthusiastically pursuing the progress of new breakthroughs and inventions and be involved in frontier breaking research. Some surgeons undertake research and non-routine surgery which leads them to new discoveries. For example Hompes et al. (2012) found out from a series of transanal[6] surgeries that surgical rubber gloves can be an efficient and flexible, disposable alternative to the rigid and expensive existing system for connecting equipment components in transanal endoscopic operations [TEO] (Fig. 3.16).

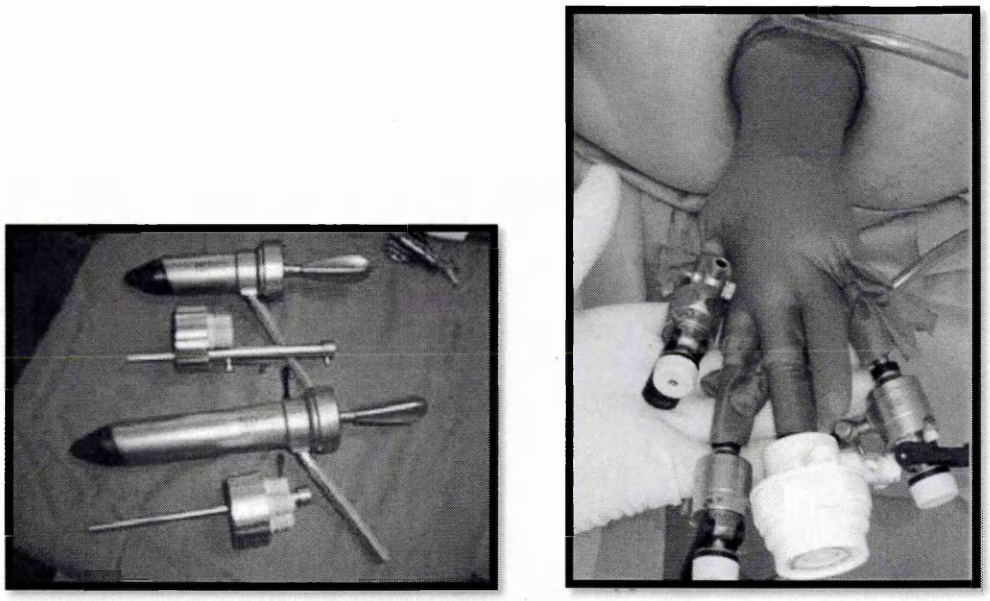


***Figure 3.16**. Left, Current instrument used in TEO(Yau KK 2009). Right, alternative material proposed by Hompes et al. (2012).*

3.4 Surgeons as 'expert users'

In this thesis, the collaborating surgeons are referred to as expert users. Patel and Arocha (1999) described an expert in the medical domain as one who possesses an extensive, accessible knowledge base that is organized for use in practice and

[6]Any surgery which use the anus as the surgical entrance.

is tuned to the particular problem at hand. They described the characteristics of experts in the medical domain from their research:

- Experts are capable of perceiving complex patterns of meaningful information in their domain.
- They are fast in processing information and at deploying different skills required for problem solving.
- They have superior short-term and long-term memory for materials related to their domain of expertise, although not outside their domain.
- They typically analyse problems at a deeper level.

Rasoulifar et al.(2008) made a convincing case for recognizing the surgeon as an expert user. He cooperated with surgeons as experts in his research project to design a new surgical instrument for minimal invasive surgery. He referred to the surgeons as expert users because of their knowledge and experience in that particular surgical domain (Minimal Invasive Surgery in lumbar arthrodesis) and described some characteristics and patterns of behaviour of surgeons that distinguish them as experts:

- Experts have a great depth of knowledge in one or two areas of medicine.
- Experts are comfortable being observed and they enjoy showing their expertise.
- Experts often do not explain to a layman what they do because of the complexity of their domain.

Patel and Arocha (1999) and Rasoulifar et al. (2008) provide the overview of characterising surgeons as experts. The general term 'expert' is widely used to describe a knowledgeable individual in a particular field. In this research I use the term 'expert user' to indicate considerable hands-on experience. This also points to Von Hippel's theories of 'lead users' likely to play a productive part in innovation as developed below (4.5.3).

3.5 Current practice in innovation of surgical tools

The collaborating surgeons and three surgical tool manufacturers were interviewed. The objective of these interviews was to understand current practice

in the development of surgical tools. Questions were developed through discussion with fellow researchers and used in semi-structured open ended interviews (Appx. 1 and 2).

Data from these interviews is described in greater detail below in 8.1. Here I will discuss some aspects of the interviews to introduce my research proposition.

The surgeons explained that currently they used standard surgical tools provided by the hospitals. They were satisfied with the current surgical tools as they 'did their job well'. They explained that manufacturers introduce new or improved product but these do not always improve on the existing tools from the surgeon's point of view.

Both surgeons stated that surgeons should be involved in the development of surgical tools. They are essential as consultants and their voices need to be considered in the design development. However, they felt that there were barriers to becoming involved or initiating a design project (3.6).

Manufacturers interviewed had experience in undertaking design development with clinical experts' involvement e.g. surgeons and sterilization service staff. The proprietor of SheffMED Ltd had a long relationship with a surgeon with whom he discussed his ideas. Sheffield Medical Precision Ltd learned about the user's context by watching surgical operations, videos of operations and interviews with surgeons. Single Use Surgical Ltd worked closely with sterilization service staff to understand problems in instrument sterilization.

The manufacturers explained various ways of participation with users in surgical tools development. Some of their projects involved the users at the beginning of the project as a source of problems and needs, and at the evaluation of the prototypes. I experienced the same process in my MA project. These methods are positive but as surgeons are recognised as innovators, there may be additional benefit to including them in actual design work.

3.6 Challenges in the development of surgical tools

In the interviews, the surgeons and manufacturers indicated several issues in developing surgical tools (Fig.3.17). More detail of these interviews can be found

in 6.2. From reviewing the interviews, I was able to identify a simple coding which helped to organise the main issues raised by interviewees.

No	Raised by	Issues	Code
1	Surgeon	Limited time and financial resources	CONSTRAINT
2	Surgeon	Need for multidisciplinary integration	NEED
3	Manufacturer	Surgeon's lack of manufacturing process knowledge	CONSTRAINT
4	Manufacturer	Experienced surgeons are more dependable	CONSIDERATION
5	Manufacturer	Need for two way understanding	NEED
6	Manufacturer	A project needs practical design skills as well as new concepts	NEED
7	Manufacturer	important to seek the right problem	CONSIDERATION
8	Surgeon	it is difficult to explain needs (tacit knowledge)	CONSTRAINT
9	Manufacturer	difficulties of dealing with official testing and approval regimes	CONSTRAINT

10	Manufacturer	We know the answers and they know the questions	CONSIDERATION
11	Surgeon	Most product development results in small changes of little benefit to surgeons	CHALLENGE
12	Manufacturer	Saving time and cost for hospital	CHALLENGE

Figure 3.17*. Issues raised by surgeons and manufacturers from the interviews.*

A large proportion of the issues have some similarities. For example 2,3,4,5,7,8, and 10 indicate a general opinion that designers or engineers do not have a problem in designing but suggested that they need to work together with surgeons as the surgeons possessed the knowledge and experience as the experts.

> *"There is nothing they can't do (laugh), that is the barrier. The surgeon knows the questions and the answers that the engineers can put together" Minutes 7:55.6*

> *"...I think we are essential, we provide you with the knowledge, in terms of use. We can't help with the mechanics of the thing but what I can tell people is that it needs to do this and we don't care about that,...." Minutes 16:34.4*

> *"..., you got the engineers on one hand, you got the surgeons on other hand, there is some way of gathering them together, very difficult for me to explain exactly what I need, ...". Minutes 6:32.9*

The manufacturers also raised issues about different knowledge held by partners. One example (3) was a statement that some surgeons do not understand the

capabilities of manufacturers, so these manufacturers prefer to work with experienced surgeons. They suggested that surgeons who may have a basic knowledge in manufacturing and experience in developing surgical tools are more likely to be invited into future projects. Another manufacturer mentioned (5) poor two-way understanding between clinical experts and designers and engineers.

Respondents also indicated problems with regulations such as clinical testing and ethical approvals (9). This was raised by one of the manufacturers who described how the process of getting the design into use as a product is lengthy. Developing something radical, especially invasive surgical tools will result in a highly regulated process and extended cost. As a normal practice for most manufacturers, cost is something they would like to keep low. He believed that the key to a successful product is a design that addresses the 'right' clinical problem and the hospital's concern to save time and cost. It is interesting to compare this statement with the surgeon's concern (11) that product development rarely addresses significant needs.

One surgeon stated that in his opinion the instrument manufacturers are only there to make money so they tend to produce "new" instruments in which only the handle has been modified which makes no difference to the use of the device at all.

This indicates a gap between clinical experts and designers (and manufacturers) regarding 'knowledge and understanding' and it is possible that bridging this gap may result in more useful product development. Participatory design (e.g. Schuler and Namioka 1992, Muller et al. 1993) may offer an approach to this problem as the approach has collaboration between users and designers as a central principle.

Bravo (1990) explained that users are essential in the process of design development because otherwise it is "undemocratic and has serious consequences for worker health, human rights, job satisfaction and work process". Furthermore, as some surgeons can also be innovators, the intersection of these two factors (methods to involve users in designing and users' ability to design) may be interesting to explore. In the next chapter, I examine participatory design and

discuss two methods from it that I suggest may be suitable for my research circumstances.

Chapter 4: Investigating design methods and approaches

In this chapter, I examine participatory design approaches which may be explored in this research to inform the development of my own design method. Two methods from participatory design were looked at as they seemed to be suitable for the research and the embedded design projects. I also discuss designing with the user and the power the designer shared with them. Last but not least, I discuss lead users in design as I believed my collaborators have these qualities which I think useful for my argument in chapter 9. I conclude the chapter by looking back at my contextual review (chapter 3) in conjunction with discussion in this chapter.

4.1 Participatory Design

The focus of this research is to explore ways of working in partnership between designers and expert users. This is often described as "Participatory design" (Schuler and Namioka 1992, Muller et al. 1993). Proponents claim that users are essential in designing something for them through designing with them.

Participatory design is a method in which the user has a significant role in design process. One of its roots was in the 1970's in Scandinavia through work with trade unions on the impacts of new computer systems on skilled work. Participatory design was claimed to offer democratic rights to skilled workers,

valuing their professional competencies and ensuring the work became more efficient and productive.

Participatory design (PD) aims to provide the people who will use a system, or in my case a product, with a voice in the process of design, evaluation and execution of the tools they will be using (e.g. Steen et al. 2007).The methods in participatory design are often meant to make available the tacit knowledge of the users and the users' experience for the purpose of design.

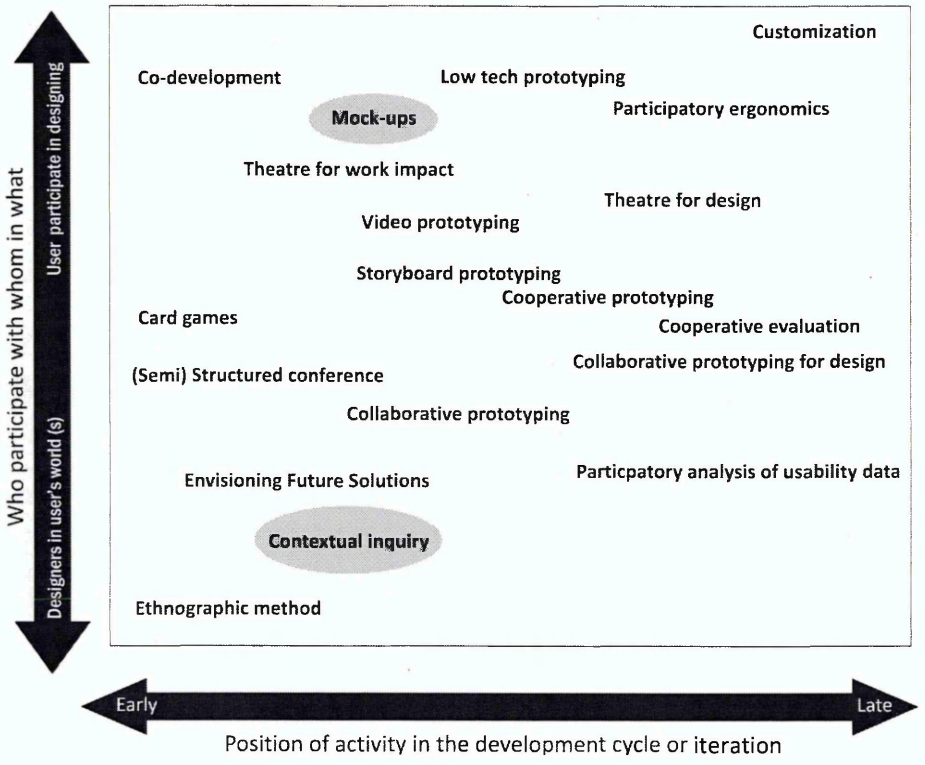


Figure 4.01*.Muller's taxonomy of participatory design techniques.*

Muller's taxonomy shows the variety of participatory design techniques which are reported in practice (Fig.4.01). Terms used in the taxonomy are Muller's generalisation from methods he reviewed from other researchers.

Many methods are used to encourage the user to participate in the design process (Bødker S. and Grønbæk K. 1991, Ehn P. and Kyng M. 1991, Muller et al. 1993, Schuler and Namioka 1992). To see the suitability of these methods for my research, I reviewed and explain them in table below.

Method	Description	Useful for	Skills and resource needed
Card games	Using cards with pictures, icons or description of works in group discussion as a tool to analyse and critique. Data collected from this process become the guideline to design.	Understand users' way of work / work tasks and make the users' need visible. Create familiar and relaxed environment for users.	Group of expert users, designers provide tool (cards with pictures),
Envisioning Future Solution	Workshop undertaken with users to generate future design and discuss how it can be realised. Referred to Kensing & Madsen (1991) "future workshop", it's divided into three phases and charts were used for listing and mapping users' proposition. Critique- expressing problem and needs. Fantasy- suggesting solutions. Implementation- users' presenting their utopian outline, discussing and evaluating the issues between groups of users.	Getting desirable system or design from users. Collective and supporting issues between involved stakeholders produce accountable users' propositions.	Participation from groups of users and stakeholders. Long time needed.

Method	Description	Useful for	Skills and resource needed
Ethnographical method	An observation method adopted from anthropology's ethnographic scheme to seek native point of view as an enquiry approach to gain users' proposition. Based on three guiding principles which are natural setting (everyday life), holism and descriptive.	Seeking genuine users' problems and needs.	Setup in users' everyday setting. Multiple observers needed to ensure records are covering the whole sequence of event observed. Video recording may be used in this process.
Contextual inquiry	Principles of way to understand users' way of work and the use of tools in workplace. These principles are context, partnership and focus. The main technique is an interview with the users while they do their work routines.	Understanding users' context which are 'alien' to designers. Involved directly with users and their context.	Apprenticeship way of learning. Can be undertaken in smaller group or one to one procedure.
Storyboard prototyping *Also become base principle for* **Collaborative prototyping for design and** **Participatory analysis of usability data**	Using storyboard to undertake interactive method modification in interface design with users which termed CISP. This allows the users to be involved in the design validation process. Storyboard technique also used as approach to analyse usability of the proposed design.	Involving users interactively in a further part of the design process. Originally used in interface design.	Interactive tools such as computer.

Method	Description	Useful for	Skills and resource needed
Video prototyping	It is a technique of initial exploration of interface design which is faster and cheaper than using computer based prototyping. Using video to capture proposed action and reaction of interface ideas frame by frame and play it to see the sequence of the interface designed.	Designing interfaces with design team e.g. developer, designers and marketers excluding users. Exploring initial ideas.	Drawing and marking tools e.g. papers, acetate, markers. Video recorder.
Theatre for work impact / for design	A technique based on Agusto Boal (1974) "forum theatre" which uses drama to include participants in a situation. Participatory designers used this to bring bodily approach into design. Users become directors and comment on the play.	Make available user's needs by seeing their ways of work enacted by designers. Having greater empathy for the users.	Designers and focused group work in team directly, video recording, and an environment similar to user's work place.
Mock-ups	A method described by Ehn and Kyng (1991) where they use low fidelity materials to do mock-ups. These mock-ups used along with language game in a way to enact current users ways of work and also possible future ways of work to inform new design.	A cheaper, fast and fun way to understand current user's ways of work which inform new design.	Observing group of expert users enacting their work using low fidelity mock-ups provided by designers.

Method	Description	Useful for	Skills and resource needed
Low tech prototyping	Based on PD techniques which focus to initiate collaboration between designers and users in designing interfaces and icons. Using drawings on papers to propose design and this Muller defined this as low tech.	Promote participation of users in idea generation. Generate acceptable design.	Drawing or sketching made by designers during process. Some of the techniques allowed users to sketch.
Participatory ergonomic	A collection of techniques and approaches to develop micro and macro ergonomics with the participation of organization e.g. management and production worker in a factory. Simulation is used in this approach. The aim is to design overall system of a work place based on the ergonomics factors.	Develop solutions on saleable ergonomics problem. Suitable for big organization	Ergonomist is essential to be in the team.
Cooperative prototyping	A method to involve users directly in prototyping process. Users were exposed to prototype and designers teach how to use it. Users were given the right to comment on the design and request for modification on the prototype they tried.	Involving users as co-creator in the near final stage of designing.	Prototype that is designed to be readily usable as a pre-production product. However, prototype needs to be changeable on the spot to allow users to test them on site.

Method	Description	Useful for	Skills and resource needed
Cooperative evaluation	Wright and Monk (1991) described that this is a method to evaluate design undertaken by a designer and the involvement of "naïve users". It is based on 'think aloud' technique where designers as evaluators can only start conversations with users when users are stuck during testing the proposed design.	Evaluation of design to detect misconception or misdirection on the design in use. Described as "cost effective" approach.	General users who are new to the product. Designers as evaluators.

Reviews on PD techniques from Muller's taxonomy showed that they are useful in involving users in designing. However, to look at their suitability for my research, I had to consider the characteristics of my project.

My intension was to develop collaboration between myself and individual surgeons[7]. It is hard to understand the surgeon's context because they are complex (as described in 3.3). So, I needed a method that would allow me to understand the surgeon's context. The surgeons had initiated ideas and they wanted to see if their ideas would work. So, the design projects were about developing the surgeon's ideas.

Most of methods above suggested that groups of users be involved in the design projects, which makes them unsuitable for the one-to-one collaborations that I was planning.

[7] In the scenarios that gave rise to this research, individual surgeons proposed problems or design innovations. These might be addressed by involving a wider range of surgeons but one of the biggest constraints on such projects is gaining access to surgeons who are extremely busy and costly. I have therefore focused on techniques for a designer to work with a single expert user.

Therefore, there were two PD methods that seemed to be appropriate and productive: contextual inquiry (Holzblatt and Jones 1992) and mock-ups (Ehn & Kyng 1991).

Contextual inquiry (Holzblatt and Jones 1992) is a methodology for designers to understand users' worlds rather than a technique for design development. My work involved experts (surgeons), who work in a very complex and demanding scientific and institutional environment. From my past experience of working with surgeons, it was evident that it would be particularly difficult to gain an understanding of that environment compared to other design contexts that I knew so this was an important design methodology problem for me.

Ehn & Kyng (1991) indicate that their approach to using "mock-ups" allows designers to explore future environments with users. It can mobilise users' experience and tacit knowledge in support of design decisions as discussed above. Ehn & Kyng claimed that the hands-on characteristics of the mock-up may clarify needs and ideas which can lead to the new design of tools (ibid).

Surgeons by the nature of their work are familiar with hands-on physical work in three dimensions and my own experience and strengths are in developing designs through mock-ups and prototypes. Thus, I decided to explore the use of mock-ups because this promised to make good use of the skills and experience of the participants, including myself.

4.2 Contextual Inquiry

In my own methodology, I use the term 'contextual immersion' rather than 'contextual inquiry' to avoid confusion with the contextual review aspects of PhD research. However, my contextual immersion follows very closely the principles of contextual inquiry described here.

Several researchers described contextual inquiry in various ways e.g. Raven& Flanders (1996); Fouskas et al. (2002); Cross & Warmak (2000). Contextual inquiry (Holzblatt and Jones 1992) was originally developed in the domain of Human Computer Interaction (HCI) to support the needs of the designer to

understanding the user's context, and to extend that context and transform it positively into a working system.

This technique is a way to working by users in articulating their current practice and associated experience. It will inform the initial design concept which supports the way of work of the user (Holzblatt and Jones 1992). Contextual inquiry was developed and combined with other decision making techniques to form Contextual Design Software Methodology (Holzblatt and Knox 1990).

Contextual inquiry has been integrated with other participatory design techniques such as mock-ups, scenario building, metaphor workshops and future workshops for the purpose of designing computer systems. Contextual inquiry has been seen as a set of principles that can combine with other participatory design techniques to collaborate with the user in designing a system. In my research I am concerned with physical tools but as with computer systems, the system of using the product is central to the design problem.

There are three main principles in contextual inquiry, namely

Context – understanding user current practices in using the system. Talking to the user in their working environment is the best way to understand their way of working.

Partnership – understanding users' experience of work and the system. A dialogue between the designer and the user will make the designer aware of the user's experience in using existing tools. The designer becomes an apprentice to the user.

Focus – the way to manage the dialogue with users which creates and directs the development of understanding.

Holzblatt and Jones suggest that to understand the users' experience in using their tools, it is necessary to interview them in their work environment. During the interview, the design idea is shared that is relevant to the work discussed and users are engaged in the design conversation. Designers and users interpret together the experience of work and usability so that by the end of the interview, designers understand the user's way of doing work and the system they use.

Contextual inquiry is not a design method but an instrument which designers can use to understand the user context in using tools and systems. It complements other participatory design techniques.

Using contextual questions with the user while they perform their work is useful because it encourages reflection in context as well as engaging them while they are involved in the tacit aspects of their work.

Holzblatt and Jones describe the designer engaged in contextual review as an apprentice to the user and this fits with the idea of surgery as a craft that is learnt via apprenticeship (3.1).

They suggest that mock-ups (they referred to Ehn and Kyng 1991) can be used with contextual inquiry as a method for designing with the user. They used it "extensively" at customer site and at internal design meetings. They described how mock-ups enabled the users to respond to the physical representation of their concerns.

My personal experience as a practitioner indicates that designers may do this in an informal way as a normal part of their work. This empathic way of understanding the user has been explored by earlier researchers and termed as 'empathic design' (e.g. Postma et al. 2012; Thomas and McDonagh 2013).This method focused on the creative understanding of the user experience for new product development (Postma et al. 2012). Review of the 'theatre' approach in PD from Muller's taxonomy shows that designers may understand users' experience of using tools through 'drama' e.g. pretending and acted as the users (Brandt and Grunnet 2000).

Steen et al. (2007), in his review of methods for involving users in the early stages of design projects, explained how "role play" can be used to build on observations of users, e.g. from a focus group. In role play the designer tries to "feel" or "shadow" the experience and emotions of the potential user so they can design as if they were the user. Another good instance of a method for empathising with users is shown by Patricia Moore, a designer who disguised herself as an old woman, including simulating disabilities of ageing. She responded to product, people and environment as an elderly person in the streets

for three years as a way to understand people with disabilities and designing products for them (Barry Katz 2001).

However, a designer may face a barrier to role playing the surgeon in designing surgical tools (Rasoulifar et al. 2008). This is because surgeons have a complex environment and practice (e.g. long training period). Patel and Arocha (1999) describe medical practitioners as expert users for whom their knowledge and experience comes from long practice in a specific domain.

To design with surgeons, in this situation, the designer may need several ways to become part of the surgeon's world. As well as observing surgeons in action they may need other methods to understand the culture of their domain through 'contextual immersion' as described above. For example in this project, I invested time in reading surgeon's technical literature as a way of understanding their concerns and priorities.

4.3 Ehn & Kyng's mock-ups

The use of mock-ups is described in the UTOPIA project reported by Ehn & Kyng (1991) where participatory design methods were practiced to develop software tools for newspaper production, at a time when professional paper workers had no understanding of how computers might be used in their work. Pelle Ehn and Morten Kyng gathered typographers and journalists together to explore the possibilities of using computers in their work. They tried to seek an approach to technical and organizational design which could support creative cooperation between typographers and journalists.

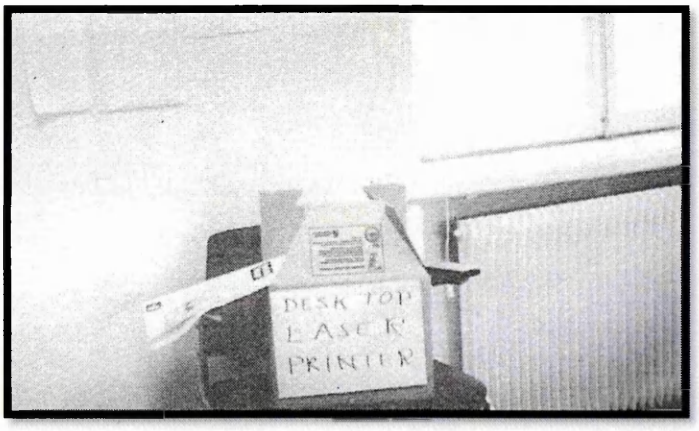


***Figure 4.02**.Ehn and Kyng mock-ups. Ehn and Kyng (1991)*

Low-fidelity mock-ups using cardboard were used to suggest elements of a future system, for example a desktop laser printer (Fig.4.02) and participants used this in 'role play'. In this 'game', participants do not try to make a new way of working by using the mock-up but play out their existing way of working. The laser printer was used in place of their existing 'proof' machine (Ehn & Kyng noted that at that particular time, laser printers were only used in high tech laboratories).

In this project, the designers aimed for a 'family resemblance' to existing practice in their terminology. Stakeholders understood the meaning of the labelled box when playing their roles. However, as noted by Ehn & Kyng, it is the responsibility of the designer to be aware of the future possibilities and to suggest the technical and organizational solution to users so that they can gain experience and find out what it would mean to their practical work.

In Ehn and Kyng's approach, participants take part actively in the design process, not proposing a design description as a designer would do, but, through 'hands-on' engagement with understandable mock-ups, they inform of their practice and needs which are later used by the designer to create a new system. The importance of the approach by Ehn & Kyng is the engagement of stakeholders in enacting their practices. The use of low-fidelity mock-ups is practical because they are cheap, quick to make, save development time and fun to use (ibid).

4.4 Use of mock-ups in designing with users

Mock-ups have a long tradition in design. It is a natural way of designing for the industrial designer and other design domains. Ehn & Kyng (ibid) was a useful starter for me to look at the use of mock-ups in a design process that involved users. Referring to various previous research studies, the use of mock-ups with users has been proven valuable when seeking a concept, evaluate the concept and usability of the product (Ehn & Kyng 1991; Long & Hughes. 2011; Vaajakallio & Mattelmäki 2007). These researches showed that mock-ups are useful to engage non-designer users in designing.

Long & Hughes (2007) made a review of mock-up usage in designing operator cabs and interfaces involving train crews (Fig.4.03). They resembled some of the

Ehn & Kyng's mock-up approach through several small projects within their bigger scheme. In these projects, the mock-ups used a variety of materials, for example card for 3D and drawing for computer interfaces. They found out that lower fidelity or "rougher" mock-ups resulted in more critiques from the users as they require less time to produce. Mock-ups with interchangeable ability supported easily made and substantial modification. As the mock-up's fidelity became higher, it gave a holistic review of the whole design and allowed testing to be made. Long and Hughes described that by using mock-ups from the beginning of the project, allowed the design team to commit little expenses and resources in the development.

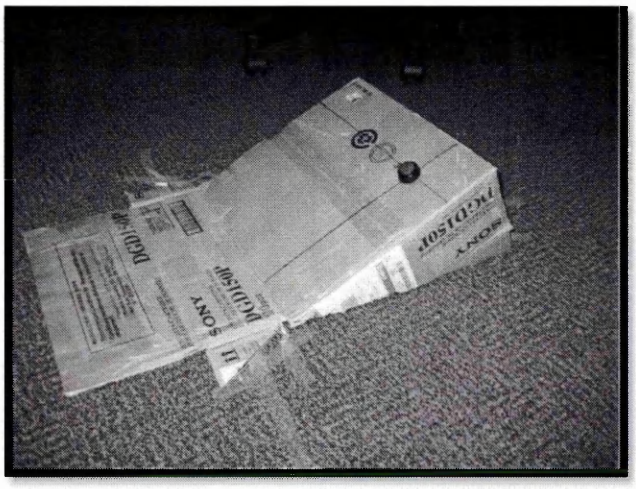


***Figure 4.03**. Mock-ups used in Long's project. (Long et al. 2007).*

Ehn & Kyng (1991) and Long & Hughes (2007) showed how cheap material to hand, such as packaging cardboards or carton boxes, may be used as mock-ups in their projects. Ehn &Kyng used a box and pretended it was a laser printer without making any major alteration. Long & Hughes modified the box by cutting, applying simple detail and made it into a foot rest which can be 'used' by the user.

Both examples showed that accessible material that can be shaped easily can be very useful in manifesting ideas and users can interact with these ideas.

Another instance of using mock-ups was described by Vaajakallio &Mattelmäki (2007) in their co-design project with elderly workers in maintenance, catering and security service firms in Finland. They used Sanders's 'Make tool' (1999) and came up with a mock-up kit consisting of a set of shaped materials that

suggest hand held devices and also other materials that suggest components to form physical interfaces (Fig.4.04). The participants composed these assorted materials into mock-ups which suggested products that they desired to help them in performing their professional work.

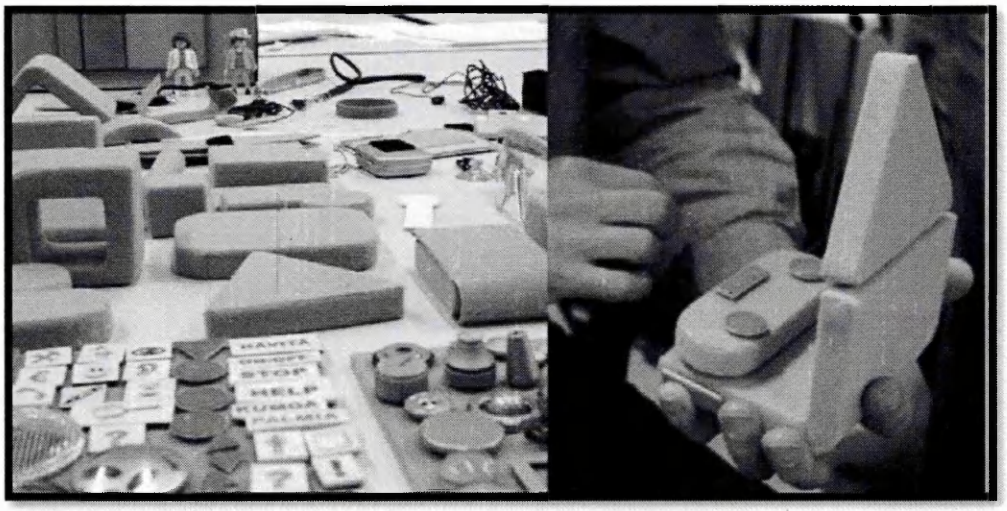


Figure 4.04*.Mock-up kit developed by Vaajakallio & Mattelmäki (2007).*

They found that users were enabled to express their ideas through mock-ups by discussing the current technology that they used. The ideas from users developed through reflection on the mock-ups and the future use of them (acting with the mock-ups). Vaajakallio & Mattelmäki (ibid) remarked that this 'kit' is limited because its focus is towards a certain direction. Materials gathered and designed were based on preconceptions of alternative design prospects.

IDEO, a multinational design consultancy reported a collaborative project with surgeons and used everyday things to form a mock-up (Fig.4.05).There is no further report giving details of this product development however the images may indicate the usefulness of a mock-up in a collaborative setting. The rough prototype in the picture showed that by using everyday things, it is possible to build products at full scale which may offer valuable hands-on experience.

The first picture shows the use of a marker pen, a film container and a peg strapped together with adhesive tape to form a rough prototype that shows the basic form of the product. This is then developed further to become the product in the second picture. The rough prototype was made near to the size of the finished

product. Making a prototype at the proposed size is significant as it can give a 'real' feeling of the product during co-creation. This example, by using materials to hand, appears to avoid the problem of preconceptions influencing the mock-ups noted above by Vaajakallio & Mattelmäki.

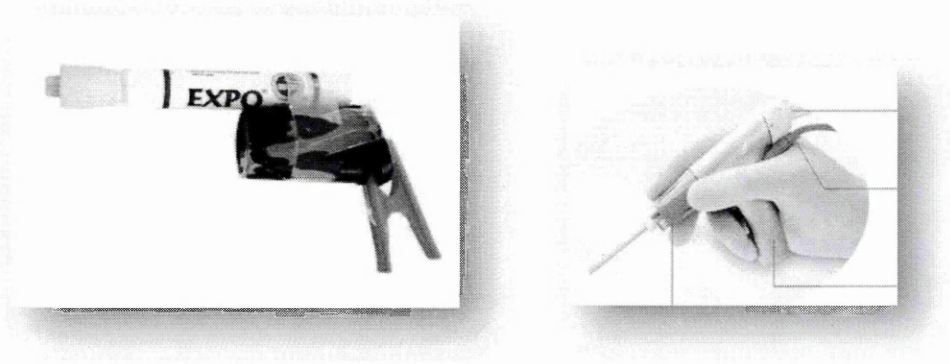


Figure 4.05*.A mock-up developed between collaborators in an IDEO project. At right, picture showing the product developed using a concept from the mock-up.*

Comments from the IDEO website regarding the above project:

> *Diego tripled our revenues in the powered instrument product segment, and elevated our profile in our served markets. What we learned from IDEO about product design has influenced the way we approach all new major development projects.*
>
> *Perry Mykleby, senior director of marketing, Gyrus ACMI, ENT Division*
>
> *Using a highly collaborative process involving designers, engineers, and surgeons, Gyrus ENT and IDEO developed the Gyrus Diego systemâc™ setting a new benchmark in user-centered design.*
>
> *Working with a panel of six leading otolaryngology surgeons, who participated in brainstorming, rough prototyping, and user testing, the team developed a design that has resulted in dramatically better results for surgeons and patients.*
>
> ***http://labs.ideo.com/about/***

Kelly and Littman (2001)[8], described how IDEO has used kits of such artefacts as a brainstorming kick starter for quite some time. Dennis Boyle, a Stanford University engineering lecturer who also worked with IDEO, had a hobby which later became his method of teaching out of which he developed a product called the 'Magic Box', a collection of mechanical parts, odd materials and other unusual artefacts.

Later, this idea was used widely within the company and called a 'Tech Box' (Fig.4.06), consisting of collections of bits from mechanical, electrical and digital leftovers which were used as creativity kick starters for the company.

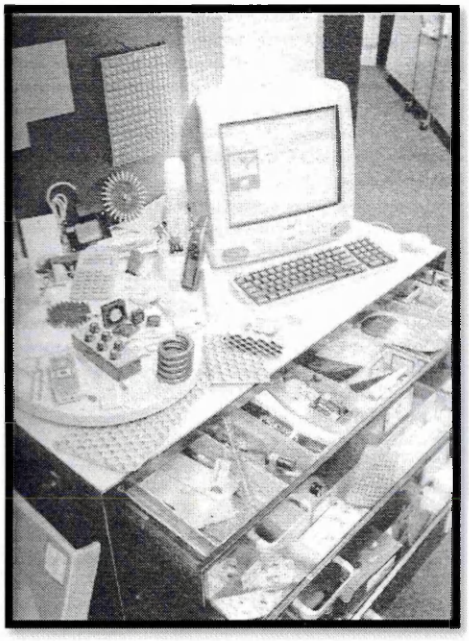


***Figure 4.06**. 'Tech Box', a development from Boyle's 'Magic box'.*

The 'Make tool' used by Vaajakallio & Mattelmäki (2007) showed that providing a collection of suggestive parts allowed the user to be active in 'making' the design. However, these were first constructed by the designer. The ENT project by IDEO showed that mock-ups can also use everyday things that are understandable by users. IDEO 'Tech box' showed that by having an eclectic collection of things can became a source of idea generation. These suggest that we may use a collection of everyday things as a set of mock-up kit and this can be used by the user to generate ideas and make them.

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[8]in their book *The Art of Innovation*, describing the creative activity, methods and projects undertaken by IDEO.

From this review, it is suggested that mock-ups are a valuable design tool to be used with users because,

- They are cheap, fast and easy to make (Ehn & Kyng 1991)
- They reveal the user's context (Ehn & Kyng 1991; Long & Hughes. 2011; Vaajakallio & Mattelmäki 2007)
- They allow users to imagine future use (Ehn & Kyng 1991;Vaajakallio & Mattelmäki 2007)
- They engage users in the design process (Ehn & Kyng 1991;Long & Hughes 2011; Vaajakallio & Mattelmäki. 2007) and
- They offer hands-on experience (Ehn & Kyng 1991; Long & Hughes 2011)

Limitations and guidelines for using mock-ups with users have been suggested by earlier researches (Ehn & Kyng 1991;Long& Hughes 2011; Vaajakallio& Mattelmäki. 2007).These researches suggest that mock-ups should be used in conjunction with design games which are based on creating a working scenario or a future situation. They can work in the sense of acting out practices via the framing of familiar language-games (Ehn & Kyng 1991).

For Ehn & Kyng, Vaajakallio & Mattelmäki and Long& Hughes, the mock-ups were at least partly 'designed' before users saw them. IDEO claim that making mock-ups was an important part of the group creative process. This appeared to be an approach worth exploring in the current project which is aimed at a creative partnership rather than simply studying the users. As it will be explained in the development of my research below, the approach of having a generic mock-up kit of objects to hand proved to be very productive.

4.5 Designing with the user

Vaajakallio & Mattelmäki's (2007) use of Steppers's 'Make Tool', described above, showed that users can also be given the opportunity to become involved creatively in design processes. However, the 'Make Tool' approach, as noted above, imposes constraints based on the designer's preconceptions of what might

be produced. So in this research, I sought to explore more open approaches which will allowed the users greater freedom in collaboration with the designer.

Bowen (2009 B) investigated ways to involve users in identifying unstated needs and novel product development opportunities. From his experience of varying success with a variety of participants, he concluded that for this to be successful, participants should be individuals who show evidence of creative or original thinking in aspects of their lives. In this he was following Von Hippel's principle (1976, 1986) of filtering participants for evidence that they were 'lead users'.

Sanders and Stappers (2008), who studied co-design approaches, suggested that everybody possessed "latent creativity". However, they also suggested that to be successful participants in co designing, non-designers will need to have a certain level of "expertise, passion and effort" (ibid).

"All people are creative but not all people become designers" (ibid p12)

User participation is central to participatory design. Experts in participatory design (Schuler and Namioka 1992, Muller et al. 1993) and other human centred design methods (Burns et al. 1999 - empathic design; Beyer and Holzblatt 1998 - contextual design; Kensing and Blomberg 1998 - ethnographic fieldwork; Jordan 1998 - design usability) suggested that designers should use some 'tools' that can engage the user in design activities.

It appears that, in all of these approaches the aim is for users to make their needs available for designers to use as data for designing. Users in their own ways may use sketches or other media to show their needs or ideas to the designers. However, the design decision is still with the designers.

4.5.1 Sharing design power

Arnstein (1969) describes that there are many levels of users' participation in decision making. He discusses the stages of contribution by citizens in federal social programmes in the US and how these democracy-cornerstone-based levels describe the power distribution between the authorities and the participants.

He explains that in participation without the distribution of power, the 'powerless' will face a frustrating process in such projects and a power holder

will be enabled to manipulate the benefit for certain sides. This then is illustrated by the steps in the level of power he calls the "ladder of participation".

Arnstein (ibid) illustrates this ladder as having eight levels and each level explains the roles and the decision power held at every division. This power increases for participants when rising up the ladder rises. The rungs are described as:

1. Citizen control
2. Delegated power
3. Partnership
4. Placation
5. Consultation
6. Informing
7. Therapy
8. Manipulation

At the rung of *partnership* at level 3, the power of decision is redistributed through negotiation between participants and the power holders. They share the planning and decision making responsibilities and the participants are not neglected in any changes. Arnstein (ibid) states that normally it is the citizens (participants) who urge for this *partnership,* rather than a power holding initiator.

Arnstein described partnership as a balance of decision power. Holzblatt and Jones (4.2) state that partnership in designing can be initiated through apprenticeship with the user and I have explored partnership through apprenticeship in the current project. It seems to be particularly relevant given the complexity of the expert users' domain.

Considering the use of tools discussed in (4.4), in order to ensure partnership, suitable tools must be chosen and this is an important consideration behind the use of mock-ups, which allow continuous participation and shared ownership in the process and its result.

4.5.2 Co-design

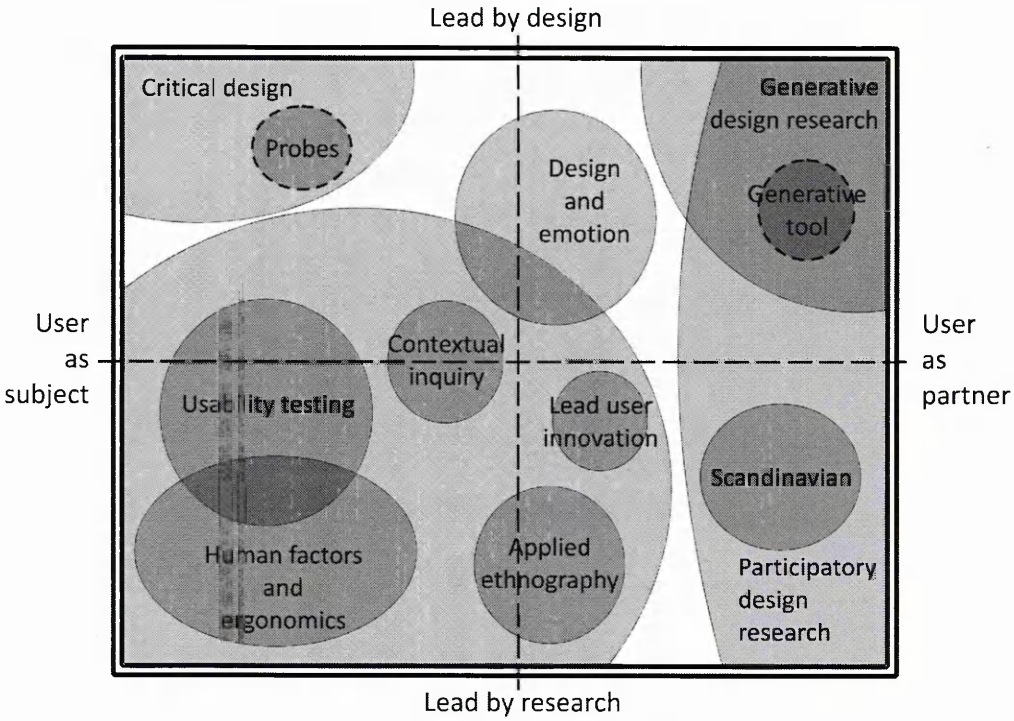


Figure 4.07*.Human centred design landscape. Sander and Steppers (2008).*

Co-design (Sanders and Steppers 2008) and co-creation has been growing within the area of participatory design (Fig.4.07). Co-creation means a collective creativity of two or more people. Sanders and Steppers (2008) described co-design as a specific instance of co-creation. Co-design is a collective creativity between designers and non-designers or people who are not trained as designers collaborating in the design development process. According to Sanders and Steppers (ibid), in co-design everybody can be seen as creative. People who have high a level of passion and knowledge can be invited to be co-designers.

Sanders and Steppers compared co-design with the classic user centred design approach where researchers collect data from users, which make users subjects of the work rather than contributors. They analyse this data to interpret user needs for designers to apply. From their own practice as designers, Sanders and Steppers (2000) explained that, by using "generative tools" based on the participatory design methods, the users can become involved during the moment of idea generation as well as the moment of decision.

Sanders and Stepper (2008) gave a few examples of generative tools used in a few co-design projects, for instance using scaled mock-ups of the furniture and equipment of a ward to enable participants to suggest a better layout for the ward (Fig.4.08).

Figure 4.08*.Designer/ researcher using mock-ups with users. (Sanders and Steppers 2008)*

Similarly Mitchell (1995) describes the use of small scale mock-ups to engage users in the design of refugee housing and office spaces. Mitchell notes that this approach gives access to a much greater diversity of experience than previous methods, for example giving a voice to all members of a refugee family which revealed a much wider range of needs than described by the dominant members of the family. This illustrates the democratising possibilities of such methods as described above (4.5.1).

Lee (2008) who also did co-design work with a different group of users in designing residential units and areas, described the users' emancipation and designers' tasks in design collaboration. He suggested that it is important to bring users into the design setting as it gives them freedom in design process. The users' experiences of using the facility were transferred and made visible to designers in a form of a design proposition. As designers, they took the responsibility to support this proposition by develop these ideas with the users

'designerly', beside facilitating the users with tools for designing which is core task of designers in co-design setting.

The report shows that this technique is beneficial for all parties involved. However, the distinction between Lee's research and mine is that their designers are trained to design a building while I have only been involved once in designing medical tools. So, I needed more medical related information to immerse myself with the project.

In co-design, the researchers or designers will act as facilitators by assisting participants in the process of expressing their needs and idea generation (Vaajakallio & Mattelmäki 2007; Sanders and Steppers 2008; Lee 2008). To facilitate this creative process, researchers or designers will need to provide "scaffolding" such as the tools described above and offer a "clean slate" to help users overcome their preconceptions. Professional designers involved in the process will use their knowledge and skill in design thinking to assist the participants in designing. They (the designers) may be required to produce the design tools for the users to use in the process (Sanders and Steppers 2008).

From the descriptions above it can be seen that co-design is proposed as a form of creative collaboration and appears to meet my aims in setting up this project, to investigate ways to enable such collaboration between designers and expert users. I explored this through my pilot research (will be described in 6.4.3) and found that the principles of co-design outlined here provided a good foundation for the methods I have developed.

4.5.3 Lead users in design

As discussed in 1.2, the surgeons came into the collaboration with their own ideas about design aims. I have also described evidence (3.3) that surgeons in general tend to be proactive and creative in designing new tools for their profession. This appears to indicate that they may be lead users as characterized by Von Hippel (1976, 1986, 2001, 2005). Von Hippel describes lead users thus:

1. They experience needs which later become general to other users in the market.

2. They are motivated to innovate because they can benefit from the solution.

Von Hippel (1986) has concluded that these lead users can be useful as a source of new innovation for the market. He also showed that most scientific instruments were innovated by the user of that instrument itself (Von Hippel 1976) and one of his examples was a medical instrument. In participatory design also it is important to include users in designing medical devices (e.g. Gennari and Reddy 2000)

Lead users can be found in domains that have a high diversity of needs, including surgery (Herstatt et al. 1991; Luthje and Herstatt 2004; Von Hippel 1976, 1986, 2001, 2005). Luthje and Herstatt (2004) reported that a large proportion of surgeons innovate their own instruments and many of them are taken up by a manufacturer to be developed as a product.

Lettl et al. (2006) conducted research to investigate the contribution of lead users in the radical innovation of medical equipment. He reported that surgeons have some particular characteristics that explained their innovativeness. Labelling the collaborating surgeons as lead users is not the priority for the current research. However, having them as lead users in design collaboration seems interesting. The importance of surgeons, as lead users, in the participatory methods developed will be returned to in chapter 9.

4.6 'Designerly' way of doing

I employed design collaboration with two surgeons as a vehicle for the research (1.3). This was undertaken in a design environment where the surgeons were involved directly in the early design development process (5.6). Here, it is important to discuss how designers think in the process of designing. This is to support my observations on the design collaboration. Nigel Cross (2007) who also refers to Bryan Lawson (1990) offers a very useful discussion on this particular issue and Henry Gedenryd (1998) discussed how this design thinking happens.

Cross (2007) discusses his and others' studies on what successful designers (e.g. Philippe Starck) do and this includes co-evolution of problem and solution. This

is the significant strategy used by designers when dealing with design problems (which are also sometimes called wicked problems).

> *'Designers tend to use solution conjectures as the means of developing their understanding of the problem. Since 'the problem' cannot be fully define in isolation of consideration of the 'solution', it is natural that solution conjectures should be used as a means to helping to explore and understand the problem formulation' (Cross 2007, pp 102)*

He suggests this as a productive strategy to deal with 'wicked problems' (ibid). Rittel (1993) claimed that a wicked problem may only be understood by trying to solve it. There is no ultimate solution for a wicked problem as its complexity can only be 'served' by solutions that are "good enough". As these solutions will generate a wave of consequences over time, every attempt to solve these problems will change them (ibid).

Designers formulate problems within the broad context of a design brief (Cross 2007 pp 103). They are not limited to the given problems and restructuring new problems from the given problem is the designer's way of attempting to solve them. Cross (ibid) adds that this as he calls it 'reframing of a problem' may re-occur along the design process. He seconded Schon (1988) suggestion which explained that designer will create a border to design problems, select a potential solution and explore within them. Cross also quotes Lloyd and Scott (1995) where they referred this as 'way of seeing design situation as the designer's problem paradigm'. I will follow Cross term of 'problem reframing' and use it in (9.3.1) below to explain a significant point happened during the design collaboration in the rectal clamp project.

Co-evolution of problem and solution described by Cross (2007, pp 102) is a situation where problems and solutions are developed in parallel. He argues that traditional problem solving theory is less helpful to solve wicked problems. These wicked problems he describes as 'ill-defined' and complicated thus designers actually formulate their problem in conjunction with relevant solutions. He adds that certain kinds of designer, that are trained to use this strategy for wicked problems, tend to use the same strategy for all problems (ibid, pp100).

Stolterman (2008) make similar arguments when he describes the failures of design methods in interaction design. These are due to the lack of understanding of the nature of design. He suggests that design problems are problems that are messy and 'wicked'.

Cross (2007) describes that the co-evolution of problem and solution is explored by designers through making and sketching out potential solutions (ibid, pp 108). This way of communicating and thinking is also explained as a 'reflective conversation with the situation' (in reference of Schön and Wiggins 1992). It is the way designers reflect on and critique their own solutions.

In a very influential thesis, Gedenryd (1998) discusses interactive cognition and uses designing as examples to develop his theory. He observes that designers sketch out their ideas to both test and evolve solutions and propose another problem framing. He argues from this that rational action models of the design process (analysis, synthesis and evaluation; including iterative loop models) are problematic when they are applied into action.

This is because rational action models assume that the development of knowledge (knowing) is separate from the world to which it linked; such models define problem identification, synthesis (action) and evaluation. In interactive cognition, action and evaluation are inseparable.

This is manifested by designers through making or sketching out (ibid, pp 85). He adds, sketching out or producing artefacts is a designer's situating strategy. A designer's concern is with something that does not yet exist. For that they cannot use the existing cognition, they have to use design artefacts e.g. sketches, model, prototype, to create the future situation as a situating strategy. These design artefacts are not the objective of the design work but the vehicle to achieve their target. This is the way the designers test their solution. I will use this term 'test' below in (9.3.2) following Gedenryd to explain the designerly strategies applied by the surgeon during the design collaboration.

4.7 Conclusions

History shows that some surgeons designed surgical tools according to their needs (3.1) and surgeons indicated that they have been doing surgical tool innovation (3.2). Today such tools are often developed by surgical tool makers in cooperation with surgeons. However, surgeons and manufacturers described challenges in carrying out this cooperation (3.6). This indicated an opportunity for me to investigate productive methods for such collaborations.

Participatory design methods using 'contextual inquiry' and 'mock-ups' were selected to be explored, as they seems to promote partnership and a democratic way of designing with users. Besides, they were achievable in the chosen context and within the researcher's skills and professional experience. These methods were explored in pilot studies (6.4) and tested in the design projects (8.3 and 8.4).

In the next chapter, I discuss the setting up of the method for the research which I undertook in the main practical work with the surgeons.

Chapter 5: Setting up method for the research

This chapter will describe my methods used in this research which include my position as participant observer and the use of video observation. It will also include a description of how I used interviews as a strategy for my contextual review for the research and also my use of contextual immersion in the surgeon's domain. This chapter will conclude with an explanation of my procedures for the collaborative design activities. These methods were set up for the main practical work (chapter 8). However, they were explored through pilot studies (chapter 6) and some adjustments to the methods were undertaken here to address an ethical constraint (6.1).

5.1 Introduction

There were several challenges in developing a methodology for this research. In practice the methods and methodology emerged through trial and error over the whole period of the research. Significant objective for me have been:

- To develop a methodology which makes good use of my established experience and skills as a professional designer.
- To work reliably with a very small sample of two expert users.
- To fit my research into the wider picture of design research which is still an emerging field with a great diversity of thinking and practices.

There are many examples of 'research through design' focusing on design methodology. A selection is shown in Fig.5.01. These articles were chosen as they included design activities, particularly with user's participation, and were undertaken within the medical domain.

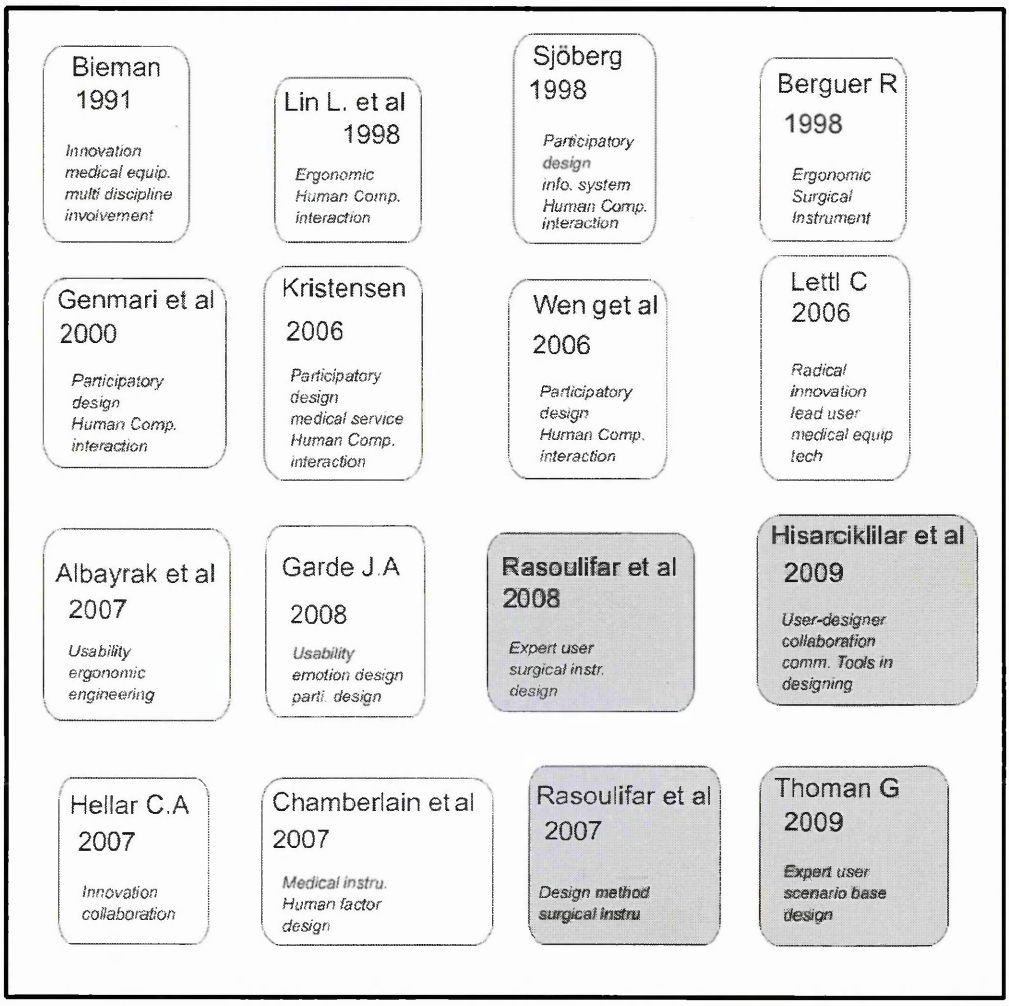


Figure 5.01*. Research projects that include designing activities relevant to this research. Highlighted examples are closest to this research.*

Some of the researchers discuss user participation in the design process as the focus of the research (Sjoberg 1998; Genmari et al. 2000; Kristensen et al. 2006; Chamberlain et al. 2007; Weng et al. 2006; Rasuolifar et al. 2007). Some examples focus on innovation (Biemen 1991; Lettl 2006; Hellar 2007) and some focus on ergonomics (Lin et al. 1998; Berguer 1998). In Fig 5.01 I have highlighted publications which appear to be closest to my research and design aims in practical terms.

5.2 Research methods employed

Practical research methods were chosen as suitable for the design circumstances (the design projects) and for their usefulness in observing and evaluating design collaborations. Action research methods were helpful with their emphasis on systematic documentation of both interviews and observation.

5.3 Semi structured interview

Interviews were undertaken with surgical tools manufacturer (designers and proprietors) as a contextual review of current scenarios in surgical tool innovation. This was also undertaken with collaborating surgeons to understand the same issues but from the user's point of view. One of the main points of the interviews was to understand the challenge faced by manufacturers and surgeons in the development of surgical tools.

A set of open ended questions were asked of the surgeons in the interviews. The full set of questions can be found in Appendix 1. The issues explored were:

1. Background
   - Years of experience in the domain
   - Specialization
2. Current situation
   - Current practice – how problems are overcome – instruments used
3. Open questions
   - Opinion about collaboration between designer and surgeon/medical expert in design projects.
   - Challenge for designer or surgeon to design surgical instruments.
   - Contributions that can be made between designer and surgeon/medical expert in designing surgical instruments.
   - Opinion about surgeons designing surgical instruments.

Further interviews with surgeons were undertaken as a platform for the surgeons to voice their propositions (problems, needs and ideas) as a starting point for the design projects.

5.4 Participant observation

The research took place through design projects where I as the designer collaborated with the surgeons designing surgical tools. I observed the surgeons while they participated in the design activities and other related activities through the design project. As I took the roles of both researcher and designer I was a *participant observer* (Dewalt and Dewalt, 2002). The core of this method is that researchers do not detach themselves from the observation subjects and expect to think and feel as the subjects. This method originally came from anthropological research.

However, unlike most participant observer research, the design collaboration undertaken was in a one-to-one situation. Besides observing the surgeons collaborating actions, I was also observing the designer's actions that is observing myself. The data collected are my observations and reflection on surgeon and designer. To do this I used camcorders to record all relevant activities of me and the surgeons throughout the projects and then I referred back to the video recording for analysis (Fig.5.03).

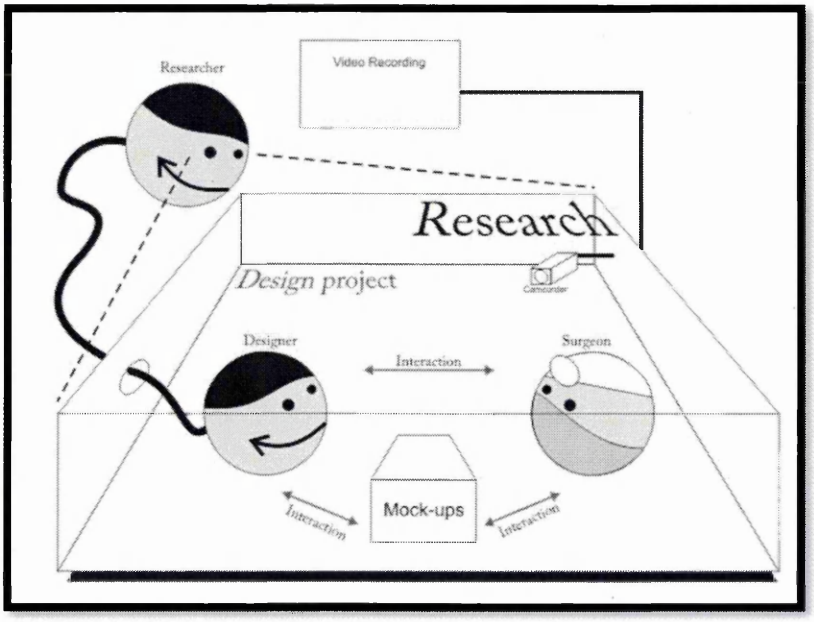


Figure 5.03. *The researcher becomes the participant observer in this research.*

5.5 Video observation

I used camcorders to capture the activities undertaken through the design project such as meetings and design activities. The video recording provided the data collection which was analysed using my reflections as a designer involved in the design project and also as a researcher looking at the actions of the collaborators (Fig.5.04). The video recordings were also used in expert review sessions where they were exposed to relevant experts invited to review the design methods used in the project.

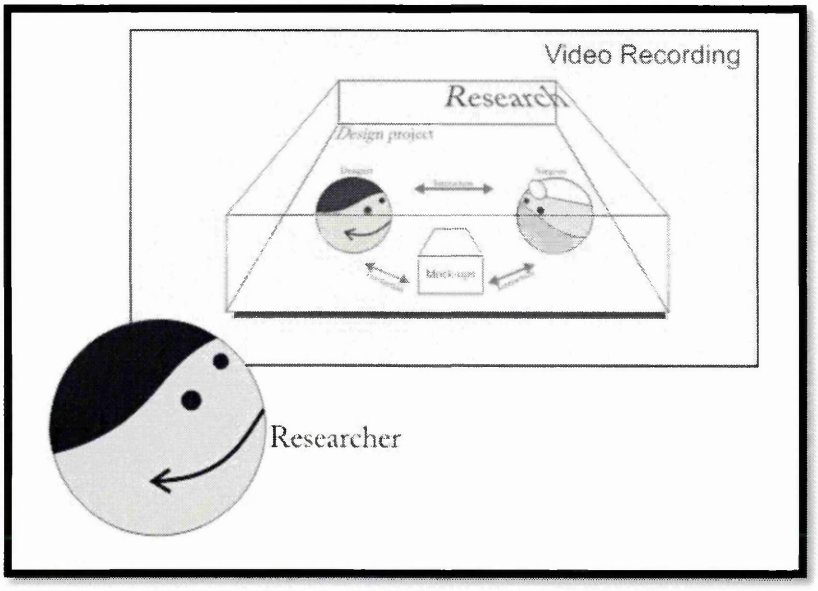


Figure 5.04. *Video recording used as soft data where the researcher observed the interaction between the surgeons and himself in design project.*

This process has some similarities to 'video ethnography', as described by Shrum et al. (2007) and Heath & Hindmarsh (2002), an ethnographical method in social research used to record social interaction in everyday settings. Video ethnography as Heath & Hindmarsh (2002) describe, is a good way to record human interaction as it helps to see the 'seen but unnoticed' character of human activity.

Nicola Wood (2012) describes her experience of using video recording for data collection in her research into ways of eliciting and transmitting craft knowledge. She reported that video observation can capture very rich material. However, she warned that the act of video recording may change the way people act during

observation. So, based on her experience, she proposes that there are several criteria which made her video observation less intrusive.

Wood suggests that the observer needs to be familiar with the equipment(s) they use so that they can confidently use them on site. This can be achieved by often utilizing the equipment before undertaking the research. She also explains that modern designs of camcorder allow very small yet high quality cameras which are less intrusive and very easy to handle.

She proposes that it is not beneficial to use additional lighting as this will make the participant act unnaturally. The position of hand held cameras also has an effect on the participant behaviour. She describes that she held the camcorder at her waist while recording. Another important criterion is mobility of the camera used. A small and light camera provides the advantage of moving the equipment quickly and quietly.

In this research, I did not undertake ethnographic research using video recording, but video ethnography approaches informed me of how this technology can be used as a tool to capture people's actions and the use of recording for collecting soft data.

The nearest example to my methods comes from Rasuolifar et al. (2007) where they used a camcorder to capture the surgeon's surgical procedure using a new design of surgical tool. They used a table to transcribe the surgeon's actions. Wood used a less formal 'coding' compared to Rasuolifar. As she had a massive collection of footage to be analysed, she chose not to use the available computer aided analysis programme but used a time log of events and flow charting as tool to analyse her data.

I chose to use Nvivo, a digital way to process my video recording, because it was easy to access and training received made me familiar with the software. A table similar to Rasuolifar's project was used. Several manual recording exercises were undertaken through the pilot studies (6.4.1 and 6.4.3a) and these helped me to develop the detail needed for my transcription tables (Table 6.01, 6.05, 6.06).

The video used in Rasuolifar's project was to describe the surgeon's action microscopically to inform further development of the design. In contrast, in the current project, the video observation was used to take a holistic view of interaction between designer and surgeons in the process of designing. Figure 5.05 shows the example of the table I used for the transcription of the video

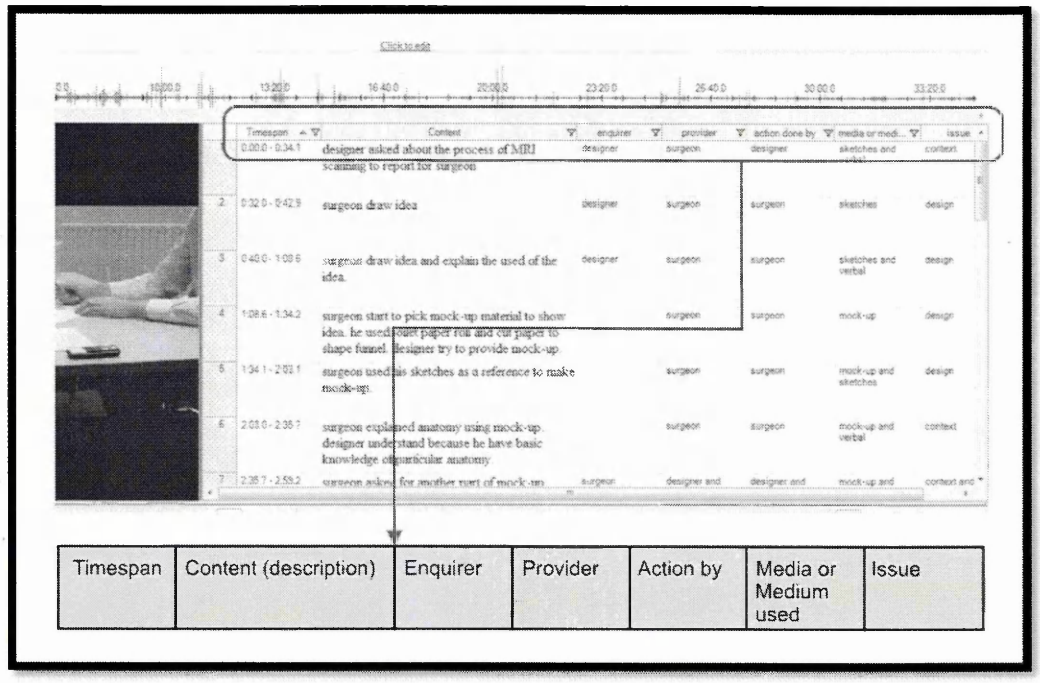


***Figure 5.05**. Details used for the video transcription in Nvivo.*

The software provided a flexible platform for video/audio transcription which could be tailored to deal with my issues as shown above in figure 5.05. 'Enquirer' is the person who requests information or physical assistance in the activity. 'Provider' is the one who gives the assistance. 'Action by' is the person who is taking practical action at that moment. 'Media or Medium used' is the tool used in providing the information or assistance.

These characteristics for transcribing were developed through pilot studies which help me to establish a general understanding of the process. This was refined by reviewing the videos before deciding on the points to be extracted.

5.6 Design projects as the environment for the research

The research was undertaken through two collaborative design projects with colorectal surgeons designing surgical tools. The design projects were not created for the purpose of the research but they were live design projects offered by the surgeons, Mr Steven Brown, for the Anorectal Clamp Project and Mr Keith Chapple for the Fistula Model Project.

The projects were undertaken in partnership circumstances to create a balance power in the design decision process. Observation as a participant was undertaken throughout the projects and recorded on camcorders for analysis. The actual design projects are explained below in Chapter 7. Details of design methods undertaken are explained below in 5.8. The artefacts from the design projects are presented as part of the research outcome. The design projects will be continued in partnership with the surgeons although the research aspect of the work is ended.

5.7 Review by expert panel

'Expert review' was used to enrich the analysis of the video data from the co-design sessions by a viewing/discussion session with a panel of experts experienced as designer or expert user in design projects. It was undertaken as a way to validate the process undertaken during the co-design session. The participant's role was to provide external views to balance my single participant observation method for the research.

The aims were to expose the participants to a video recording of a co-design session in the fistula project (8.5) and they were asked to reflect on the collaborative activities shown in the video and their value in the project. A video of the experts viewing and responding was synchronized with the video they watched so my timeline shows the action in the video, my interpretation and the evaluator interpretation (comments and opinions).

'Experts' in this session are people with experience in collaboration work between designers and medical experts in design projects. They are people who

may benefit from adapting the methods explored in this research and can compare them with their own experience.

Questions for the experts to answer during the session were,

- How does this relate to other experience you have?
- What are the important events in the video?
- Could you adopt any ideas from the process in your own work?

They were gathered in a comfortable conference room equipped with a video projector and space to set up a video camcorder to capture the screen and the group of experts in order to synchronize the audio of the discussion with the screen video. The experts' comments and opinions were transcribed onto a table similar to the surgeon action table used for the analysis and synchronized with the analysis I made of the same scene/minutes, such as shown in the table below (Fig.5.06).

No	Min	Designer interpretations	Screen shot (co-design session)	Expert comments / opinions	Screen shot (expert review)
01	00.00 – 25.01	Designer explained the agendas for the session. Surgeon explained the process of getting the MRI report and relevant issues.			

Figure 5.06*.Sample of experts review table.*

5.8 Exploring design method

I discussed design methodology broadly in chapter 4 to establish the context and aims for this research. Now I will explain the specific design methods used in the collaborative design projects. I explored two participatory design approaches (as discussed in 4.1 and 4.2) as a method to develop my own design approach in this research. They were 'contextual immersion' and 'working with mock-ups'. As discussed in 4.1, 'contextual inquiry' uses apprenticeship via partnership to

understand users' contexts. As discussed in 4.3 and 4.4, working with 'mock-ups' has been shown to be useful in designing with users.

Below, I will explain my design method based on these two participatory design methods.

5.8.1 Immersing with the user's context

I explained above (4.2) on contextual inquiry as a way to understand the user's context. I also explained that I will use my own term 'contextual immersion' to describe the technique I used to understand the user's context. This is to avoid confusion between 'contextual reviews' for the research with the method to inquiry for designers. Below is the explanation of 'immersion' I used for this research. Then I will continue with explanation of how I did this.

A designer can be an apprentice to the user through partnership. In this project, the designer and the surgeons became partner in design collaboration (1.3). Meaning that they both have the same levelled of responsibilities towards the design they made. This is my interpretation for partnership in this research.

The surgeon's context is complex (Chapter 3). Their profession requires long training and practice and each surgeon has a complex specialism (3.4). They work in multiple clinical environments and attend professional conferences to be aware of other surgeon's experiences and concerns. Plus, their professional ethics and obligations make them sharp in their concerns and decisions.

To be an apprentice to the surgeon will take a long time because of their complexity in the context. However, in this research, apprenticeship undertaken was focused on the superficial knowledge from the surgeon i.e. basic understanding about the surgical issues. This also includes empathising the surgeons' feeling during they professional work i.e. observing a mock surgical procedure.

So, to do this 'contextual immersion', a designer can do this over apprenticeship through partnership. For this, I undertook several attempts to familiarize myself with the surgeon's issues so as to help me in designing with them.

5.8.1a Reviews of related scientific literature

It is normal for a research project to make a contextual review of relevant knowledge. However, in this case, reviews of scientific papers and books normally used by surgeons in their work also helped me to understand the surgeon's professional world and concerns, as well as give me an oversight of the particular diseases, treatments and anatomical understanding relevant to the projects.

In this project, I was supplied with books recommended by the surgeon. He also provided explanations of suggested topics (Fig.5.07). Reading these scientific publication on my own did not help me to completely understand the issues as they used very technical terms. However, these publications also came with pictures and explanations which provided enough superficial understanding.

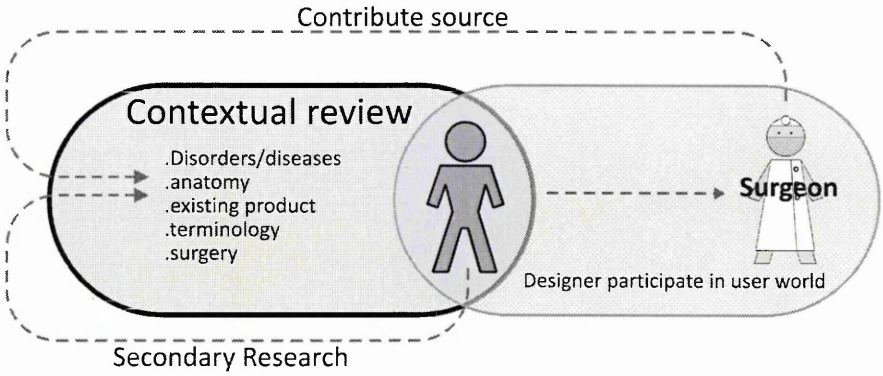


Figure 5.07*.Contextual understanding as a designer in Mr Brown's project.*

5.8.1b Interviews with the surgeons

Interviews with the collaborating surgeons were undertaken as part of the contextual review for the research (8.1.1). These also formed part of the professional enquiry for the design projects.

5.8.1c Study of anatomy

As surgery is a specialized domain, the designer needs to understand the related anatomy. This was undertaken in the clamp project by studying a full scale anatomical model of the lower abdomen. With the surgeon's explanations, this gave me a sufficient understanding of relevant anatomy for the design projects. I will explain this in detail below in 8.3.1.

5.8.1d Observation of surgical procedure (rectal clamp project)

This method is grounded in the project with the surgeon, Mr Steven Brown because the designer needed to understand the particular surgical procedure and this can be only really understood by observing the surgeon in action. This observation was also the first part of the co-design session. Contextual enquiry (Holzblatt and Jones 1992) principles were adopted in this session where it is suggested that in order for the designer to understand the user's way of work in using tools, one needs to be the user's apprentice. This apprenticeship suggested to be undertaken in partnership situation where the designer can stop the user to ask contextual questions (4.7).

This observation was undertaken through the simulation of the surgical procedure. The original plan with the surgeon was to undertake an observation during real surgery. However, my ethical enquiry[9] led me to create an alternative surgical environment – a simulation. The simulation was set up at an emergency room simulation unit at Sheffield Hallam University (Fig.5.08). A tailor-made surgical model was developed with Mr Brown through several meetings by using low fidelity 'mock-up' materials (Fig.5.09).

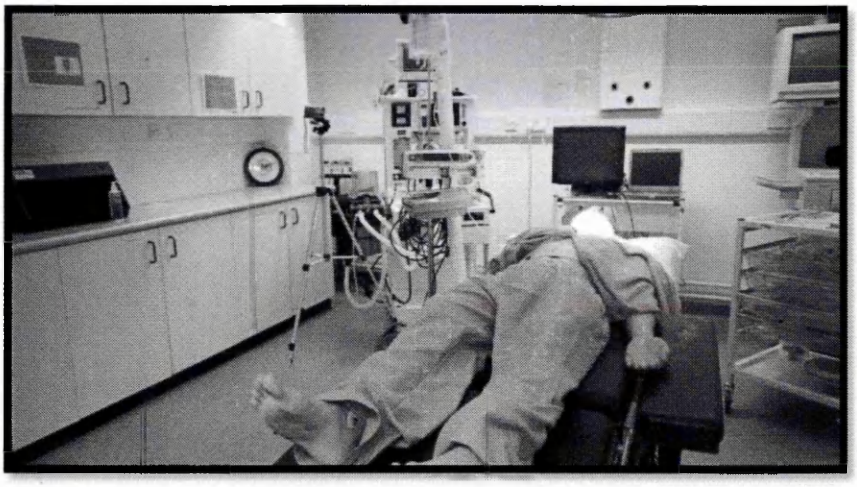


***Figure 5.08**. Emergency room simulator unit at Sheffield Hallam University, Sheffield, UK.*

[9]Detail about ethical enquiry will be explain in 7.2.3

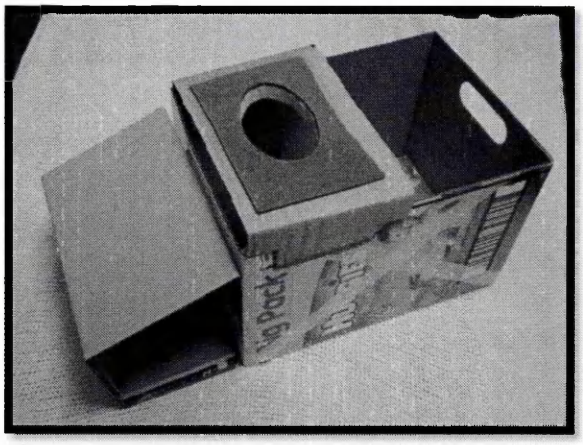


***Figure 5.09**. A mock-up of surgical simulator model developed and built between the designer and the surgeon.*

5.8.2 Co-design sessions

The collaborations were undertaken with the objective of developing the surgeons' ideas for new products. I, as the designer in this project, worked to develop the collaboration with the surgeons in these projects by providing them with a design environment (tools, place and design skill) and a semi-structured activity plan. I describe these sessions as co-design. Sanders and Steppers (2008) described co-design as a situation where designer and non-designer user work in collective creative activity (see 4.5.2 for a wider discussion of this).

Two projects were undertaken in distinctly different circumstances. A co-design session with Mr Steven Brown was carried out in a surgical environment (as in Fig.5.08) while a session with Mr Keith Chapple was undertaken in a design setting (Fig.5.10). These sessions were set up as this is the needs and it is suitable for the projects.

***Figure 5.10**. Design environment setup for fistula project.*

The rectal clamp project was carried out in surgical environment because the designer needed to understand the surgical procedure in order to see the problem(s). This was also due to limited time the surgeon can provide for the project. So it was the requirement of the project that led to a 2in1 session. The fistula project on the contrary was focused on developing the surgeon's idea and required an understanding the process of transferring information between radiologists and the surgeon.

Moreover, I, as the designer, already had a superficial understanding of the particular anatomy (anus, rectum and colon) and the clinical disorder (fistula-in-ano) gained from Mr Brown through my previous MA project. In addition, a test run in the pilot studies showed that a research context could also gained through design session with users as explain below in (6.4.3).

I adopted the principle from several earlier researches of using mock-ups (Ehn and Kyng 1991; Long et al. 2011; Vaajakallio and Mattelmäki 2007). As discussed in 4.3, Ehn and Kyng (1991) provided a useful starter for me in reviewing issues regarding the use of mock-ups in design research. However, the mock-ups used in my research were not enacting a design game (language game) which is central to Ehn and Kyng's approach.

As explained in (4.4), in this research, I was particularly focused on the process of making mock-ups. As the designer, my intention was to build the mock-ups of the surgeon's ideas using the mock-up kits. Gaver (1999), who introduced cultural probe kits which were not highly finished, thus enabled his participants to engage undaunted in his project. This suggested that the use of less finished material may attract the surgeons to be involved actively in the making process. It is fun as well to make mock-ups as described by Ehn and Kyng (1991). For this present research, two sets of mock-up kits were developed through pilot studies using these approaches. They were:

Mock-up kit 01: Packaging cardboards, plastic straws, pipe cleaners, easy formed clays and masking tapes (Fig.3.11) and

Mock-up kit 02: A collection of assorted everyday things (Fig.3.12)

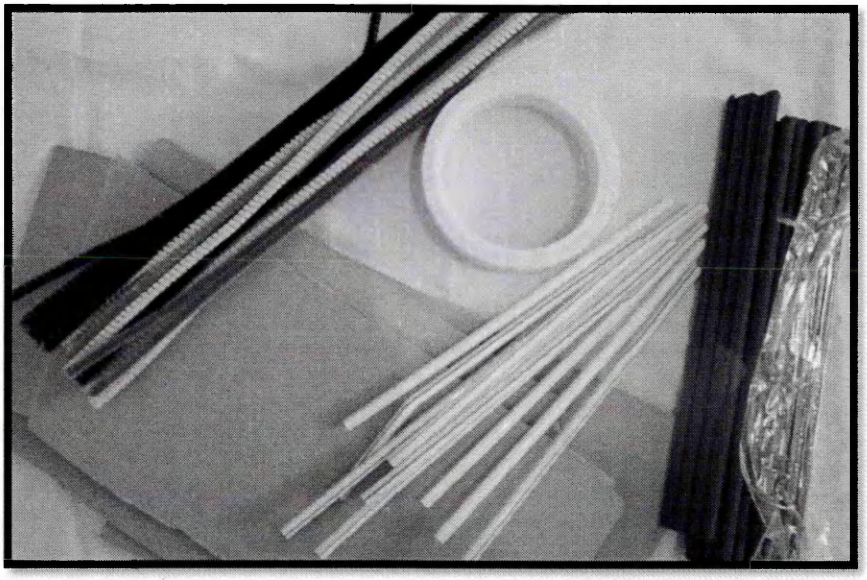


***Figure 3.11**. Mock-up kit 01*

Figure 3.12. *Mock-up kit 02.*

Before describing the use of these kits in the two main projects with the two surgeons, the pilot studies which preceded and informed them will be introduced next.

Chapter 6: Pilot studies

In the pilot studies I explored potential participatory design methods which I have identified from my literature review. During the pilot studies I also developed my own methods for engaging with the participants and recording the activity. Because there are considerable practical and institutional constraints to working in a clinical environment, I aimed to carry out as much of the pilot work as I could with studies using non-clinical working practices and settings. For the last pilot study T was able to include the medical background of the participants (dental surgeons) once the ethical questions had been resolved.

Pilot studies were divided into three sections according to their purposes and participants. The first section was undertaken with industrial cleaners to understand how mock-ups can be used to expose user experience in using tools. The next pilot study comprised interviews with musicians to test the method of detecting lead users. The last section of the pilot study tested the method of building mock-ups with users in seeking design concepts.

6.1 Ethical constraints

The original plan for the research involved both surgeon and patients (in fact patients were not involved in the eventual main study). Information published by

the UK National Health Service (NHS) National Research Ethics Service (NRES) indicated that research needed to have ethical clearance before any activity could be taken with the NHS staff or patients[10], which could have delayed the pilot study. Furthermore, working with senior surgeons is a rare opportunity not to be wasted on pilot studies. So, my problem was how to test my method before my sole opportunity to work with the surgeon participants.

For this, I invited more accessible participants, who had non-medical backgrounds, to be involved in my research. These groups were selected because they had some similar characteristics to the surgeons. They 'shadowed' the surgeons' experience in their work using tools, and they were expert users (musicians), such as surgeons. For the last pilot study I was able to include the medical background of the participants (dental surgeons) once the ethical questions had been resolved.

6.2 Developing the topic of the research

The aim of the research is to investigate participatory design methods in a collaborative design project.

Methods investigated were adopted from a contextual review in setting up the research plan. The participatory design techniques dealt with contextual inquiry (Holzblatt and Jones 1992) and the use of mock-ups (Ehn & Kyng 1991; Long et al. 2011; Vaajakallio & Mattelmäki 2007) and were explored through the series of pilot studies.

As discussed above in 4.2, contextual inquiry is a method of understanding the user's context through apprenticeship with the users. The technique suggested by Holzblatt and Jones generally is interview with the users while they are working.

Mock-ups were proven as good tools for engaging users in the design process (as discussed by Ehn & Kyng 1991; Long et al. 2011; Vaajakallio & Mattelmäki

[10]Eventually in negotiation with NHS Clinical Research Office Sheffield, it was confirmed that this particular work could proceed without NHS approval as it was seen as technical development which does not really meet the criteria of generating new and generalisable clinical knowledge. Therefore, it does not constitute research in the way that the term is used in NHS research governance.

2007). They make the users' working experience available to be seen and understood and can be used in designing (ibid). They are also suggested to be a good tool in generating ideas with users (ibid). I explored both of these characteristics of mock-ups in the pilot studies to develop my own method of using mock-ups in design projects.

6.3 Developing the methods of the research

Undertaking analogous practice of surgeons with non-surgeon participants

My approach to working with a variety of experienced participants in these pilot studies could be described as 'shadowing'. The term 'shadowing' has been discussed in the Human Computer Interaction (HCI) domain within participatory design by Kristensen (2006). A group of participants were trained as emergency workers (ambulance staff, police, fire and rescue, etc) and they were asked to role-play in a 'fake' emergency setup, while the researcher made observations on the setup scenario for designing an emergency call and response system. The participants became actors by 'shadowing' the user, while the researcher observed.

The term 'shadowing user emotion' has also been mentioned by Steen et al. (2007) in reviewing design and research methods, which involved users in the earlier process of design. He describes 'shadowing' user emotion when discussing role-playing in empathic design. In this approach, the designer seeks the emotional insight of the user by becoming the user in the process of designing (Koskinen et al. 2003). In my pilot works, the non-surgeon acted as proxy for the surgeon by undertaking familiar analogous practice, rather than engaging directly in surgical work, since skill and experience are essential for participation.

Non-medical participants were used as proxies for surgeons for the pilot studies. Therefore, it was important to know which of the surgeon's characteristics were used in parallel with a non-medical participant's characteristics. Surgeons are expert users (Patel & Arocha 1999; Rasoulifar et al. 2008), but there are no relevant definitions of the exact characteristics of the surgeon.

However, from the various sources (3.1, 3.2 and 3.3), it can be concluded that a surgeon's characteristics can be regarded as having two levels, namely general, or surface level, and in-depth, or specific level (Fig.6.01). For this study, only the general characteristics of surgeons label (1) and (2), are considered because only these features can be regarded as similar to generalised features hold in common to some degree with industrial cleaners, musicians and chemists. For the intersecting features between cleaners and surgeons, only general characteristic (1) was used. For musicians and chemists, features (1) and (2) were used because their work can be considered more delicate than what of cleaners and they need greater practice in order to become experts.

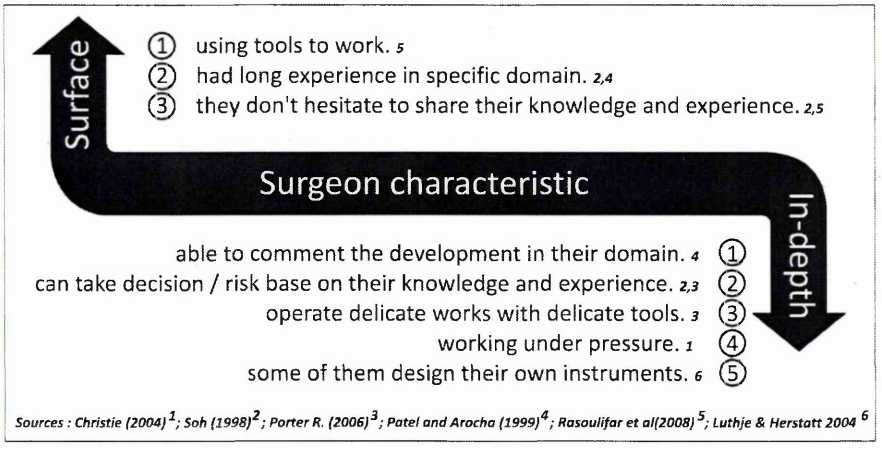


Figure 6.01 *- Surgeon's characteristics*

There are some clear differences between surgeons and cleaners. For example, surgeons tend to use delicate instruments, while cleaners may use heavy duty tools. The study was looking at the relationship between users and their tools in working environments, as discussed above (4.1) in the context of participatory design. Cleaners provided an accessible group allowing me to explore this in general terms before moving on to a more sophisticated expert user.

Experience in using tools may be exposed by user demonstrations and designer observation. Such observation may be supported by interview via a contextual inquiry method (Holzblatt & Jones 1992).

The pilot studies, therefore, initially included unstructured or semi-structured interviews and practical tests with workers, who use specialised tools (industrial

cleaners and musicians). I also used the pilot works to explore how making mock-ups can reveal participants' particular knowledge and practices. When mock-ups (Ehn & Kyng 1991) were involved, participants had no hesitation in demonstrating how they manage the tools at work. Some of them were also able to give critical explanations of their work. Unstructured interviews with musicians particularly focused on finding ways to detect lead-user-ness (Von Hippel 1986,1988; Luthje and Herstatt 2004;Bowen 2009) among expert users.

Following the pilots with cleaners and musicians, the third study tested the method of using mock-ups in co-creation between designers and users. Participants with a design background (metal and jewellery designers) and scientific backgrounds (chemists and dental surgeons) were invited to participate in this study.

As discussed above (4.5.3), Von Hippel (1976) strongly suggested that scientific instrument innovation has been dominated by the instrument users themselves, and Luthje and Herstatt (2004) indicated that this includes surgeons. Therefore, getting the chance to use participants from the two domains of science and dental surgery seemed to be potentially beneficial to explore. Moreover, having dental surgeons in the pilot studies provided more useful feedback as they are nearer in professional terms to the main participants of this research.

Again, I would like to remind the reader that this exercise is to test the method of co-creation using mock-ups as a design tool and to test and refine the usability and suitability of the mock-up kits developed through the pilot studies. Mock-up materials gathered consisted of everyday materials, such as packaging, and were organised according to their function and form.

6.4 The work.

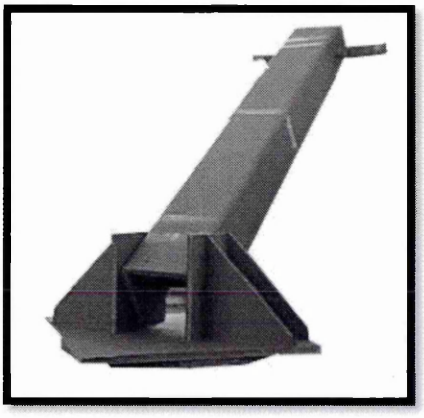
As described above, pilot studies used participants from various backgrounds and professions. They were selected because some of their characteristics shadowed the surgeons' in some regards and they were more accessible than consultant surgeons. There were three pilot studies, each with particular objectives.

6.4.1 Pilot Study A: Interviews with cleaners and demonstration of cleaning tools used

My first study was with a group of industrial cleaners. I chose them for several reasons. First, I had ready access to a group of postgraduate students who did part-time work as cleaners, so as well as having specific experience of the work they were also able to understand and engage with the research process. Second, their work involved using a variety of tools, some requiring specific training and skilled operation. Lastly, it was relatively easy to set up a role play exercise which was closely modelled on their actual workplace.

Interviews and demonstrations were conducted away from the work place. A mock-up of a buffer machine was used in the interview, as a tool for users to share their experience. The study allowed me to evaluate the method with a mock-up.

The buffer machine (floor polisher) was selected because it requires specific training and skills to operate (Fig 6.02). The mock-up buffer machine was built from cardboard, suggesting the basic shape and function (Fig 6.03). A standard procedure from a cleaning proficiency manual by the British Institute of Cleaning Science (BICS) was also referred to and provided an interesting comparison in the actual method observed.



Left, Figure 6.02 *a standard buffer machine with basic features.* ***Right, Figure 6.03*** *a cardboard mock-up of buffer machine used in interview/demonstration.*

6.4.1a Participants

The two participants were chosen because they used the machine regularly and were trained to use it. As mentioned before, they were university postgraduate students working part-time as cleaners. I believed that using a well-educated cleaner would provide more critical responses for my interview. As a user, they would understand the broad aims of the project, as would be the case in participatory design.

6.4.1b Procedure

Following an initial session in the participant's workplace, interviews were conducted in a private house as it was more convenient, more relaxed and free from the time constraints of the workplace. However, having a demonstration of the workplace tool was helpful as 'showing' is clearer than 'describing', which led to the use of mock-ups in the domestic setting. A set of open-ended questions was asked to participants covering:

- Background of participant, and
- Job task.

They were both supplied with a mock-up to help them demonstrate their method of using the machine.

The participant 1a (Fig 6.04) was given the mock-up from the beginning of the interview session, while participant 2a (Fig 6.05) was exposed to it after answering background questions. The difference between the two was that the first participant demonstrated 'unconsciously' while holding the mock-up and while responding to questions, even though he was not instructed to do so. He then repeated the same actions when it came to the demonstration session.

The second participant was given the mock-up to 'play' with after the background questions were answered. He showed an eagerness to hold the mock-up and tried it straight away while copying the sound of the machine, which the first participant also did.

Figure 6.04*.Participant 1a*

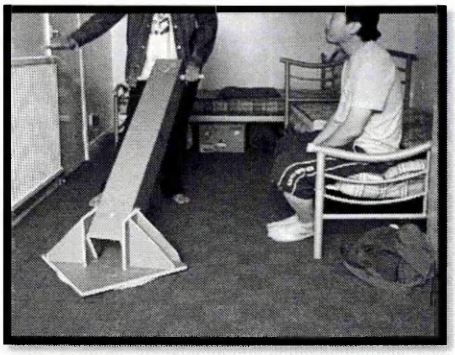


Figure 6.05*. Participant 2a*

6.4.1c Observation

The interview and demonstration sessions were in the Malay language. They were then transcribed into English for the analysis. Video recordings of the sessions were transcribed into tables containing questions, answers and action involved (Tab. 6.01 and 6.02). In this transcription, 'action involved' means actions executed by the participants while they were interviewed, including questioning and answering time. Capturing actions is important for the observation of a user's working experience (using tools) and revealing implicit practices. This exercise gave me an idea of how to record an interview/demonstration session and also provided me with the opportunities to refine my technique.

Questions	Answers	Action involved	Support Image
Why do you push it forward?	I think it is not proper to pull it backward. It is hard to control. It is a machine that needs skill to operate. It will bump around if we use it wrongly…and it is better if the movement is just	Pulling backward	 Min 9.35

	one-way. Moving forward. I think I never use it backward.		

***Table 6.01**. Observation table - Participant A*

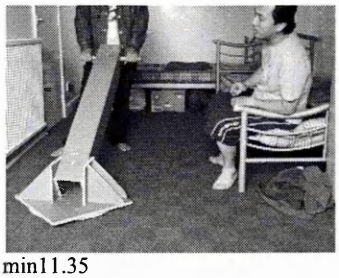
Questions	Answers	Action involved	Support Image
Did you push or pull the machine to buff?	Ok…normally its motion is to move left and right, so I push it forward	Wiping motion and move forward.	 min11.35

***Table 6.02**. Observation table – Participant B*

The sessions were carried out on separate days, allowing time for review and adjustment of the set-up before the second session. From the observation, significant actions were performed by the participants using the mock-up:

1. Participant voluntarily helped setting up the mock-up at the beginning of the session.
2. Participants verbalised the actual sound of the machine while 'role-playing'.
3. Some of the questions about the process of performing the works were only answered with actions.
4. One participant pushed an imaginary button while role-playing, even though there is no button on the mock-up or on the real machine.
5. They continued to hold the mock-up while answering the questions.
6. Participants corrected their actions after the first attempt.

These observations supported Ehn and Kyng's (1991) work indicating that mock-ups are effective in revealing users' experiences and techniques in using tools. The mock-up gave opportunities for participants to 'play' and imagine the mock-up as a real machine. By using the mock-up, participants can 'rewind' and 'play forward' any action in the session, giving them the space to correct and refine their actions.

The users did not have to be instructed on how to demonstrate with the mock-up, but only what to demonstrate. This may have been because my mock-up approach differed from Ehn & Kyng's mock-up (Fig.6.06).Where as Ehn and Kyng were introducing completely new working practices, my study was of existing practice and tools so the users did not have to be instructed on how to demonstrate with the mock-up, but only what to demonstrate.

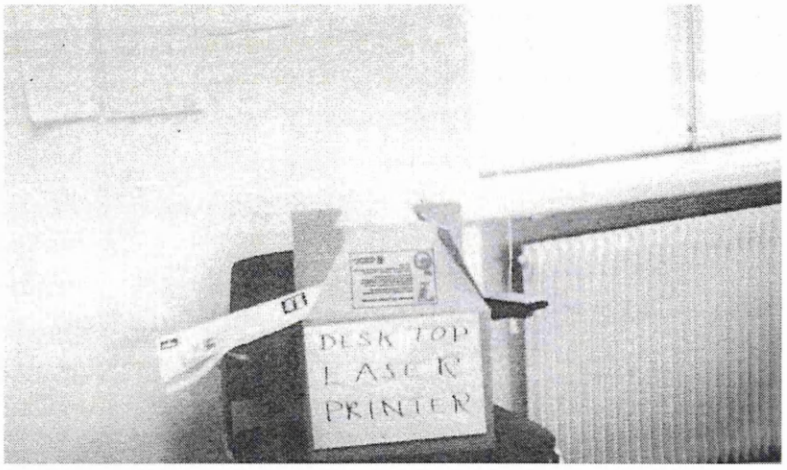


***Figure 6.06**. Enh and Kyng (1991)*

6.4.2 Pilot Study B – Interview with musicians on their personalizing tools

The aim of the study was to investigate methods for detecting innovativeness among expert users (detecting lead users). In this study, I used three musicians to do this.

Drawing on the sources in Fig 6.07 below, I use the term 'expert users' to describe professionals in their field, having developed a particular skill through years of training in the same domain.

As described above in 4.5.3, Von Hippel (1976, 1986) strongly suggested that users with particular characteristics, which he termed as lead users, tend to innovate new product for the market. These musicians may possess these lead user's characteristics. As musicians shared some characteristics with surgeons, especially on the surface level, they became proxy for the surgeon and seem to be beneficial for me to investigate this method and develop it for the main project.

From my personal experience, I believe musicians tend to personalise their instruments. This personalisation may suggest creative intuitiveness in designing or redesigning their instrument.

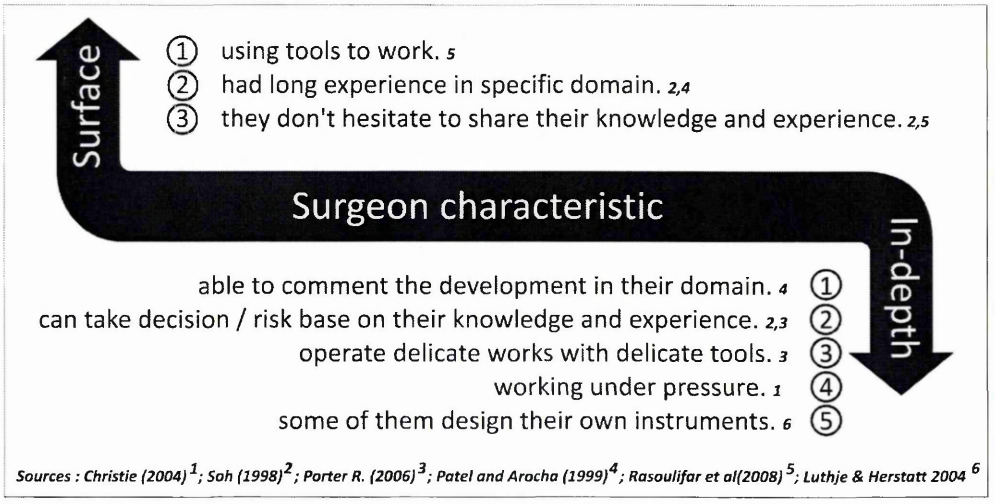


Figure 6.07 *- Surgeon's characteristics base on collective sources.*

Procedure

Participants were interviewed together in one session. It was undertaken in that manner because it provided some advantages that benefitted the research. Advantages as well as disadvantages in using a group interview were discussed by Frey and Fontana (1991). Relevant to this research, issues raised by one participant were found to stimulate elaboration by the other participants.

This pilot study was undertaken through a semi-structured interview with open-ended questions. Open-ended questions were used to give opportunities to generalise, revise and create questions for the main project. Participants' backgrounds were taken into account, such as years of experience in music and

performance. Some background questions were asked, as in Pilot A. However, significant issues were raised:

- How do you know the right/most suitable specification?
- How long did it take to reach the desired specifications?
- What changes have you made to your instruments?

The questions were devised through referring to two lead user characteristics suggested by Von Hippel(1986,1988) and later by Luthje & Herstatt (2004):

i. Lead users face new needs that will later become general for other users (capability).
ii. They significantly benefit from the innovation that provides solutions to those needs (motivation).

Participants showed their instruments, and explained how they operate them. They highlighted the changes they had made to their own instruments and discussed their reasons for the modification. Sessions lasted 2 hours and were video-recorded for reference purposes and re-observation (Fig. 6.08).

***Figure 6.08**. Semi-structured interview with musicians*

All the participants had the same years of experience as music students; at the same time, they also had professional experience of performing in public, joining a band in concerts or clubs. Only participant 1b had extensive experience in playing classical guitar. Others had changed music genres since attending music college. Participant 2b was exposed to heavy metal rock before he learned

traditional music. Participant 3b played classical piano before choosing the accordion as the main instrument during his college course (Table 6.03).

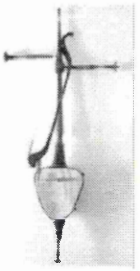
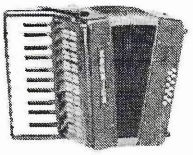
Participant	1b	2b	3b
Years of experience	5 years	7 years	5 years
Instrument	 Guitar	 Rebab	 Accordion

***Table 6.03**. Significant details of participant*

6.4.2b Observation

Observation was undertake during the session and observed later during the video recording. Below are the responses from the interviewees that have been generalised in order to support the next practical work with the surgeons.

1. Participants select their instruments in response to suggestions by their teachers, seniors and other review sources.

2. Participants talk about the history and current developments in their domain and related instruments.

3. However, from long experience in using the instruments, and with their particular needs in mind, they were able to discriminate and compare the brands and design of instruments for best results.

4. They changed their instruments because of the instrument features that are interchangeable. An instrument that had a long history of unchanged features and elements e.g. traditional music instruments also became the presence of the changes made.

5. Not all participants changed their instruments radically. However, one particular participant who does make radical changes to his instruments may have lead user characteristics as described by Von Hippel (1986, 1988).

6. Participants seemed more confident in answering questions while their instruments were present (participants were questioned without their instruments in the first half).

Questions used were roughly devised taking account of lead user characteristics. Based on the study, questions can be grouped into categories:

- *Participant's background*

  Background questions are queries about the participant's professional experience. These included years of experience, domain of work and how they choose the domain.

- *Current practice and related instruments*

  This query concerns the tools they used in the specific domain. This is most important because this is where the user explains their experience using instruments at work. The questions look into how they choose the instruments and whether they change the type of instruments through time.

- *Open questions*

  It is beneficial to understand what participants know about the current development of their domain and their opinions about it. One of Von Hippel's (ibid) lead user characteristics is that they are at the leading edge of their domain and face needs which motivate them to innovate. Participants who know and are able to explain the innovation-related issues of their domain may possess this characteristic of lead user.

- *Query about their needs*

  Lead users experience new needs that emerging the market, which will be general to other users (Von Hippel ibid). To open the opportunity to work together with the users, questions of needs were asked. These questions of needs are typical designer questions posed to their clients.

Using musicians as participants in a pilot study was valuable for the research. They share some characteristics with surgeons, and one participant showed he may possess lead user characteristics. From this, the pilot allowed me to test, revise and redesign my questions in detecting lead-user-ness for my further work. Due to the nature of this pilot, I did not use mock-ups but instead used the participants' own instruments as a tool for sharing their experience. This added to my observation that the presence of artefacts (mock-ups or real tools) made participants appear more confident when answering questions in the interview, as shown in pilot study A and B.

However, these pilots showed that the studies were only able to test the use of interviews and mock-ups to understand user contexts (experience and technique), but they did not reveal user needs and ideas. Ehn and Kyng's (1991) mock-ups not only revealed user experiences, but indicated future designs and systems. Taking this into account, I did a further series of pilot studies to test the use of mock-ups for users to express their needs and ideas. In this pilot, I tested three methods on scientific and medical background participants:

- Contextual inquiry (interview to understand user context)
- Lead user approach (detecting lead user characteristics)
- Mock-up (as a tool to reveal participants' experience, needs and ideas).

6.4.3 Pilot study C: Investigating methods of engaging users in design activity using mock-up as a design tool

In my main research, I collaborated with surgeons in designing surgical instruments to explore ways of engaging them actively in designing.

The surgeons had previously expressed their needs through verbal communication and sketches to show their ideas. They often used sketches to explain human anatomy in an academic and professional setting. Although sketching can be useful in co-design work, I decided to explore mock-ups as a more interactive tool. Ehn and Kyng (1991) used cardboard mock-ups to explore design requirements for novel IT systems for newspapers. By creating role play using mock-ups with experienced journalists, they were able to learn about the participants' practices and needs. Mitchell (1995) describes how mock-ups can be

used to help users in expressing their needs for housing and workspace. Mock-ups are dynamic because they are hands-on, easy to use, low-cost and fast to make or alter. In this study, I explore the process of making the mock-up (from rough material) with participants.

6.4.3a Study with designers

As previously, to avoid delays in medical ethics approval, I looked for opportunities to conduct research in a non-medical setting. Two participants from a background of crafts design were invited to participate in this study. These designers were chosen because they have similar characteristics to surgeons, such as:

- They do design work with delicate tools on precious materials – surgeons perform delicate work in surgical operations on the human body.
- They sometimes design their own tools in order to produce distinctive results – some surgeons invent their own instruments to get better results in operations.

They were interviewed in the researcher's office individually. A list of questions was put to the participants regarding their background and experiences in their work. They were given mock-up material such as modelling clay, cardboard, pipe cleaners and plastic straws. All of these materials were selected because they were easy to form and manage (Fig.6.09). The sessions were video-recorded for reference and the purposes of analysis.

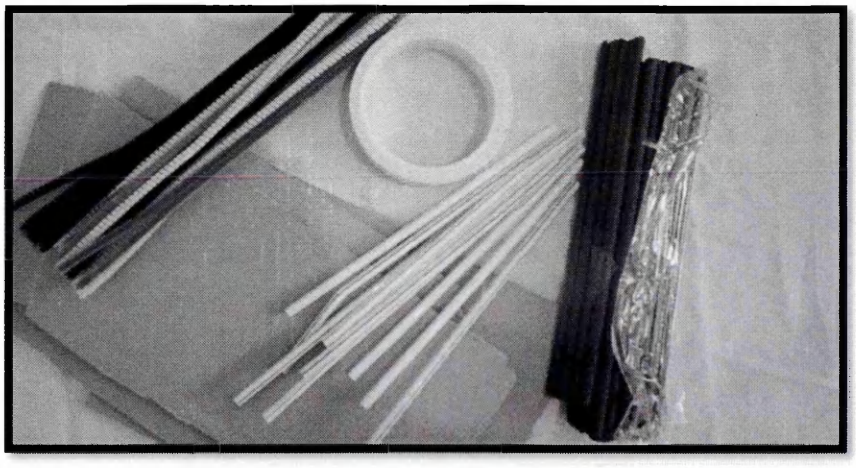


Figure 6.09*.Mock-up material for designing kit.*

Figure 6.10. *Participant A*

Participant A (Fig.6.10) had extensive experience in jewellery making, with nearly 10 years in silver smiting. In the interview, he was asked to use the mock-up material to rebuild self-made tools he had previously made (Fig.6.11). However, during the interview he did more sketches while explaining rather than using the material to mock-up his tools. Although sketching can be useful in co-design work, it does not provide an interactive environment.

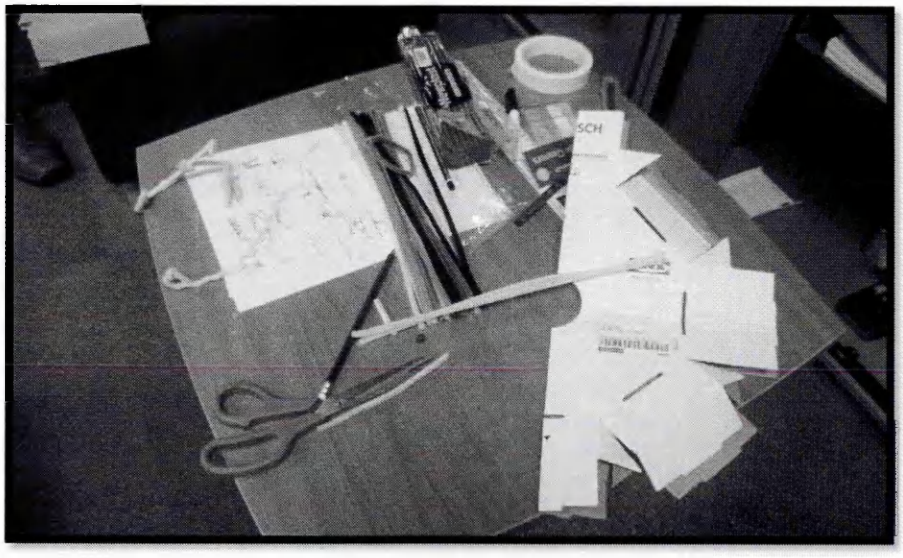


Figure 6.11. *The setup with participant A*

Figure 6.12.

Setup with participant B

Participant B (Fig.6.12) was involved in both graphic and 3D design. I asked her to use the mock-up materials to model design ideas that she was working on at that time. Participant B chose pipe cleaners and modelling clay to build mock-up of her designs (Fig.6.13).

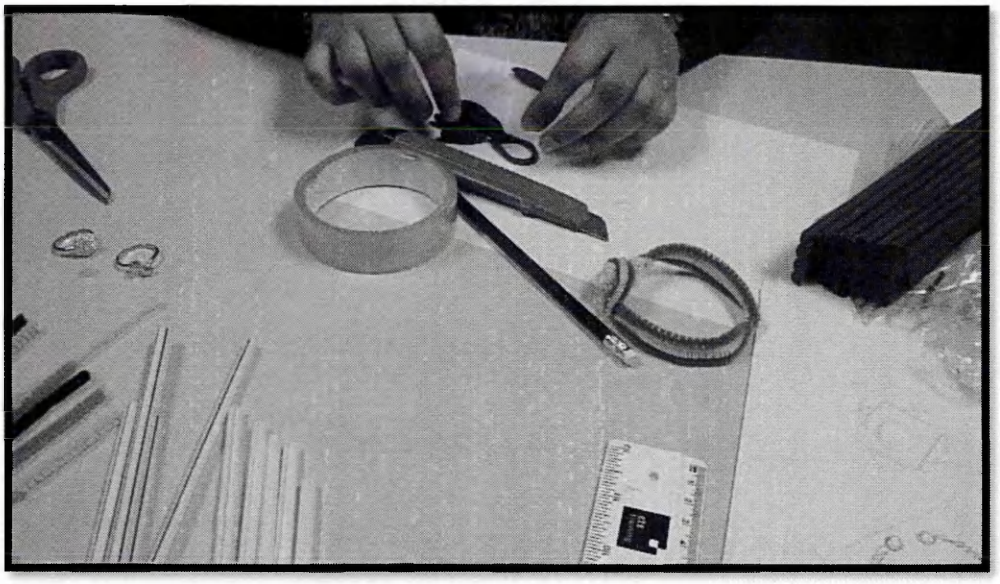


Figure 6.13.*Participant B building mock-ups using soft clay and wire.*

From the observations of participant A, I realised that he was more comfortable with sketching rather than building mock-ups. His background as a designer may explain his preferred approach. Furthermore, the tools that he mentioned are

perhaps better shown in sketches. I also believe that maybe because he realised he was having a conversation with a designer, a simple sketch may have seemed more useful in order to explain his idea.

Participant B showed that she was comfortable to use and 'play' with the kit to create mock-ups. She made the mock-ups of jewellery modelling them onto her hand to get the full scale of the product. She did rough sketches in the beginning (Fig 6.13) and continued making the mock-ups confidently using the modelling clay and pipe cleaners.

Mock-up kit designed for this study was successfully used by the participants. As expected, it offered flexibility for forming an objects proposed by the participants. However, I found that this particular study with designers was not very helpful for simulating any aspects of design collaboration. This maybe because designers are trained to be innovative and well versed to use the materials given. My intention in this research is to develop a co-design method which may be used between designer and expert user following the description of co-design by Sanders and Steppers (2008). So I looked for a participant who might be closer to the surgeons in their needs and expectations from the project.

From my contextual review (4.5.3) I noted that, Von Hippel (1976) suggested that the innovation of scientific instruments was dominated by the users of such instruments. I followed this principle by recruiting a participant who had conducted laboratory research in the biochemical domain, as explained below.

6.4.3b Study with a laboratory chemist

This study was my first attempt to set up a realistic co-design process with mock-ups and a participant who might be compared with the surgeons. It was also the first test of my methods using a detailed transcription of the video and review with the Nvivo software. Observation was undertaken both during the session and via the video recording afterwards.

This participant was invited because he worked regularly in a laboratory and had used a number of scientific instruments. He also comes from a background where his working and academic experience requires extensive lab work. Long experience in using tools is an important factor for this study, because this

experience could allow him to recognise difficulties with the design of instruments.

Developing the mock-up 'kit'

I used this particular pilot study partly to investigate what might be included in a useful mock-up kit. My earlier pilot study on building mock-ups shows that selected materials, e.g. pipe cleaners, modelling clays, straws and cardboard, may require participants to have design skills in order to manipulate them. Still, it does not restrict other participants from using them. Thus, I continued using them in this study.

I was influenced by seeing children creating toys by gathering a variety of scraps and putting them together as imaginary objects (Fig.6.14). This is not new as IDEO had deployed similar techniques using everyday things (4.4).

Figure 6.14*. My son and his friends made their toys from scraps and leftovers gathered from my residence backyard.*

I gathered a full box of unwanted everyday materials and scraps from around my residence, and some which were 'donated' by my friends, to be set up as a 'kit' for a mock-up session with my chemist participant (Fig.6.15). This was based on the Vaajakallio & Mattelmäki (2007) mock-up kit in conjunction with Dennis Boyle's 'magic box' (4.4).

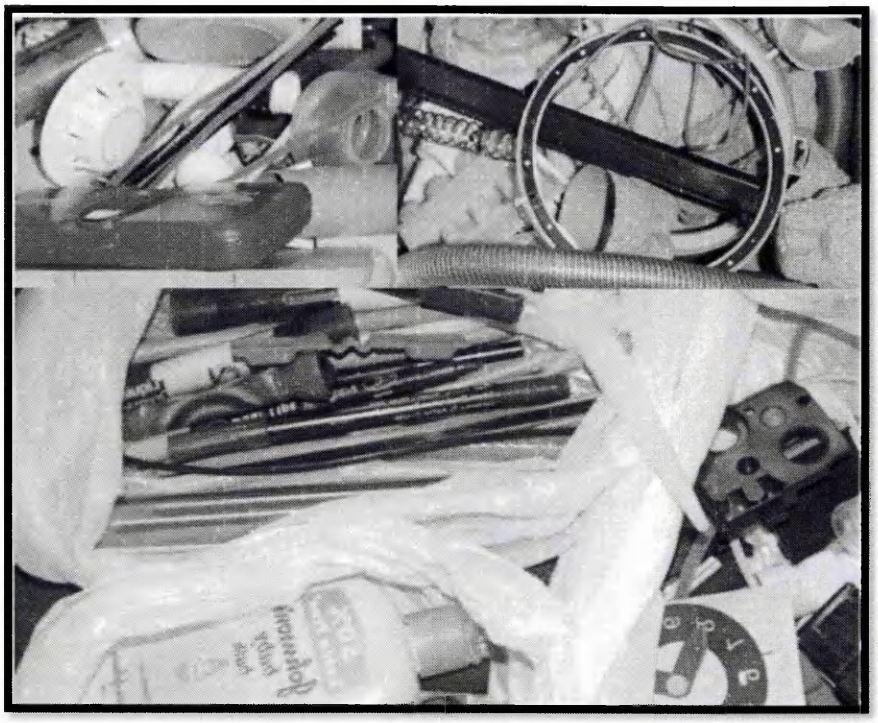


Figure 6.15*.Materials gathered to become a mock-up 'kit'*

Procedure

Sessions were taken at the researcher's private house and questions developed from Pilot study B were applied in this exercise, which included:

- Background and experience
- Current practice + instruments used
- Needs for improve equipment

The session lasted for 2 hours. The mock-up kit was supplied to the participants from the beginning and toward the end of the interview. Papers and pencils were also provided for the participants. Two digital camcorders were set, one at an overall angle to capture the whole process, and another was focused on the discussion area, where sketch and mock-up activities could be viewed in detail (Fig. 6.16).

Figure 6.16*.The view from two cameras*

User's need

I will explain the context of the user in this study before I explain further how and what the mock-up was used for by the participant in the session. The participant was undertaking research at the time which involved experiments in a laboratory. One particular instrument he needed to use was located in another laboratory. This particular instrument is a tool to make a transparent chemical mixture visible to the eye for result purposes. It has two florescent lights, which have different units of illumination (lux) to show different levels of mixture. Because the experiment is an iterative process, he told me that he needed this instrument with him so he doesn't have to travel from room to room just to use it. He suggested that the instrument needed to be mobile for this purposes

Observation on video recording technique

Video recording was taken in this study as a main source of the research data, an approach also used in the main project. Two videos were observed (Fig 6.16), but only one was chosen to be transcribed using computer-aided research software (Nvivo) (Fig. 6.17). The video was chosen simply because it had clearer audio for transcription purposes. From this video, it showed that the camcorder distance and angle were appropriate if the device was set near to the participants or their working area.

The chemist did not show any discomfort or change in behaviour because of this close proximity. Maybe this was because the camcorder was small and was not

noticed by the participant. Additionally its small size allowed me to move the camera around easily, for example, to bring it closer in to catch clearer images of the mock-up. This approach follows Wood's (2012) suggestion of how to use a camcorder to record participants' actions.

Exploring technique for analysing the video recording

As a researcher, I am searching for actions in the design process that show the interaction between participants and the tools they use, in this case mock-up. To do this, I transcribed the video using Nvivo. With this software, the transcription is synchronised with the video, so one can watch the participant's actions and the explanations at the same time. This is important because the participant's actions in using the mock-up kit can be observed while explaining the current practice, needs and ideas.

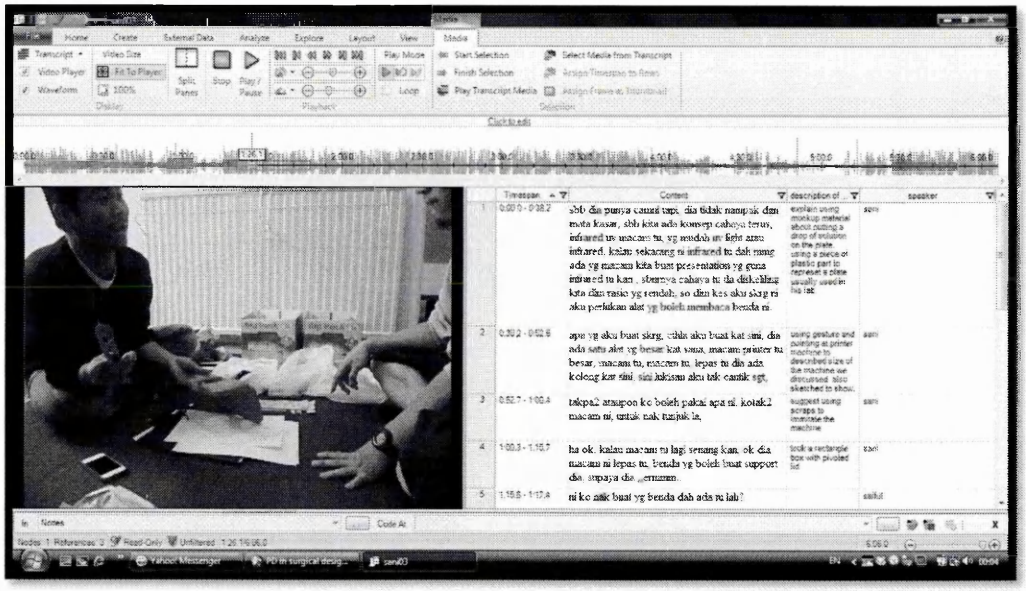
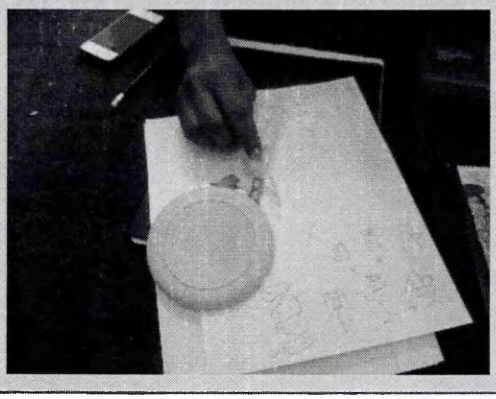


Figure 6.17. *Video transcribed using Nvivo software*

Significant actions from the video were selected during re-observation of the session (with the use of Nvivo). Below are the chosen actions:

Table 6.05.Significant participant actions

Descriptions	Images
Participant explained about his current practice and instruments involved using sketches.	(1) 
Then he used the 'kit' to explain instruments used in his work.	(2) 
Participant used general terms and analogy rather than jargon used in his domain to explain his work.	No clip applicable
Participant used mock-up to express needs. Participant shows and points at mock-up kit used and says 'like this' or 'like that'. He was not explaining in detail with words to show what he meant.	(3) 

He continuously used the mock-up kit to design the instrument.	(4) 
The designer (me) proposed use of other suitable material to do the mock-up. He also proposed use of material and some solution to encourage usability so it can be manufactured.	(5) 
Participants suggest technology to be used on new design.	No clip applicable

The use of mock-up by participants in the study

In this pilot study, the mock-up was used by the user to substitute for the real instruments he used in order to demonstrate current practice (row 2 from Table 6.05). This was shown before in my first pilot study with cleaners (6.4.1) where the mock-up was able to be used to share the user's experience of using a tool in the workplace. However, in that particular study, the mock-up was built before hand by me and it resembled of the current tool. While in this study, the mock-up was built by the participant by simply picking a material from the kit that he saw

suitable to simulate his current practice. For instance, the participant took a red plastic box and detached its cover to represent the current equipment he used in the lab (Table 6.05, row 2).

He also used mock-ups to express needs and ideas through the process (Table 6.05, row 3 and 4). He stated that he needs the instrument to be mobile while the current instrument is fixed in a particular room. This was shown by selecting some materials and putting them together without fixing them with any tape. Materials he chose indicated the form he wanted to have for the new design, such as the pink disk as a casing for the light. He also selected some materials to show the function of parts in the new design, such as a mini disk; this was selected because it had a reflective surface, which he used as a reflector for the light. Here, then, the participant suggested the basic technology to be used in the new design. Below in Figure 6.15 we see the materials used and the meanings the participant gave to them:

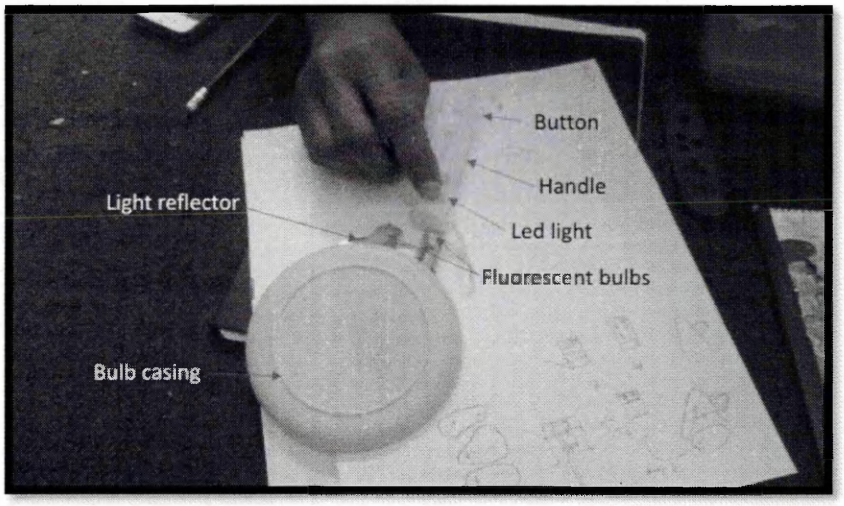


***Figure 6.18**. Mock-up built by participant.*

Designer's/ researcher's role in the study

As a participant observer (5.4), I played two roles in this study. On one hand, I was a designer who is taking a role in the simulation of co-designing. On the other hand, I was a researcher who was studying the use of mock-ups in the co-design process and other methods included in this pilot study, including the use of video recording for gathering research data.

Some of the mock-up material used by the participant at the start was not suitable for the form of the purposed design and its relation to its function, as envisaged by the participant. So, in this study, the designer used his design skill and knowledge in manufacturing to suggest and change the material used earlier by the participant, and then fixing them together using temporary sticky tape and blue tack. The designer also suggested materials to be used for the new design anticipating manufacturing possibilities.

Conclusion

A contextual interview equipped with a mock-up kit showed that such a this technique offered an opportunity to participants to used mock-up as a communication tool for sharing their experience of using equipment at th e workplace. This sharing was also expressed through sketches made during the process. Some of the uses of the sketches were for explaining concepts and work flow.

The mock-up kit was also used to express the participant's needs and ideas. The materials gathered were used by the participant to design new instruments by putting them together to give meaning to the mock-up. The participant looked for functional equivalents, for example a part which opens in a similar way to a real object he uses. A mini disk was used as a light reflector because of its reflective side. Then the pink disk was used as the casing because of its round shape, which could fit the mini disk.

He was not only motivated by his needs, but was also able to come up with an idea for a new design. This may also indicate that he had the characteristics of lead user (Von Hippel 1976,1986; Luthje and Herstatt 2004) as discussed in 4.5.3. This study suggests that a suitable mock-up kit can be used as a tool for co-creation between designer and expert or lead user.

As discussed above, two video recordings were taken but only one was used as data. From this event, it shows that it is always appropriate to have back up for recording data. In this case, it was simply safer having two video recorders in the set up. Through discussion with a research colleague it was suggested that video

data can also be supported with audio data as an audio recorder can capture better quality of sound. I explored this technique in the next pilot study.

6.4.3c Study with dental surgeons

Medical ethical questions were resolved in January 2012 which allowed me to use participants with a medical background for the pilot study, as discussed in 6.1. Three participants were interviewed together at their office in this pilot study. The participants were postgraduate students in the area of dental surgery.

The mock-up kit used in the previous pilot study with the chemist was used in this pilot because it provided valuable feedback response from the study with the chemist and it worked well. Interviews regarding their background and experience were audio-recorded, while the second part of the session was video-recorded where participants shared their experiences in using existing instruments, expressed needs and proposed ideas.

All participants had at least 5 years clinical practice in public hospitals in their country. They were in their final year when they were interviewed. Two of them had clinical experience in a typical dentistry job, while another one had more experience in advanced surgery. Even though they were in the same profession, they had different experiences which led them to have their own sub-specialty.

Procedure

Participants were questioned in a semi-structured group interview with questions developed from earlier studies (6.4.3b). Participants were asked about their background and experience before they were brought to the designing session. They were exposed to the mock-up kit from the beginning to the end of the session and they were told that they could use the mock-up kit during the interview session as a tool for explaining. Besides giving them the mock-up kit, they were also supplied with papers and pencil so that they could write and sketch. After they finished sharing their experiences, they were asked to express their needs and ideas by using the mock-up kit given. Mock-ups and sketches were made through the session to express the participants' needs and ideas.

User's context for the study

Every participant in this study had their own problems and needs. However, they also shared a number of them. Problems and needs arose from the same issues, which were never solved with the use of existing instruments. Most of the problems shared were about access, visibility and protection, illustrated as Fig.6.19.

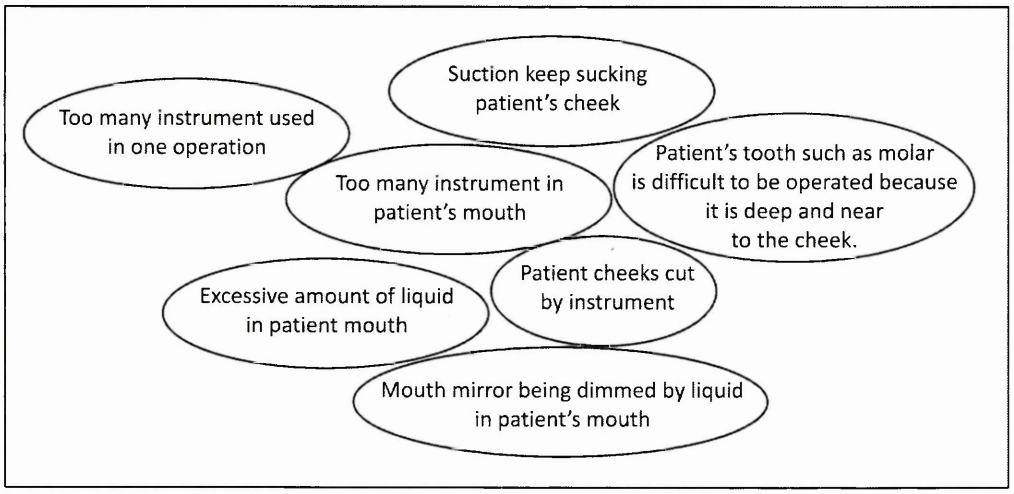


Figure 6.19. Problems and needs shared in the pilot study with dental surgeons.

Observation

Observation was undertaken through the interview and re-observation was done from the transcribed video in Nvivo. The interview setting is shown in Fig.6.20.

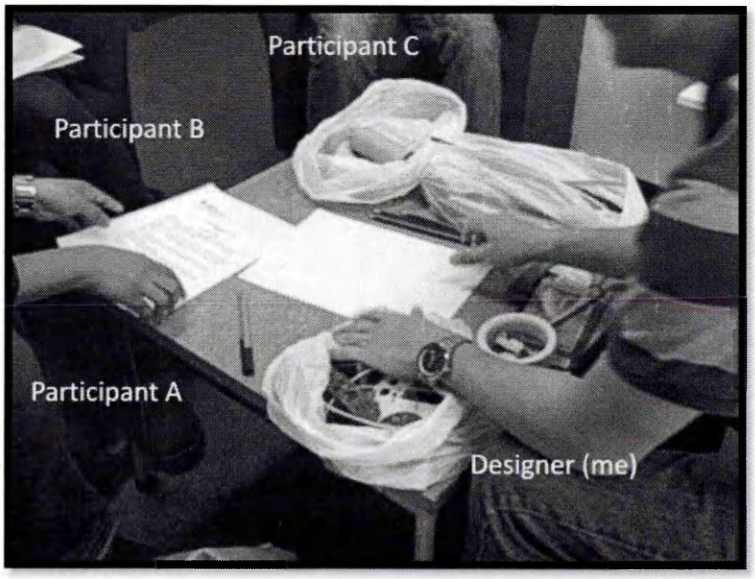
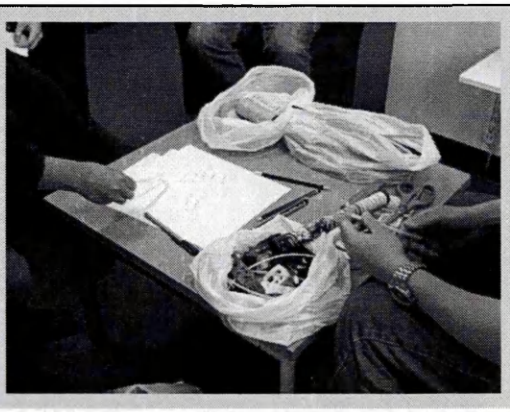


***Figure 6.20**. Interview setting with dental surgeons*

Participants were asked about their background and experience one after another. They communicated with each other by sharing their stories, and then shared their concerns and needs, subsequently expressing their ideas. The participants seemed surprised to learn of each other's professional experience, which they did not know before even though they shared the same office. Significant actions of participants extracted from observation through Nvivo are listed as Table 6.06.

Minutes	Descriptions	Images
4:59.0 – 5:52.9	Participant used mock-up kit to show existing instrument's shape.	
7:10.9 – 7:56.5	Designer offer selections of mock-up materials for participant to show the proposed size of new idea.	
9:51.7 – 10:25.2	Participants use material to show desired specification	

16:12.3 **19:23.0**	–	Designer requires from participant to explain steps of procedure. Participant 1 and 2 did diagrams of steps and sketches of existing instruments used in the procedure.	
27:32.7 **28:45.1**	–	**Participant 2 showed needs and idea with sketches.**	
28:45.1 **29:19.5**	–	Designer used mock-up kit to show existing dental instruments he knew.	
29:34.1 **30:22.2**	–	**Participant 2 showed existing instrument's features by using sketches.**	

33:04.5 **33:24.9**	–	Designer offered participants to use mock-up kit to build their idea. Participant 1 took one of the materials and commented about the suitability of mock-up material to be used.	
33:24.9 **34:22.9**	–	Participant 2 browsing for suitable material to be used.	
34:22.9 **35:13.9**	–	Participant 1 used mock-up to explain existing instrument. Participant B used mock-up to express idea. Designer used mock-up to ask participant whether the existing instrument feature is similar to the one he picked.	
37:31.4 **38:40.4**	–	Participant 2 demonstrated dental procedure voluntarily using the mock-up she built.	

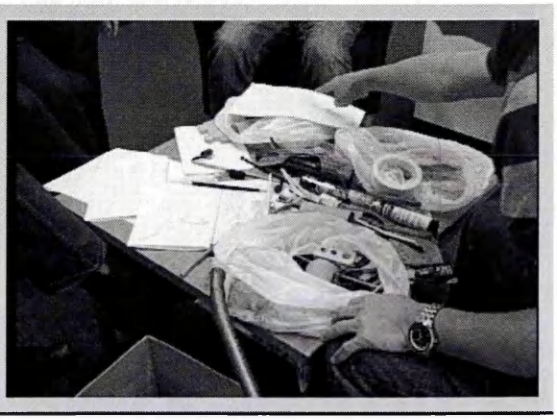
38:39.5 **41:56.3**	–	Participant 1 built mock-up to express her idea.	
52:16.9 **54:40.2**	–	Designer built mock-up of existing instrument for participants to show current practice and how to incorporate new idea with it.	
55:56.9 **58:40.0**	–	Participant 1 used mock-up to show current practice and new idea to be incorporated on the existing instrument	
1:01:55.4 **1:02:53.5**	–	Participant 3 proposed idea by using sketches.	

Table 6.06. *Observation table for dental surgeons*

Analysis

Sessions were planned in three sections. First, the participants shared their background and experience. Second, they shared their problems and needs. Lastly, they expressed their idea through the mock-up kit given. However, in practice, users went through this cycle several times as new factors emerged from reflection or questioning by the designer. This had a similar trajectory to that reported by Frey and Fontana (1991) on the advantages in undertaking a group interview. They suggested that group interviews may encourage elaboration of the issues discussed in a session. This is illustrated in Fig.6.21, which shows the iterative process of context, needs and ideas during this interview.

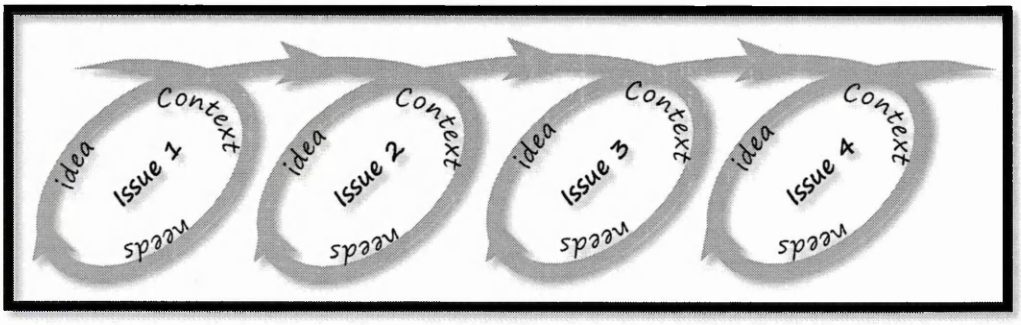


Figure 6.21*. Iterative process in the pilot study*

Participants used sketches and some of the mock-up kit to explain their experience in using their instruments (min 4:59.0-5:52.9 and min 16:12.3-19:23.0). Mock-ups were used willingly by participants to show the shape and features of the existing instruments.

At an early stage of proposing ideas[11], there were no mock-ups or sketches made. Ideas were proposed by me as the designer and the participants tended to discuss the limitation of these ideas and possible solutions. Participants discussed these concepts against the current situation based on their experience. For example, this can be seen in the following conversation:

Between min 38:39.5-41:56.3

[11]This happened iteratively because every single idea proposed was evaluated on the spot and discussed further for its suitability in the current situation.

Designer : I just imagine that the 'leaves-like-silicon' will be like 'bloomed' after it was placed in the patient's mouth.

Participant 2 : there is no point if it's 'bloomed[12]*'.*

Designer : it will not be bloomed or inflated like a balloon but more like an umbrella.

Participant 2 : umbrella? That might work. It may prevent the water from going to the patient's throat.

From the interview, a few solutions were suggested to address the participants' needs:

- Combined crowning tool
- Angled headed scalpel
- Suction with cheek retractor
- Cheek retractor
- Dental mirror with suction ability.

Participants used the material to build simple mock-ups as well as sketches to show their initial ideas. They were told that the mock-up kit can be used during the session. There were a few times when I used the mock-up to suggest an existing instrument and its features to persuade participants to use the mock-up kit; however, the mock-up was only built when instructed to do so. Participants used mock-ups when the idea could be shown by physical appearance. On the other hand, they showed the function of the new design with sketches and verbal communication. For example:

Ideas proposed	**Function highlighted**	**Expressed by using**

[12]A Malaysian expression used for expanding, like a balloon.

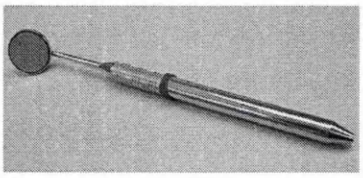
Filling instrument 	Double ended similar shape but different size.	Mock-up
Mouth mirror 	Suction ability around the mirror	Sketch

Figure 4.22. Ideas proposed by participants

Most of the conversation was dominated by participants 1 and 2. They came up with problems, needs and ideas based on their experiences. Participant 3 was passive, while participants 1 and 2 and myself were engaged. Participant 3 however, proposed an idea which was more convincing and was based on participants 1 and 2's needs. Participant 1 and 2 also agreed with the idea (min 1:01:55.4 – 1:02:53.5).

Solutions were proposed by participants and the designer through the interview and were discussed further to achieve a better solution. Every solution proposed by the designer was 'assessed' by the participants, putting the ideas in a scenario created by the participants so they could see the use of the proposal in the real situation. These were done by verbal discussion between participants, with some sketches made by them, for example:

> *Transcript 01.Between minutes 15:07.1 – 16:06.2*
>
> *Designer : If we expand the cheek can we get a good access to the back teeth or will it not?*
>
> *Participant 2 : It is difficult if it expanded, the cheek needs to be relaxed in order for the dentist to easily insert their instruments. You can't open the mouth too wide because it will tighten the cheek.*

Participant 3 : The muscle around there needs to be relaxed and then we can use the mouth mirror to retract it for procedure. That's why I told you if we can get suction equipment with a retraction, which is good, right?

There were several ideas proposed for a single, or two problems at a time. A solution raised was evolved each time the context became clearer. Some solutions proposed by participants were discussed and revised and the designer came up with another solution. In the above transcript (Transcript 01), for example, participant 3 proposed a 2 in 1 instrument in the first place. But, through the session, the designer developed more understanding of the user context and made him propose an idea which was accepted by the participants, as below:

Transcript 02.Between minutes 55:56.9 – 59:32.6

Designer	*: this is the below teeth so you just imagine that there is something pop-up after you inserted it here. It is like a silicon.*
Participant 1	*: Ermm... do you know Ultragate, it does have this we got things like but it's limited for front teeth.*
Participant 2	*: Oh! I know that white thing right?*
Designer	*: I think it can work like you said. We could use the mouth anatomy of the mouth for this design. I think we can use this bone to hold the silicon cup and expand the cheek.*
Participant 2	*: How to support it?*
Designer	*: It is self support.*
Participant 2	*: But there is no bone back there to be the holder.*
Participant 1	*: it will retain itself at the sulcus.*
Participant 2	*: But it something 'pop' to make it retain on that.*
Participant 1	*: So, if we can use this sort of cheek retractor, we don't need an additional retractor on the suction equipment, am I right?*
Designer	*: Yes, exactly.*

I simplified the above issue as a brief note below to make it clearer.

Context	: participants had problems on accessing teeth at deeper area. Not only that but the small tolerance between cheek and the teeth also made them hard to access. Water dispensed from mechanical dental device, or they called it dental hand piece, plus patient's saliva, put more obstacles for the deeper teeth to be operated on.

Needs : access to deeper teeth, cheek needs to be retracted further from teeth and remove water and saliva.

Current solution: Cheek being retracted using mouth mirror. Water and saliva was being removed using dental suction.

Ideas :

Dental suction c/w retractor		Cheek retractor
Idea proposed by participant and supported by designer. The main idea is to add a cheek retractor to existing dental suction.	Idea discussed through interview	Idea proposed by designer and supported by participants. A silicon cup to be positioned between patient's cheek and gum.

The actions shown by the dental surgeons indicate that the mock-up kit is practical and can be used for the fieldwork with colorectal surgeons (Table 6.06, min 9:51.7, 33:24.9, 34:22.9, 37:31.4, and 38:39.5). However, this study also indicated that I as the designer need to find a way to persuade the participants to use the mock-up kit (Table 6.06, min 7:10.9, 29:34.1, and 33:04.5). Participants, however, were comfortable to talk about their idea in the presence of the mock-up and did not hesitate to build it if requested by the designer.

In this study, I interviewed three participants in the same session. It can be seen that the exchange of opinions about their needs developed their ideas and these were concurrently explored through making of the mock-ups. The proposition development through response (Transcript 02) showed that it may be beneficial to have multiple participants in a single session. This is in contrast to my main project, where my projects were carried out on a one-to-one basis.

6.5 Conclusion from the pilot studies

The purpose of the pilot studies was to explore the research issues and methods identified as relevant in my review (chapter 4). I used the practical work of the pilot studies to gain a better understanding of participatory design methods suitable for design collaboration with surgeons as well as social research methods which would support this investigation. They were:

1. Semi structured interview with open questions
2. Video recording as research data
3. Video observation and analysis (transcriptions)
4. Participant observation in design process
5. Detecting lead-user-ness among expert user

Two methods from participatory design were explored in the pilot studies and they were,

1. Contextual inquiry (as discussed in 4.2)
2. Mock-up (as discussed in 4.3 and 4.4)

I used the practical work of the five pilot studies to gain better understandings of:

1. Investigating how to understand a user's way of working using a tool (cleaners)
2. Investigation of how to detect lead-user-ness amongst expert users (musicians)
3. Investigating the use of a mock-up as a tool for collaboration (designers, laboratory chemist and dental surgeons)

These methods were investigated in the first three pilot studies with a variety of participants (cleaners, musicians and design students) chosen as having relevant characteristics in their work but without the organisational problems of working with clinical experts. Observation from these three studies raised some issues which led to the refinement of the methods investigated. They also led me to plan for the next issues to be explored in the fourth pilot study (Chemists).

The pilot studies helped me to develop, modify and refine interview questions which then I used in my main study (8.1.1). Semi structured interviews with open ended questions helped me to identify issues which could be explored more deeply in later pilot studies. For instance, in Pilot Study B, as I interviewed musicians regarding them and their instruments, I recognised that there was an issue in choosing an instrument which suits their own style of playing and choice of music, which was not an issue in Pilot Study A since the cleaners were given a specific polishing machine by their employer. The musician's descriptions of how

and why they choose instruments were particularly valuable in helping me to understand their context so I used similar questions as part of my 'contextual immersion' with surgeons in the main study (8.1.1)

The use of a video recorder was also refined through the pilot studies. Issues such as numbers of camcorder used and positioning the camcorders arose in this process. For example, only one camcorder was used in the beginning of the pilot studies (6.4.1 and 6.4.2) and this provide only one angle of recording of the overall view of all musicians and me but was not able to see the individual's expressions when talking.

The quality of the audio also became an issue when using one camcorder which was unable to record sound sufficiently well to be able to get a full transcription when the camera was a distance. This then led me to use two camcorders in the next pilot studies and main project.

Wood (2012) suggested that using a small and compact camcorder, which nowadays most are makes it easy for moving it around (5.5). As an observer, she needed this advantage as she kept changing her position to get a clear recording of her subjects. But this did not happen in my pilot studies because I captured the participants, myself and the activity as my research subject.

The pilot studies also allowed me to explore the method to analysing the video recording. The technique of transcribing the video was refined through:

- Capturing images from the video and word processing in a table.

- Transcribing the audio beside the on-going video via Nvivo

I started to use Nvivo for the last two pilot studies. I found that using Nvivo allowed my work of transcribing to become more efficient and enabled me to add a column of new issues on the spot. For instance, at the beginning, I just followed the standard column structure that Nvivo has in its system, which was also similar to that which I had for my earlier manual transcription. However, I added more issues in the table through the process of transcribing the video because those issues detailed the participant's interaction in the video.

The pilot studies also allowed me to practice myself as a participant observer. On the one hand, I was the researcher observing the design process. On the other hand, I was the designer who involved in the design process. The challenge I faced was to keep these tasks distinct from each other and this was also a big challenge through the process of conducting the research and writing this thesis. As Dewalt and Dewalt (2002) described:

> *'The beginning researcher is urged to practice at every opportunity the specific skills that are important in participant observation. Those skills include both learning to be an observer and learning to be a participant' (ibid pp20)*

Being the participant (a designer) was an advantage for me as I am an experienced designer. However, some aspects of design practice in this research, participatory design, especially contextual immersion, are quite new to me. On the other hand, acting as an observer (a researcher), observing the interaction in the design process is new to me. Learning from this process in pilot studies, I practiced them in the main study when I played the role of designer. I continue to take care of the observation process by managing the session to stay on track for the research e.g. reminding participants to use particular tools or methods and prompt the participants to verbalise their design thinking.

Two design methods from participatory design were investigated in the pilot studies. First, it was contextual immersion which I followed through the contextual inquiry principle of learning the user's context by apprenticeship. I tried interviewing cleaners at their workplace and asked them to demonstrate their way of work at the beginning of the research[13] (6.4.1). This is not very suitable as it was restricted to the participants limited working periods. So I arranged further similar sessions for the pilot study at a private residence as this was more convenient for the participants and myself. Nevertheless, I came back to use the principle of 'learning the user's context by apprenticeship' in the main project with Mr Brown (8.2.1).

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[13]Briefly, Holzblat and Jones 1992 suggested that apprenticeship can be initiated by interviewing users in their work place and while they performing their job tasks.

As discussed earlier in this section, contextual questions (which were used in the interview) were developed through a series of pilot studies and tested and reviewed in the main project. These questions served the purpose for the research in the contextual review of the surgeon's working culture. Another purpose I assigned to the contextual questions was to try to understand the challenge of surgical tool innovation from the viewpoint of surgeons and the surgical tool manufacturers. This highlighted the need for the development of a collaboration method.

These contextual questions also functioned as part of contextual immersion. They were used to understand the context of the issues reviewed e.g. the use of lab instruments by chemists. However, when I investigated the second method, mock-up, together with a contextual interview (for contextual immersion), it seemed that users made available their working experience with tools through role play with the mock-up, as suggested by Ehn & Kyng (6.4.1, 6.4.3b and 6.4.3c).

This is not a new discovery by me because, as discussed in 2.5.1, Holzblatt and Jones suggested that mock-ups can be used to strengthen contextual inquiry in a contextual design method (Holzblatt and Knox 1990). The mock-ups I used in the pilot studies also confirmed the findings of Ehn and Kyng (1991); Long and Hughes (2011); Vaajakallio and Mattelmäki (2007) about mock-up - that they can be used as a co designing tool (4.4).

I continued to use this in the main projects with the surgeons and found interesting issues which I discuss later in Chapter 8.

Chapter 7: Planning the major study

In this chapter, I will first explain the research plan which I undertook in the co-design projects. Then I will explain my preparations for the collaboration projects with surgeons. This includes developing working relationships with surgeons, choosing the design projects, and resolving ethical and safety issues.

7.1 The Research Plan

I have made my contextual review about research methods as well as design methods which then I explored in my pilot studies to form an approach for the main study.

In this co design project, I took position as participant observer. I was a designer in the collaboration, with tasks such as observing the surgeons to understand their way of work. As a designer I will used my design knowledge and skill to solve the design problems raised by the surgeons. On the other hand, I took care of the research process during the design activities.

Then, I observed the data collection from the co design activities which in a form of video recordings distinct from the design process. This was where I fully acted as an observer (the researcher), observing and analysing the research data using Nvivo. I also gathered a group of relevant experts to review data from the video

evidence of the co design activity. This was to enrich the data collection and my analysis of the video. Findings of the research are discussed in Chapter 9.

7.2 Setting up the Co-Design Projects

The research data was gathered through two co-design projects:

7.2.1 Collaboration with Mr Steven Brown, NGH, Sheffield. (Clamp project)

As reported above (1.1), I had the opportunity of working with a surgeon during my previous project, which led to evaluation work with Mr Brown who then invited me to collaborate with him to design an instrument which will be used in colorectal anastomosis surgery[14]. Our first meeting was to introduce each other's specialty and to hear the surgeon's concerns. It was also to discuss initial issues regarding ethical clearance and official arrangements.

Mr Brown has more than 20 years' experience in surgery generally and 10 years' experience in colorectal surgery. He also had training outside UK. He had his colorectal training in South East Asia region. He explained that he became used to the customs and language while he trained there. This gave me the confidence that both of us would have a good rapport in this collaboration.

He explained that he was having a problem in using existing rectal clamps during anastomosis surgery. He showed me pictures of related surgery and anatomy from his collection of medical textbooks and let me take the books home to study. This activity of referring to medical textbooks became part of my researcher's contextual review and designer's contextual immersion.

Arranging meetings with the surgeon was a good experience because the surgeon only had limited time. Meetings were arranged for only 30 minutes each which trained me to be focused in my conversation with the surgeon.

We explored ethical issues and official arrangements needed in the NHS including ethical approval. In this initial stage, we agreed that I would need to

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[14]Colorectal Anastomosis – surgical union of parts especially hollow tubular part eg colon . source – www.meriamwebster.com.

observe surgery in action to understand the context. However, we found out that this would require ethical clearance which would be time consuming and delay the early stage of the inquiry. So we decided to use medical models, demonstration aids used for training, for the observation.

However, there was no suitable medical model that could be used for the surgeon to demonstrate the particular surgery. So we took this as an opportunity to construct our own medical model which gave us the advantage of tailoring it for our purpose (8.2.2). Mr Brown saw the development of such a model as being more useful for surgeons than the surgical instrument he had proposed and we agreed to change the aim of the design project towards developing a medical model for Colorectal Anastomosis. As this proceeded, it became clear that this activity was also very helpful for our shared understanding of the context and also for design considerations.

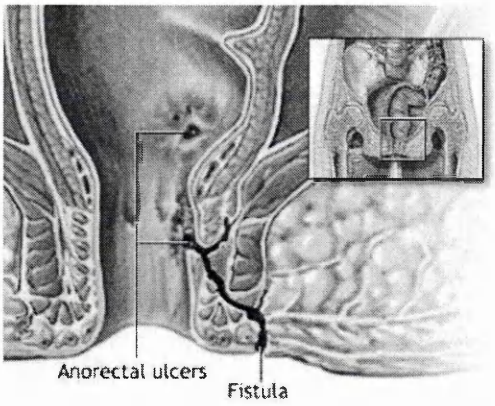
7.2.2 Collaboration with Mr Keith Chapple, NGH, Sheffield. (Fistula project)

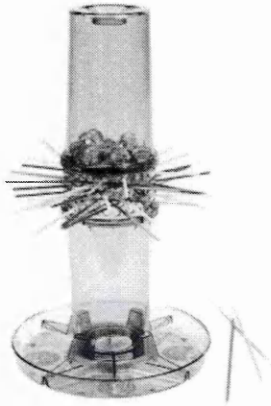
My MA project led me to be introduced to another consultant colorectal surgeon, Mr Keith Chapple at Northern General Hospital. Early communication with Mr Chappel was online then a first meeting was undertaken to discuss his needs for about the project. The second meeting was for contextual inquiry via interview.

Mr Chapple's design idea did not involve patients directly. The context of his needs was difficulties in understanding the MRI report sent by radiologists for the complicated cases of fistula-in-ano[15] (Fig.5.01). MRI scans produced collections of pictures from three angles, top, front and side which are later transferred into a report for the surgeon to carry out treatments. A simple path of a fistula may not be a problem for the surgeon to understand but reports of complicated ones require the surgeon to have long meetings with the radiologist in order to arrive at a clear understanding. The surgeon explained to me that previous attempts have been made to help surgeons to visualize reported fistula-in-ano, for example by digital 3D images. However, the surgeon expressed the view that a hands-on

[15]Fistula-in-ano is an abnormal communication between the anus and the perianal skin.
Source - http://fitsweb.uchc.edu/student/selectives/Luzietti/Painful_anus_fistula_in_ano.htm

three dimensional artefact may be the answer to their problems. He got the idea while he played Kerplunk (Fig.5.02) with his little daughter where he imagined the same principle can to be used to visualize the fistula tracks.





(Right) ***Figure 5.01****. Image of fistula-in-ano.*

(Left) ***Figure 5.02****. Kerplunk™ game.*

The surgeon had an idea but needed somebody to help him to make it a reality. Knowing me gave him the opportunity to design it together with designer. The surgeon expressed his needs verbally and through sketches in the meetings. Paper mock-ups were used in the co-design session with Mr Chapple. Using mock-ups as a design tool gave the surgeon opportunities to modify his idea (8.3).

7.2.3 Ethical and safety issues

National Health Service (NHS) has a rigorous ethical approval process. As the practical work of the research is seen by the NHS as product development, this did not require such approval[16]. However, the programme of work was designed to ensure that no ethical problem would arise.

The first idea to understand the user context was to have direct observation during real surgery which was agreed with the surgeon (Mr Brown). We modified this method from observing surgery on real patients to observation of simulated

[16]Issue of getting the ethical approval was resolved through communication with National Research Ethic Servis (NRES) who is part of the NHS in January 2012. Two departments from the NRES were contacted in order to get advice for the status of the research which are Health Research Authority and local Clinical Research Office. Both of them agreed that the proposal sent to them do not meet the criteria as a research in the way that the term is used in NHS research governance. For this, there is no ethical approval need from the NHS for my research.

surgery using a medical model. Using mock-ups for the medical model and observing it in a simulated scenario gave the surgeon the opportunity to demonstrate, reflect and alter his actions and tools used at the same time.

The observation was undertaken in the emergency room simulation unit at Sheffield Hallam University which has a similar basic setting to an operating theatre and was suitable for performing the simulation. The arrangement for the use of this simulation unit required a risk assessment (Appx. 3) to be made and gave the opportunity to refine the methods used before the simulation was undertaken. The first refinement was to change the type of camcorders used and repositioning their setting in the simulation unit according to the safety measure. Second, no NHS equipment was used because we decided to use the surgical instruments available in the university simulation unit. The instruments were not the same as the surgeon used for the particular surgery; however it did not prevent the surgeon from manipulating them in the simulation.

7.3 Contribution from the preparatory works

My collaboration in the Clamp project developed through planning meetings during two years before the main activity of the project started. This developed a rapport for both of us as a team in the project. The long period of preliminary work with Mr Brown gave the chance for understanding the nature of the work of the surgeon, especially his professional tasks and the time allowed for them. My time with him was limited which trained me to be focused in our meetings. In these meetings, Mr Brown was able to give me a comprehensive understanding of his problems and needs (to be described below in 8.2.2).

Designing a surgical simulator opened the opportunity for the model to become a product (to be described below in 8.2.2c). The primary purpose of building the surgical simulator was because to make it as a substitution for a real patient in a surgery observation. At the meeting where we completed the medical model for the observation purpose, the surgeon saw the prospect of the model to be used in surgical training and the financial benefit from getting the product to the market.

Communication for the groundwork was shorter in the Fistula project. Experience learned from the clamp made me more ready for the work with Mr Chapple. So,

only two meetings were arranged with the surgeon. My recent MA project gave me the advantage of familiarity with the context of the disorder – fistula-in-ano. The project was not about surgery nor required patient involvement and co-design work was done in a non-surgery setting through collaboration with Mr Brown. The setting was similar to my pilot studies with chemist (6.4.3b) and dental surgeons (6.4.3c).

Dealing with the ethical and safety questions had a major impact on my research. They changed the way I planned things as well as providing a good training for managing research within the medical domain. As a designer from outside the NHS, I had to pay attention to these ethical approval issues which are different from my industrial experience.

Practical work undertaken with the two surgeons was conducted after the preparation work was completed and the design of 'participatory labs' was carried out. Further discussion of the practical work is presented in the next chapter.

Chapter 8: Practical works

In this chapter, I report on the progress of the design activities as the means for the research, the observations I made, the data obtained and the initial analysis of the data.

8.1 Interviews with the surgeons and manufacturers

Interviews were undertaken with collaborating surgeons and three surgical tools manufacturers based in Sheffield, United Kingdom. These interviews were part of contextual immersion in the user's domain. Another part of contextual immersion happened during the activities that included the construction of the mock-ups. Below is the review of all the interviews undertaken.

8.1.1 Interviews with the surgeons

Interviews with surgeons were undertaken to identify their background, experience, needs and ideas. The intention was also to understand the current practice of how surgical instruments were chosen and used in hospitals. The surgeons' explanations were recorded with a digital voice recorder. The questionnaire addressed ten broad issues described below with examples of surgeons' comments and my discussion.

A. Choice of instruments

Mr Brown

> *"A lot of the instruments are pretty standard and have been around for hundreds years, ... tend to use what we've got on the shelves, occasionally you going to pick up from other hospitals, colleagues or even in annual meeting where tools manufacturer come in and just bolt in there, ... For the majority of time we used the instrument that is here". Minutes 2:53.5*

Mr Chapple

> *"in terms of surgical instruments, basic surgical instrument, which is hospital supplied, and they are pretty basic throughout any hospital and then you have more specialised instruments. There are conflict in working process between the hospital, because they will pay, on what we want, a surgeon and we normally come to an agreement. ...hmm, very difficult, you know we have to get to charity, it's a charitable trust and to try to get it..." Minutes 4:10.4*

Surgical tools used by both surgeons were normally picked up from the standard hospital list. There are times when manufacturers come to the hospitals and introduce innovative surgical tools and surgeons may request them from the hospital. A choice of available and newly designed tools can be collectively considered among the surgeons in the same domain. Some surgical tools can also be requested due to the special needs of a certain procedure. However, surgeons may get less preferable choices of surgical tools due to a hospital's managerial arrangements and financial capacity. The surgeons understood and respected these constraints, e.g. limited funding from charities.

B. Change of tools

Mr Brown

> *"Not really, I had changed a few instruments, I had requested too few instruments but most of the time we used what's on the shelves". Minutes 3:47.3*

Mr Chapple

> *"no, they are remarkable resilient instrument, to be honest, anytime we really change the instrument is not like get out dated, some do but by large of anytime they broke and beyond repair and go for a repair, most of them go for repair and more increasing now is disposable instrument". Minutes 6:21.3*

Changing instruments was not a big issue for the surgeons because the current 'on-shelves' surgical tools were good enough to do their job. They had changed the choice of materials, in the case of the surgical tools, where most of the latest ones were made for single use that is disposable.

C. Design development in surgical tools

Mr Brown

> *"that's very good, I must say they are traditional instruments that have been around for years since 1920s and 30s, they tend to work very well in the operation, they do, ...hmm there has been a lot of support from big companies such as Johnson and Johnson in terms of developing laparoscopic instrument, and they are really into that" Minutes 4:06.7*

Mr Chapple

> *"... the new kits that come around are very subtle improvement of what's already there, and how we involved in the design... we wouldn't get in the design, we will feed back on the instrument manufacturer... if they want enough comment about that they look at subtle improvements, but all the kit that's come out is a lot of new kits came out, there are only a subtle improvement" Minutes 7:53.1*

Surgeons agreed on the history of the tools they used; they also know the latest developments in surgical tools on the market, e.g. types of tools and manufacturers. Mr Chapple commented that most of surgical tools he confronted were only subtle improvements from the existing ones. New surgical procedures lead to more innovative designs of surgical instruments (Kirkup 2006). Mr Brown, on the other hand, remarked that manufacturers such as Johnson and Johnson developed the laparoscopic instrument, which he preferred as the latest innovative procedure and tool on the market.

D. Consciousness about the needs of new surgical tools

Mr Brown

> *"There's always an instrument needs a redesign, tools and instrument progress you don't appreciate the improvement until you got them, so there always, I think what missing is a surgeon who knows what's going on in the operation ... very difficult for me to explain exactly what I need, that body or model is just superb actually, in term of getting the perfect model then people can work out what the requirements are." Minutes 6:32.9*

Mr Chapple

> *"instrument is always being improved, ...what we have to do laparoscopic or keyhole is putting the stapler down there to divide the bowel and that's quite difficult, so the instrument manufacturers are always trying to improve that, but it is still not right, that probably in my specialty that probably the biggest or the barrier of intention of improvement. Other than that, there isn't much really, you learn how to do operations with the kit you got, and what you can do is, it's usual piece of cake. Come along that make a huge different to have the all customised in it." Minutes 10:28.5*

The surgeons agreed that new tools can be developed from those that surgeons currently use in surgery. Mr Brown said that involvement from surgeons in developing such surgical tools would be significant. Mr Chapple described the biggest design challenge for him was to get the new tools to do their job just right, giving an example of the laparoscopic instrument. He added that surgeons may have the ability to learn quickly to use newly designed surgical tools. Mr Brown expressed the view that surgeons may not know what they want and, by working together, the surgeons may identify their problems and needs. He believed that the surgical simulator represented by the mock-up might be developed more as a product, so it can be used to help surgeons see their needs from using the model.

E. Surgical tools made or designed by non-clinical background designer/stakeholder

Mr Brown

> *"I think it has to be engineers that's who involved because engineers know what the answers are, trouble is do they know what the questions are? The surgeon needs to apply for the questions and the engineers needs to come up with the answers and maybe other people as well, I think. Who else needs to be involved? Just somebody with the knowledge of what is available in term of material and expert." Minutes 7:18.4*

Mr Chapple

> *"... , I guess the instrument manufacturers at the end of the day are there to make money, they are not there for the patient's benefit, they are profit-making company so their interests are to promote instrument has been better lots of equipment. I get bored when I got it and in practical term there is no difference. Then they sell and said that it got better handle etc.. In term of my ways of operation it makes no difference what so ever, but they pushing it as a new thing that a last or better". Minutes 11:57.3*

The surgeons believed that the surgical tools they have now are designed by engineers /designers because they know how to solve design problems. However, they pointed out that surgeons experienced the problem and questioned whether surgeons' needs were always understood by designers. As most current instruments worked well enough in operations, surgeons concentrated more on the delicacy of their surgical procedure (how they do their work) and have less involvement in developing surgical instruments.

The surgeons were concerned that manufacturers might concentrate on financial returns before the benefit of the patient. The surgeons believed that the important thing in a surgical tool is that it can do the job according to the surgeons' requirements. The surgeons know that it is important for them to be involved in surgical tool design development; however, they did not believe that they are also capable of coming up with the solution (they believed solutions are provided by the designer or engineer).

F. Challenges in designing surgical tools

Mr Brown

> *"There is nothing they can't do(laugh), that the barrier, the surgeon knows the questions and the answers that the engineers can put together" Minutes 7:55.6*

Mr Chapple

> *"The biggest barrier is time, from my point of view is time, and I have no spare time, money to be spend on it, ...it is worth spending all that time and effort for a bit of kit that and the end of the day I don't really need? More better earning a bit of money in private sectors so I can hand it to my family, but you know the sort of the conflict you have." Minutes 14:59.6*

Mr Brown believed that the challenge is to have multi-disciplinary expertise together as a team in developing surgical tools. Mr Chapple believed that time and financial resources are the main challenges when developing surgical tools, which may end up as tools that did not provide any more significant functions than the existing one. Surgeons may gain financial benefit when working with manufacturers in developing surgical tools, however Mr Chapple points out that this may not be his motivation.

G. Consciousness about surgeon-innovator and their contribution in the design process

Mr Brown

> *"my predecessor Andrew Shorthouse helped Bolton to develop an instrument that he required for his operation and he did a fantastic job actually, the trouble is, one surgeon and its seem that surgeon enquires for that but nobody else like to use that instrument" Minutes 8:16.4*

Mr Chapple

> *"do I know any surgeon, you told me about Steve Brown, I don't know, do I know any other surgeon involved, hmm... no I don't, what can we provide, I think we are essential, we provide you the knowledge, in terms of we can't help with the mechanics of the things but what I can tell people is it's need to do this and don't care about that, ... so only get that from discussion with the surgeon, that our key role I think." Minutes 16:34.4*

Mr Brown was aware of his colleague's involvement in the development of a particular surgical tool and realised that other surgeons prefer not to use the product. He thinks that this may be caused by focusing only on a single surgeon's opinion. He may think that more than one surgeon's involvement in a design project might help to generalise the surgical tool's design. Mr Chapple did not know any surgeon-innovator, even though he has the same innovator colleague as Mr Brown. Mr Chapple believed that surgeons have an important role in surgical tools development because of the knowledge they have.

8.1.2 Interviews with manufacturers

All of these manufacturers have experience in developing and manufacturing surgical tools in their respective markets. The personnel interviewed were also experienced designers and engineers in designing and constructing surgical tools, where all of them had spent at least 10 years in the same field. Information about the stakeholders is shown in the tables below.

8.1.3 Information about the manufacturers interviewed.

Name of Company	**Sheffield Precision Medical Ltd. (SPM) – Design engineer**
Website	http://www.sheffieldpm.co.uk/
Products	Joint prosthesis and precision surgery tools for fixing the prosthesis.
How marketed	Design and manufacturing surgical tools to suit large brand name companies supplying hospitals.
Expertise	Precision engineering in manufacturing metal-based material using CAD CAM technology.
Development process	The SPM design and manufacturing team work together with larger brand name companies as a sub-contractor. They observe directly surgeons performing real operations using existing tools and note the problems. They are also supplied with a video recording of the surgery as a design reference. They then redesign the existing tools with advice from the development team (from the main contractor).
Role of medical experts	Surgeons demonstrate the problems through performing surgical procedures and later explain the problems they face.
Advantages	Knowledgeable about the abilities within their manufacturing processes and the limitations. Focused on a

	specific surgery domain (expert).
Disadvantages	Does not have the right to develop own designs (as they are not licensed for it). Thus, the developed surgical tools and prosthesis IPs go to the main contractors.

Name of Company	**SheffMED ltd (SheffMED) – Managing director / Founder / Designer**
Website	http://www.sheffmed.com
Products	Surgical instruments for ENT, Gynaecology and breast surgery. They also develop surgical headgear for holding light sources and surgical cameras.
How marketed	They develop products with surgeons and market them under their own name.
Expertise	Development for new products based on the needs of surgeons. Twenty years in the surgical instruments market has enabled them to recognise that the needs of surgeons cannot be satisfied only by established products.
Development process	The managing director develops a close working relationship with a surgeon, who then becomes an evaluator and his source of ideas. Designs are normally developed by the managing director with the help of a prototyping company. However, he has also hired an external designer to help him develop his ideas into realistic designs and to get them prototyped. They normally evaluate the design and the market by exposing these ideas and obtain feedback from experts in national and international exhibitions.
Role of medical	Surgeons express their needs through discussions and

experts	feedback on prototype designs.
Advantages	Close working relationship with surgeons enables the company to get the user's issues first hand. This is a company that has the courage to explore possibilities in producing new products for the surgical tools market.
Disadvantages	Does not possess an in-house designer which may make the target of developing new surgical tools take longer to achieve as one man has to do multiple tasks on a daily basis, e.g. sales, managing, designing etc.

Name ofCompany	**Single Use Surgical Ltd (SUS) – Founder, managing director, design engineer**
Website	http://susl.co.uk
Products	Disposable surgical instruments in ENT, neurology, suction pumps, surgical drills.
How marketed	They develop products under their name and subcontract to established brand names. They use their own salespeople to expose their products to the market.
Expertise	The founder had years of experience in mechanical engineering and developing surgical tools under MEDILINK before he set up SUS. The company specialises in developing disposable surgical tools that are used in relationship with the issue of sterilisation.
Development process	The managing director has developed a close working relationship with a sterilisation service company and has developed products to overcome the sterilisation issue by making use of single-use instruments. They also approach surgeons to evaluate their designs. They have their own

	engineers, but they also use external designers, e.g. industrial designers, mechanical and electronic designers.
Role of medical experts	The sterile service company demonstrates the process of sterilisation for surgical tools and other related materials to give an idea of how the process works. They also become partners in developing the surgical tools by testing the designs (by sterilising it) and give an opinion about the design to be incorporated with the sterilisation process.
Advantages	The founder is very experienced both in design development and marketing of surgical instruments, which gives the company a strong base in the respective market.
Disadvantages	They develop products from established reusable products, which may limit them from discovering the possibilities of other new radical designs (however, the researcher respects their exploration in developing designs that are suitable for use with the sterilisation process).

Involvement of divisions engaged in surgical tool development in current practice

The manufacturers were experienced in collaborative projects with different experts and this was revealed through the interviews. It was also useful to understand how much time and effort was spent by these manufacturers in the project and to use this information in order to compare with the work involved in this researcher's work. Questions concerning these workloads were asked in the interviews to understand how much time and effort was spent by all the collaborators in the development of surgical tools. The bodies were separated into three divisions, such as manufacturer/ designer, medical expert and third parties.

The stakeholders held different positions in the product development. SPM described themselves as the engineer and manufacturer in the process. SUS preferred to be called the designer, while SheffMED declared themselves as sales people who came up with the initial ideas. SPM and SheffMED put designers as

the third party in such collaborations. SPM put their main contractor as the third party.

The stakeholders interviewed put themselves as the manufacturer and main designer in the development process. They claimed to have devoted most of the time on the collaborative projects by as much as 60 per cent. For instance, SheffMED stated that they did the initial design and developed the product, followed by the marketing of the product. The use of a prototyping service was only to have the developed design on-hand so they could provide the design to third parties. SheffMED used surgeons to obtain a professional evaluation of their ideas and final design and the company mentioned that it was difficult to get the surgeons involved due to their demanding responsibilities. This issue concerning surgeons was raised similarly by all of the stakeholders.

SUS agreed that surgeons have reasonable ideas; however, they do not necessarily know the whole process, e.g. aspects of mechanical production, the manufacturing process and sourcing. Historically, the SUS manager knew about most of the typical surgical tools named after surgeons. He added that new approaches in surgery resulted in new innovations in surgical tools, for example laparoscopic surgery, for which the SUS manager gave the name of one of the major UK manufacturers of laparoscopic instruments.

SPM explained that surgeons are very good at knowing what they want to achieve. Some of their ideas may be practical from the manufacturing point of view and sometimes not. SPM tends to work with more experienced surgeons who are developing new concepts/ways of doing procedures as they go because they know exactly what is required.

SPM explained that the challenge is always to get the two sides to understand each other, between the medical experts and the engineers. The engineers need to understand the user's problems and needs in order to design a product which will fulfil the requirements. The surgeons need to understand the capabilities of the manufacturer when they suggest or request features they want in the instruments.

SheffMED stressed how they can get the design concept to hand. It was explained that, without something visual (e.g. a sketch, 3D model, prototype), of

what the stakeholder suggests for the user it may result in a different interpretation from what the stakeholder expects and vice versa. With the right visual tool, the user understands what the stakeholder is suggesting and the user can give appropriate comments.

SUS explained that the challenge is about finding the right approach to save time and funds for the hospital. It was clarified that the national health authority will consider taking on any medical tools that will serve these two aspects, time and funds. This is also the point for manufacturers such as SUS to consider when putting any new ideas into reality.

From the information gained from the interviews, I interpreted and illustrated this information as a diagram (Figure 6.01) in order to gain a picture of current practice in the innovation of surgical tools, based on interviews with the manufacturers.

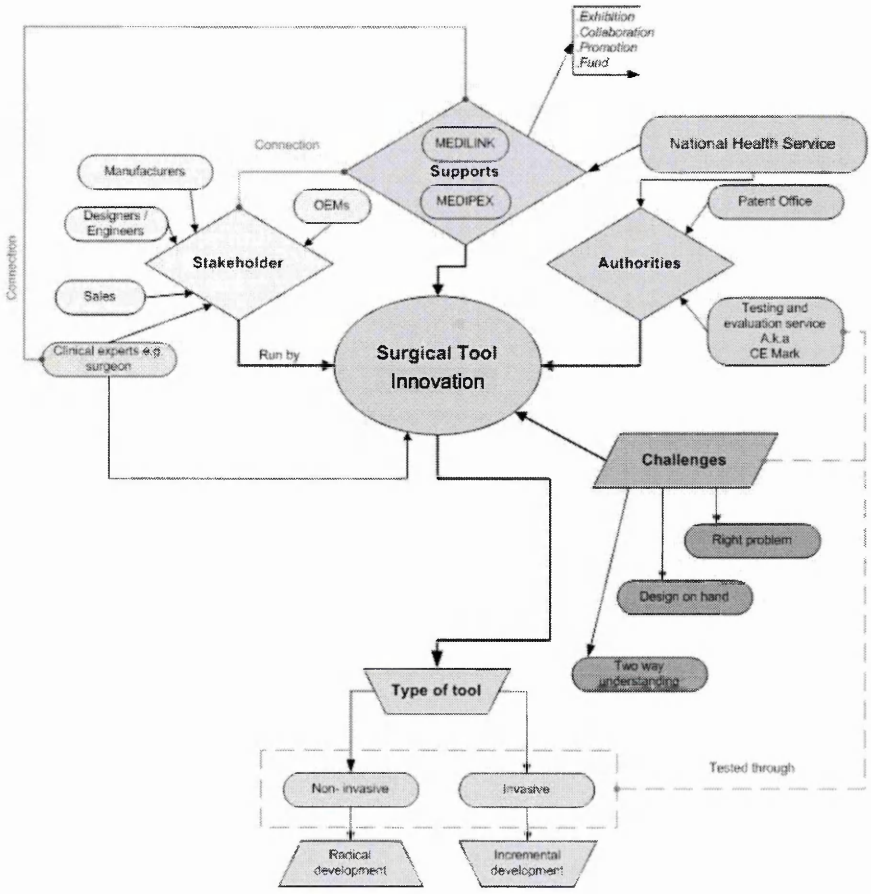


Figure 6.01*. Surgical innovation from the manufacturers' point of view .Based on information gathered from manufacturer interviews.*

SUS provided a long explanation regarding the process of getting newly-designed instruments onto the market. This extended conversation was initiated when I asked the interviewee about my previously completed MA project (1.2), especially in terms of testing and patent. To use a new designed instrument, one needs to go through a long process of clinical evaluation and clinical testing.

Clinical evaluation is a process whereby a new design will be evaluated by comparing it with an existing similar product or similar concept (e.g. pivot method, blade, grasping surface) in order to obtain the CE mark before clinical testing. Clinical testing is a process of testing the instruments to check the usability of the product.

The interviewee did not stress these two processes as barriers for new products to be developed, but agreed that manufacturers were generally anxious when it came to these types of tests. From a business point of view, these processes are costly and time-consuming. Developing instruments that are not invasive and use the existing concepts will shorten the process time and allow the manufacturers to mass-produce the new instruments in a reasonable time.

However, from the point of view of the surgeon, this may result in a new product which will not be significantly innovative or help them enhance their job. The surgeon, Mr Chapple said during the interview (8.1.1):

> *"....so less need for us to get involved. I guess the instrument manufacturers at the end of the day are there to make money, they are not there for patient benefit, they are a profit-making company so their interest here is to promote instruments that have been improved. Lots of equipment I get bored. I get the instrument and in practical terms there is no difference, then they sell and said that it has a better handle etc. In terms of my way of operation it makes no difference whatsoever, yeah, but they are pushing it as a new thing that lasts or is better." Minutes 11:57.3*

He agreed that they normally act as an evaluator for new products rather than getting involved in the process of design. He suggested that they are aware of the problem and how to overcome it:

> *"...well yeah, most of them are not designed by non-surgical background as far as I'm aware, I think the surgeon would rather have their input right, you know when the tool is first being designed, but other than that do we have direct input? Not that I am aware of,..."*

He added,

> *"...I think we are essential, we provide you the knowledge, in terms of need. We can't help with the mechanics of the thing, but what I can tell people is its need to do this and don't care about that. We have bolt stapling guns and a Rep says their handle is better; maybe the handle problem is irrelevant. It is not a big thing. What I need is a stapling gun with an angle at such a degree; you know, that is more is the key thing. So you only get that from discussion with the surgeon. That is our key role I think." Minutes 16:34.4*

So, Mr Chapple indicates that surgeons are important in the process of developing such tools. Their knowledge will inform the designer/engineer of the essential aspect to be designed. In fact, they (surgeons) in history (and also in the current day) developed surgical instruments themselves. These surgeon innovators are celebrated by a few surgical instrument enthusiasts for their significant contribution in the surgical world.

8.2 Co-design process in action 01: A rectal clamp project with Mr Steven Brown (Clamp project)

Mr Brown is a consultant colorectal surgeon based at Northern General Hospital, Sheffield. He had more than 20 years' experience in surgery generally and 10 years' experience in the colorectal surgery domain. He explained that he was experiencing a problem in using an existing rectal clamp during colorectal anastomosis surgery (7.2.1). He also saw this as a topic for a project to redesign a rectal clamp. The project started with the aim of investigating new designs for clamps but later on it was seen that the investigation had thrown up more interesting opportunities for new products so the final design was a surgical simulator (8.2.5) rather than a rectal clamp.

8.2.1 Contextual immersion in action 01

Holzblatt and Jones (1992) suggested that users' working systems and experience in using tools can be studied by undertaking interviews with users in their working environment and while they doing their work. But, in my case, restrictions on access to hospital facilities (6.1) led me to create an alternative environment for both of the collaborators.

Before the co design sessions, I made a study of aspects of the surgeon's professional background. Scientific literature such as surgical text books and papers was reviewed in order to have an initial understanding of surgery, the disorder and the anatomy, as well as to immerse myself in the surgeon's profession. Contextual immersion was also undertaken on human anatomy by observing a skeletal and an abdominal model. Then, I setup a simulation of a medical environment for the surgeon and used this to learn how Mr Brown conducted colorectal anastomosis surgery while looking at the use of rectal clamps in a simulation session (8.3.2).

Experienced gained through working with surgeons before this PhD research (1.2), meant that I was familiar with the surgeon's terminology. Arguably, a designer with less experience of working with surgeons may need to do more to explore their context than reported here.

In my interviews with surgical instrument manufacturers, familiarity with surgical terms appeared to be normal in their practice. Designers and engineers interviewed understood and were able to use terms from the surgical domain well and are able to use that knowledge to communicate with medical experts. However, one manufacturer interviewed felt that the designer did not need the same detailed technical knowledge as the surgeon. One of the interviewees, with 20 years' experience in trading surgical instruments, said,

> *"if you design this, you don't have to know about anatomy, the physiology of the body, didn't even have to know about the name of all the vascular areas of the muscle, what you have to do is to watch how does it use, you don't even need to know the name, but when you watch it you can see the problem without knowing the detail."*

SheffMed, min 29:09.5 – 29:54.0.

8.2.1a The design problem presented by Mr Brown

In colorectal anastomosis, as the surgeon explained, the infected part of the intestine is removed and the two cut ends of the remaining parts will be sewn or stapled together (Fig. 8.02). In this process, this part of intestine needs to be clamped to prevent leaking. The use of the current rectal clamp (Fig.8.03) made it difficult to handle the pivoted type of instrument for retracting and closing the clamp. The current angle of the clamp is inadequate, especially when the patient is male, because they have a tighter pelvic arc than the female (Fig. 8.04). The surgeon needs a clamp which has an easier type of handle, as well as being at a suitable angle.

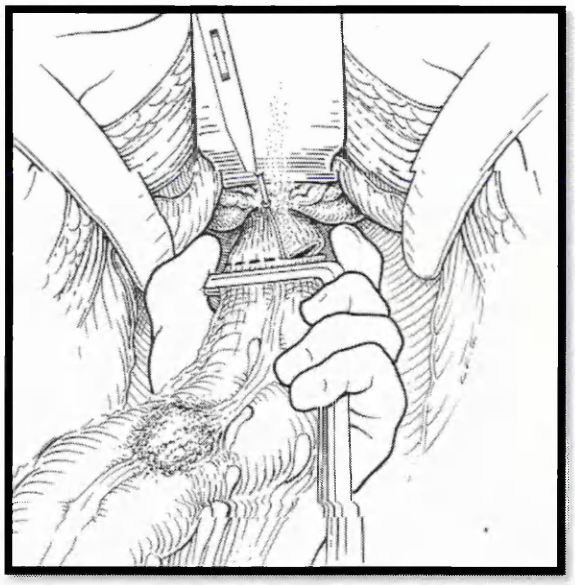


Figure 8.02.*Image showing anastomosis surgery. Clamp and specimen are held by surgeon's hand and rectum divided below the clamp. Nicholls and Dozois (1997)*

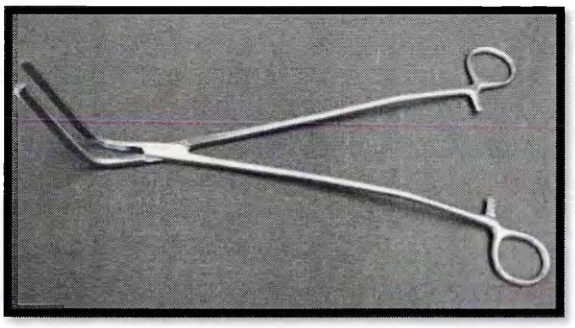


Figure 8.03. *Current design of rectal clamp used in relevant surgery. It comes in various sizes and beak length according to its purposes.*

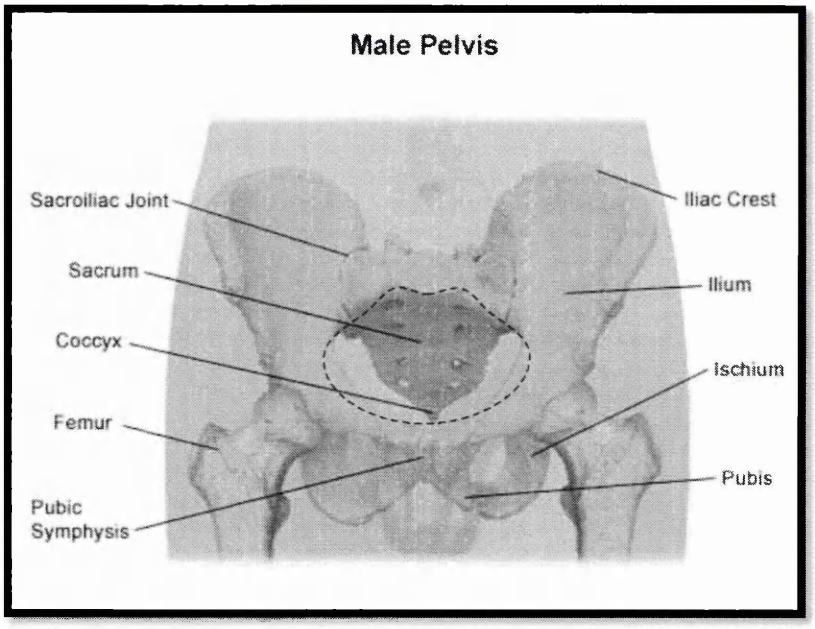


Figure 8.04. *Image showing the male pelvis. Dashed line shows the size of a female pelvic arch compared to a male one.*

8.2.1b Understanding the surgical background

At the early stage of the project, the surgeon provided me with medical text books for reference (Nicholls and Dozois 1997) on the related surgery. The use of the rectal clamp is also shown in the book (ibid) and this gave me an idea of how the surgery is conducted. One of the books (Agur et al. 1999) also showed the related anatomy involved in the anatomosis surgery. The surgeon not only provided the text books, but also suggested the sections to be referred to and explained the context by pointing at the relevant images from the books.

The surgeon also suggested that I search some videos on the internet that showed the surgical procedure and also the use of surgical instruments during the operation. However, after I made some internet search, no video was found that can helped. As a result, we agreed that it would be important to have observations of the actual procedure concerned.

Another approach I took to understand the context was to visit a medical simulation unit in Sheffield Hallam University used to train nursing students, to have a look at the surgical setting and also to observe a model of the human pelvis (Fig.8.05 and 8.06). The simulation unit was used to replicate the surgical

procedure in the main co design session with Mr Brown. This will be discussed in 8.3.3.

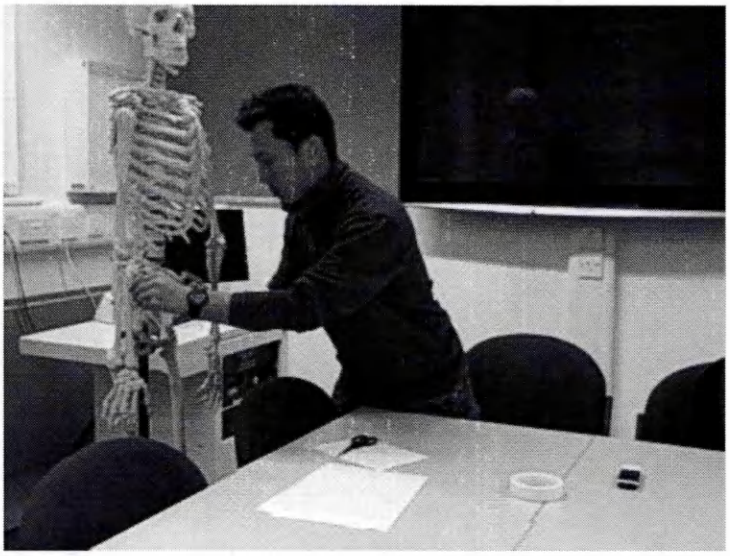


Figure 8.05. *Human skeleton model was observed by measuring the pelvic bone.*

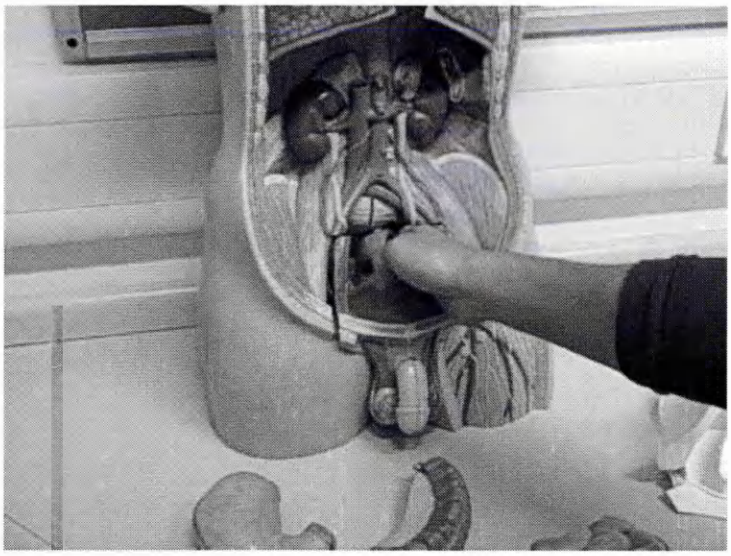


Figure 8.06. *Human abdominal model was observed by putting my hand through the pelvic arch to understand the nature of the particular anatomy.*

I used the facility to learn about the surgeon's working environment and the issues brought up by the surgeon. Equipping myself with this knowledge was important because, I could concentrate and understand the surgeon's problems and needs more clearly in the co-design activity.

8.2.2 Developing the toolkit for co-design

Ethical constraints drove the project to use a simulated environment. However, there was no existing simulator that can replicate the surgery. Yet, the surgeon had explained that there is a simple model he uses for training. It is a box with a hole at the top to suggest an incision cut through the abdomen, and a tube inside the box to suggest human intestines. We agreed that a similar medical model could be made for this project using materials to hand.

We also agreed that there was something we could do to improve the simulator making it nearer to the feeling of the real operation. This became the focus of the collaboration at this time. The development of the surgical simulator undertaken through meeting with Mr Brown is discussed below.

8.2.2a Meeting 01

Interviews were undertaken in this meeting with questions developed from the pilot studies discussed in (5.3). Questions covered the surgeon's background, experience and his concerns. Initially, through long communications with the surgeon, I became familiar with the surgeon's context. Therefore, the interview was used to test the questions developed earlier from the pilot studies.

Meetings with the surgeon were held at his office and activities which involved mock-up were undertaken on the office's main desk. Mr Brown's responses to questions tended to confirm my expectations from previous reading about surgeons' training and culture but added to my understanding of how instruments were selected and the role of standardised sets of instruments or manufacturers in introducing new tools (8.1.1 A, B and C).

My approach was flexible enough to allow me to improvise questions arising from the surgeon's responses, e.g. about the working relationships with manufacturers (8.1.1 E). From this experience it appeared that my approach to questioning was productive and I carried it forward to the Fistula project.

In this meeting, the surgeon reviewed of the materials and suggested we seek more suitable material to be used for the model, because the initial material chosen (e.g. a bellow hose used with vacuum cleaners) had no resemblance to the real anatomy. For example, he suggested the size of the hose and how it should

feel to replicate colon and rectum and also showed where to position it (Fig 8.07). Then he marked on the box to indicate the current practice regarding the incision made into the abdomen for the operation (Fig. 8.08).

Figure 8.07. *Surgeon commented about the suitability of the hose as a human intestine.*

Figure 8.08. *Surgeon suggested incision by marking on the box.*

The surgeon explained how real human organs feel and how they might be reproduced in the model. For example, he suggested that the model needed to have a bladder and that this could be built using a deflated ball. He did not offer any explain further explanation about the type of ball to be used, but I interpreted this suggestion by reflecting on my personal experience on handling animal internal organs and the feeling of a deflated beach ball. I took from this understanding i brought a deflated beach ball to the Meeting 02 with the surgeon.

The time I had for Meeting 01 was only 30 minutes. This gave a limited time to work on making the medical model. Therefore, the meeting focused on evaluating the new materials suggested. After this session, I made the first prototype model using notes from Meeting 01 (Fig.8.09) before taking it to Meeting 02.

8.2.2b Preparing the mock-up for Meeting 02

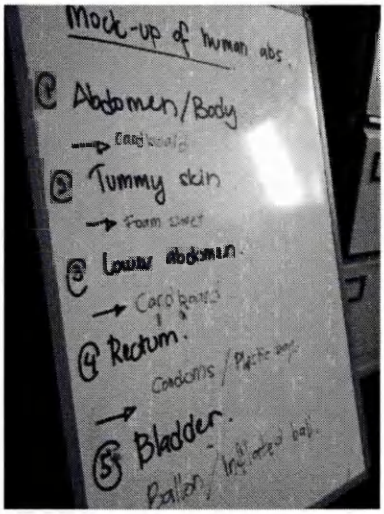


Figure 8.09.*Notes of materials from meeting 01. To be used to replicate particular human parts.*

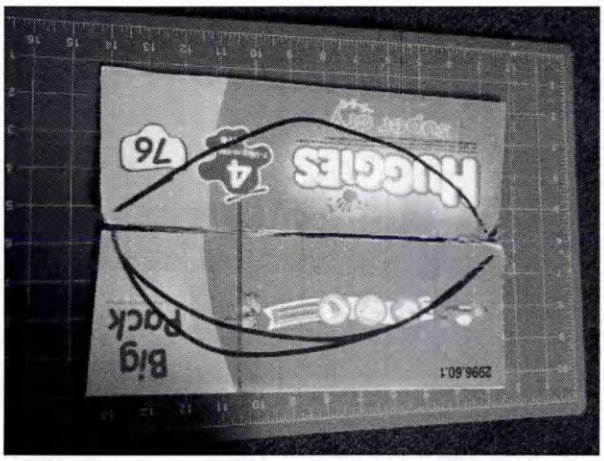


Figure 8.10. *Marking by the surgeon from meeting 01 to show the standard incision made into a human abdomen.*

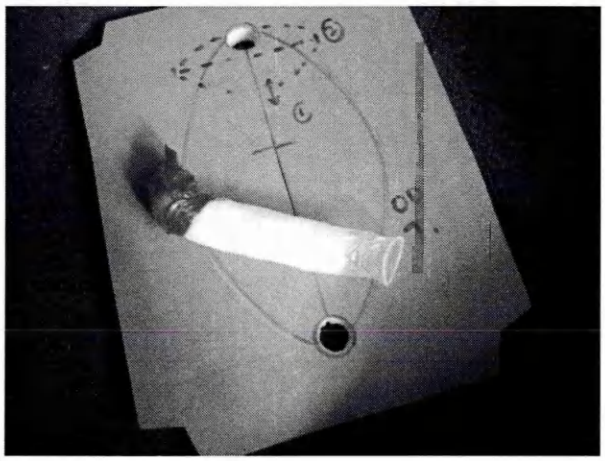


Figure 8.11. *The incision marked on the packaging box by the surgeon (Fig 6.10) transferred to a foam sheet.*

I stuffed a condom with soft filling to replace the bellow hose from meeting 01.

Figure 8.12. *Hole cut and marked by the surgeon in meeting 01 to suggest the human pelvic arch.*

The challenge in making the mock-up was to choose materials that resembled real human organs. I transferred the surgeon's markings on the box (Fig. 8.10) to a foam sheet to suggest a surgical incision so as to replicate skin of the human abdomen (Fig.8.11).

The surgeon explained how the bladder has a similar feels as a deflated ball but he did not talk about the feeling of other parts, especially the intestine. So, I used my personal experience and selected a condom for this, because the soft feeling on its surface and its diameter are similar to the colon and rectum. I stuffed it with fibres to retain its cylindrical shape and used a foam sheet as a skin (Fig.8.11).

The surgeon suggested the pelvic arch by marking it on the mock-up as he found that the cut he made in Meeting 01 was too small (Fig.8.12). I cut a hole on the same box using this mark and took it on the next meeting.

8.2.2c Meeting 02

The pre-designed mock-up was brought to Meeting 02 with the surgeon for evaluation. In this meeting, the surgeon commented on the materials used and performed alterations to the parts so they have the similar feeling to the human organs (Fig.8.13 – 8.18). As the designer I explained how I built the mock-up and why the materials were selected.

First, the surgeon compared the feeling of the foam sheet to real human skin by retracting them (Fig.8.13). He marked on the foam sheet to suggest a cut out for the proposed incision size and also another incision type used in the surgery

(Fig.8.14). Second, he tested the flexibility of the stuffed condom to compare it to the real colon and rectum (Fig.8.15). He also altered the condom by wrapping it with adhesive tape and explained how the similar feeling of the colon and rectum had a near likeness to the taped condom (Fig.6.16).

Figure 6.13. *The surgeon compared the flexibility of foam sheet to human skin.*

Figure 8.14. *The surgeon marked incision size to foam sheet to suggest cut out and another incision's size.*

Figure 8.15. *The surgeon compared the feeling of the stuffed condom to a human colon and rectum.*

Figure 8.16*. The surgeon altered the stuffed condom by wrapping it with adhesive tape. (in the background by window).*

Then, he compared the feeling of the deflated beach ball to the real human bladder as he had suggested earlier. However, in the meeting, the designer gave another option by suggesting a stuffed plastic bag for the bladder, which was agreed to as more suitable (Fig.8.17). Lastly, the surgeon suggested how to create a resemblance to the fat covering around the rectum by covering the condom with soft filling (Fig.8.18). He suggested this detail can be included in an upgraded version of the surgical simulator.

Figure 8.17*. The surgeon compared the feeling of the deflated beach ball to a human bladder. The designer suggested stuffed plastic to suggest bladder.*

Figure 8.18. *The surgeon showed the designer the fat which covered the rectum using the soft filling on the stuffed condom.*

Later in this meeting, I interviewed the surgeon as discussed in 8.1.1. In this interview, the surgeon said that he had become interested in the model as he was developing the instrument. He believed that the medical model may have market potential as there is a need for it. At this point, we agreed to continue to develop the simulator in conjunction with the rectal clamp. He also talked about other possibilities for new innovations to be made in his domain.

8.2.3 Practical design session 01: Clamp project

The original plan for this session was to observe the surgeon's professional way of working plus developing the surgeon's idea for a new rectal clamp. However, the plan was changed into developing both a rectal clamp and the surgical simulator after the surgeon proposed that there is more need for a surgical simulator.

The session basically divided into two main activities. There was simulation of a particular current procedure during the first half being part of the contextual immersion and was only a small part of the session. This was followed by co-design activity which was the main activity of the session. The session was held in a medical simulation unit (room) of Sheffield Hallam University. The surgical simulator (mock-up) was used as an alternative to show operation of the procedure carried out on patients and the mock-up kit was also used as a co-design tool for the rectal clamp.

8.2.3a Setting up

The simulation unit is designed to replicate an emergency room at a hospital for training purposes (Fig.8.19).I used this unit as it was suitable for this research. A similar setting was used by earlier researchers for various purposes (Rasuolifar et al. 2007; Trejo et al. 2005; Albayrak et al. 2007). In my project, the surgical setting was used to demonstrate the procedure and as a means developing the idea for a surgical instrument.

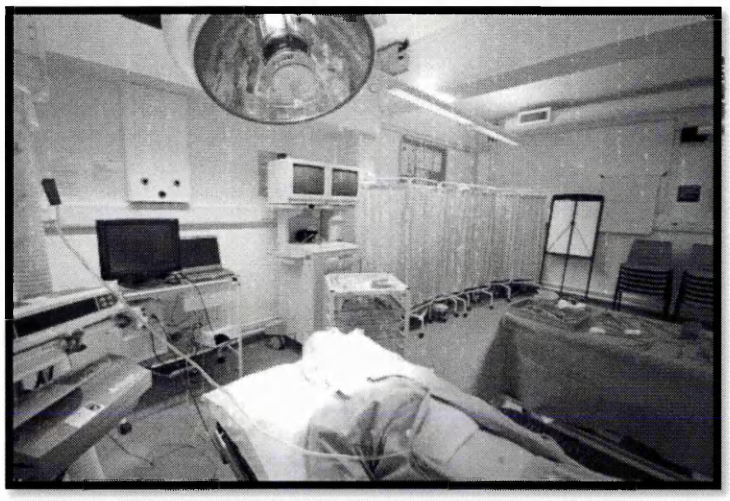


Figure 8.19. *Emergency Room simulation unit at Sheffield Hallam University, Sheffield, UK*

Working with mock-ups can make users experience in using tools, visible for designers to see (e.g. Ehn & Kyng 1991; Long et al. 2011; Vaajakallio & Mattelmäki 2007). As discussed above (8.2.2), we made a surgical simulator from packaging cardboard and used this as a mock-up in the design session (Fig.8.20). The model was a mock-up of a human abdomen with specification fit for the use of an anastomosis surgery simulation.

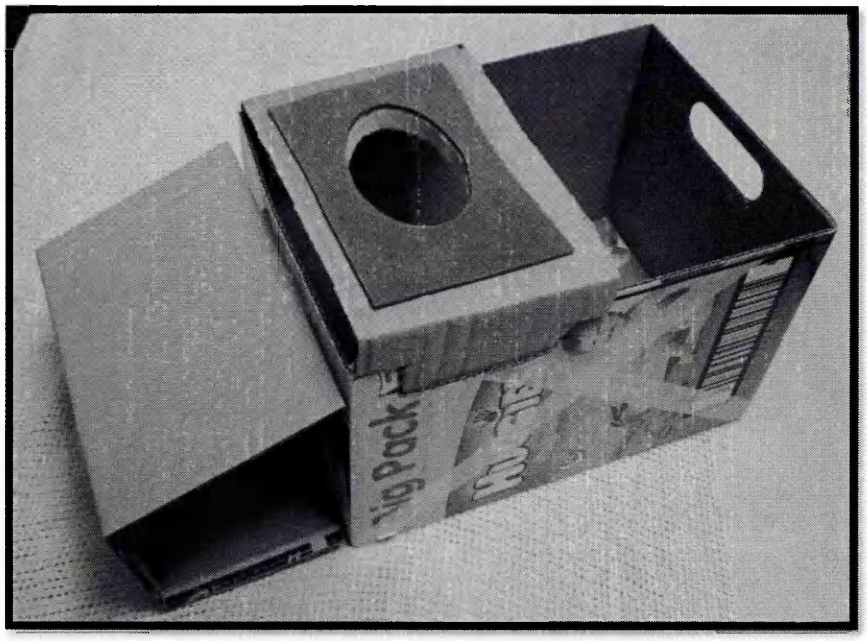


Figure 8.20*.Surgery simulator (mock-up) used in the session.*

Left ***Figure 8.21****.View of overall simulation environment .Right* ***Figure 8.22.****More focus view on simulation activity.*

As discussed in (5.5), two digital camcorders were used to capture multi-angled recording of the simulation (Fig. 8.21and 8.22). One was set to capture a focused area and another one was set to capture the overall scene. Both cameras were set up so they could be moved easily to different angles. Surgical instruments from the simulation unit were used by the surgeon on the surgical simulator to act out the operational procedure. They were set on surgical trays for ease of use by the surgeon during the demonstration (Fig.8.21). In the observation session, the

model was positioned on the lower abdominal area on the surgical couch (Fig.8.22).

8.2.3b The activity

The co-design (4.5.2) session was undertaken together with the demonstration of surgery. A design area was setup at the side of the surgical setting and was equipped with a mock-up kit for modelling, developed through pilot studies, together with papers and pencils (Fig.8.23).

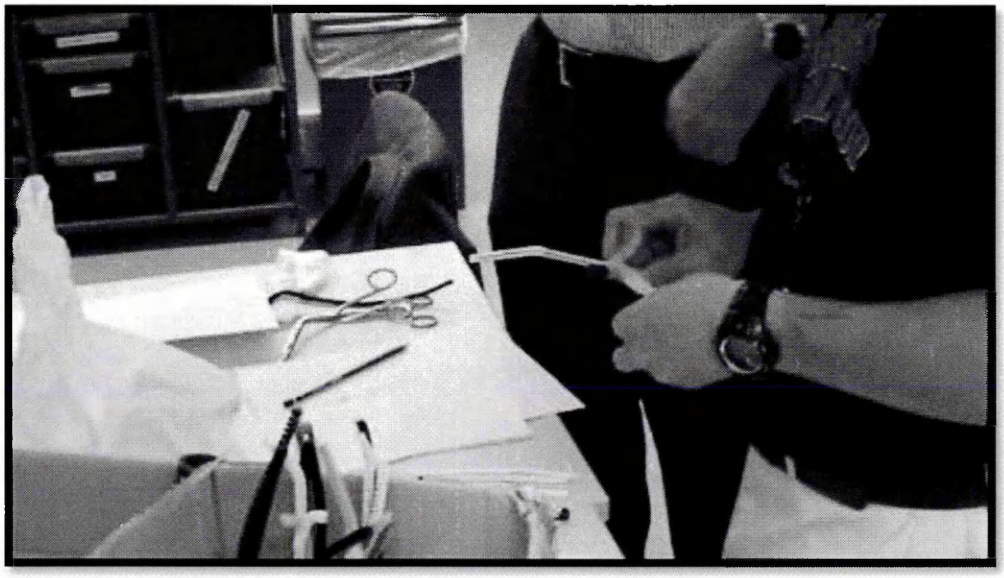
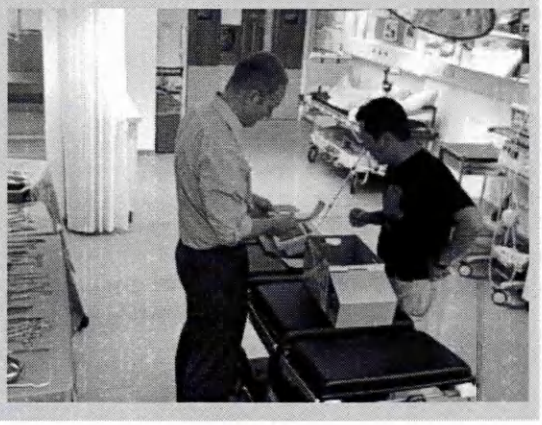
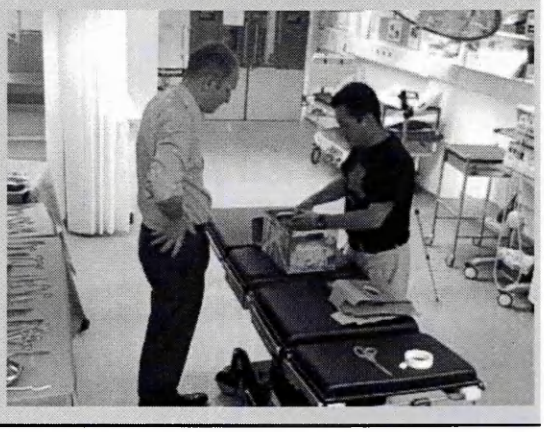


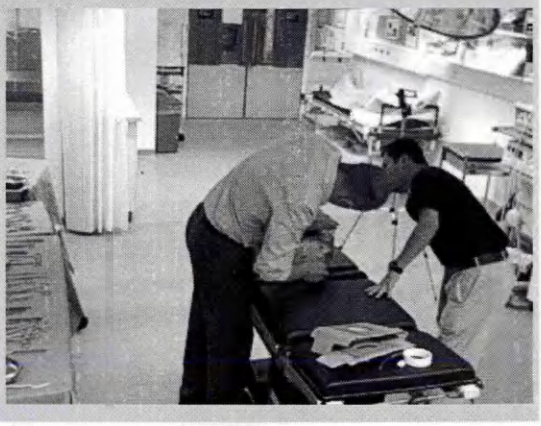
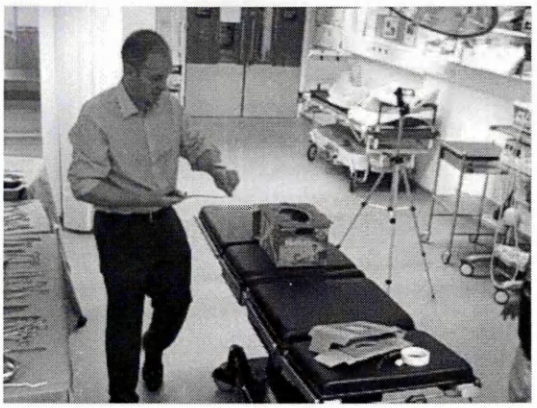
Figure 8.23. *Design area set-up.*

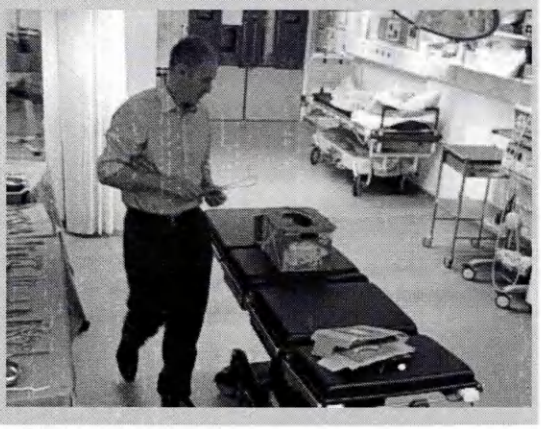
In the session, the surgeon demonstrated how he conducts an anastomosis surgical procedure by using the surgical simulator while I, as the designer observed. I explained to the surgeon that he may repeat, pause or forward his procedure as he required and use any of the surgical instruments and design tools as he needed. The session was planned to last for three hours, but on the execution it lasted only for one and a half hours, at the surgeon's request.

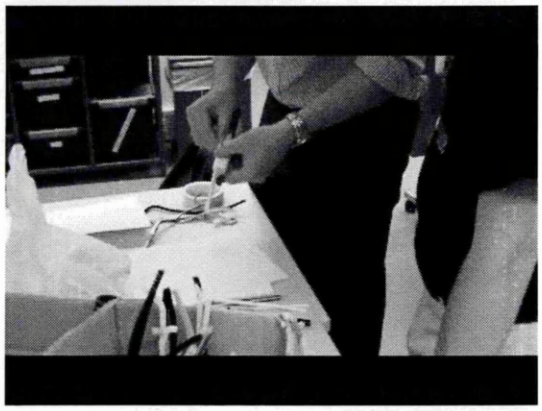
As developed in 6.4, the session was video-recorded and later transcribed and analysed using Nvivo. Table 6.01 is extracted and simplified from Nvivo. I called myself as the 'designer' in the table as I acted as the researcher who transcribing a design activity between a designer and a surgeon.

Table 8.01. *Actions made by collaborators in Mr Brown's project.*

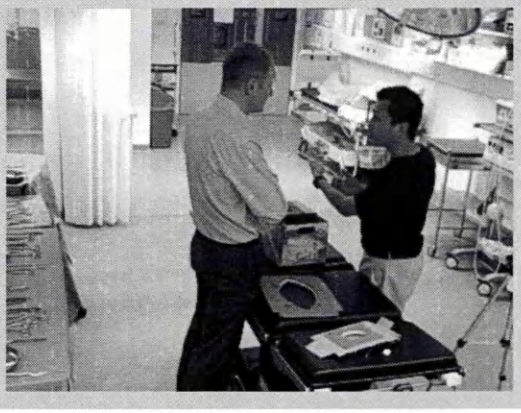
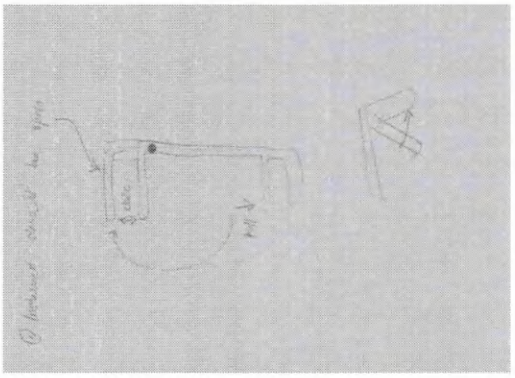
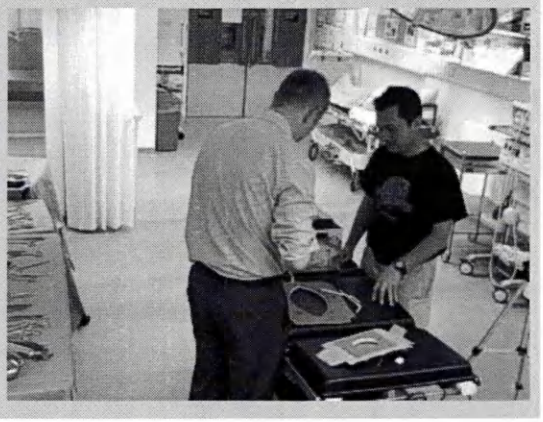
No	Minute	Descriptions	Images
1	00:23.00	Designer briefed to the surgeon about the agenda for the session. Surgeon checking the surgical simulator parts before being assembled.	
2	09:29.96	Surgeon placing the surgical simulator at the proper position on the couch.	
3	12:14.60	Designer conducted alterations on surgical simulator as the surgeon commented.	

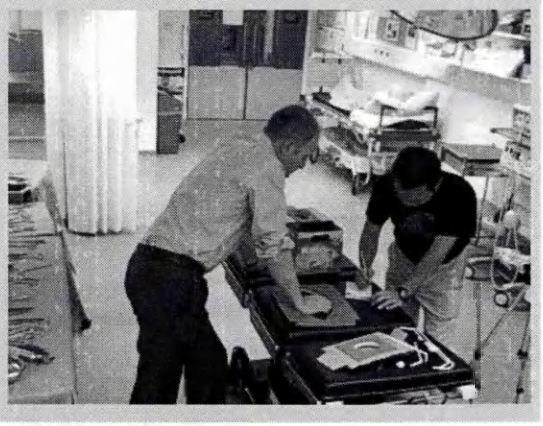
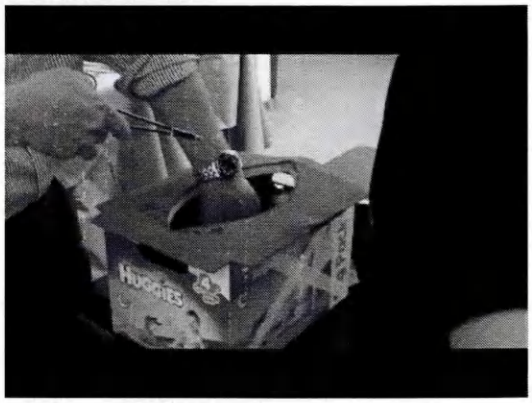
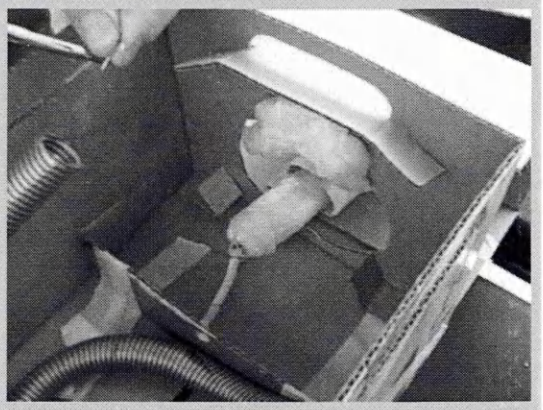
4	13:31.92	The surgeon selected incision size for the surgical simulator.	
5	13:57.48	The surgeon tested the size of the incision by putting his hand through it.	
6	14:19.76	The surgeon took one of the surgical instruments from the room to show the clamping procedure. However, the instrument was inappropriate.	

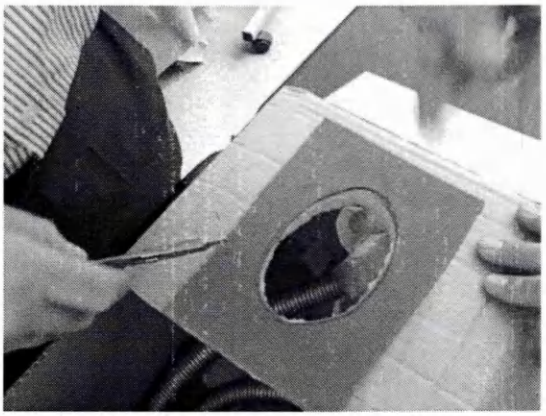
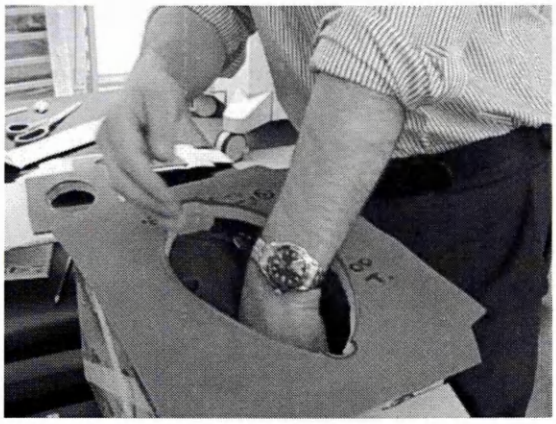
7	**19:45.16**	**The surgeon took another instrument that similar with the one he used and we modified it by putting plastic straws to a current rectal clamp.**	
8	20:01.24	The surgeon demonstrated the clamping procedure in anastomosis surgery.	
9	20:12.36	Designer observed and recorded it with camcorder.	

10	23:31.26	Designer and surgeon started the idea development for the rectal clamp. The surgeon sketched the concept.	
11	24:45.00	Designer made a mock-up by referring to the surgeon's sketches.	
12	25:37.24	The surgeon took over the mock-up and made it a workable mock-up instead of the block mock-up made by designer.	

13	31:36.28	Designer and surgeon setting up the surgical simulator to test the mock-up.	
14	31:51.20	Surgeon showed how he will use the product by using the mock-up to demonstrate.	
15	31:32.88	Collaborators discussed the details and specification for the new design.	
16	33:41.72	Surgeon demonstrated again to reconfirm specification.	

17	34:51.28	Collaborators discussed the concept and usability.	
18	34:52.00	Surgeon went to design area and discussed the design and sketched to explain.	
19	42:03.64	Surgeon altered the mock-up with an instrument he picked from the tray to make the mock-up durable; he tested it again on the model.	
20	42:48.28	Designer did a brief post-mortem for the session. He explained the activities undertaken and the planning for further development of the products.	

21	43:39.68	Designer took notes on surgeon's suggestions for further development of the surgical simulator.	
22	46:18:96	The surgeon suggested suturing features to be included to the medical model and demonstrated how the features will work with the use of surgical instrument.	
23	50:27.54	Surgeon then took suture equipment (hook needle and thread) and demonstrated the procedure in detail. We took a hose from the mock-up kit to make it resemble a colon.	

24	51:06.92	We changed smaller incision size to add some challenge and tested the simulation usability. Surgeon showed his suturing procedure.	
25	55:35.50	**Surgeon altered the model using my jacket to simulate the internal organ that should be included in the model.**	
26	55:39.52	Surgeon then put the belly skin and tested it through the incision opening.	

8.2.4 Analysis and discussion

The data collected from this session were the actions and reactions of the collaborators observed directly from the session and from the video recordings. Their actions were observed on the making of the mock-ups (rectal clamp and

surgical simulator) and how they interacted with them. In the descriptions below I refer to myself as "the designer" to differentiate from my other role as observer.

I analysed the data focusing on these elements that would help me to answer my research questions as above in (1.4). First element was my own reflection on the participant's actions from the video. Secondly, I looked for the activities and events that appeared to be influential on the design process in moving the design (of either simulator or clamp) forward. Lastly, I looked at any incidence of collaboration in the use of mock-ups shown in the video. I extended this process to include an expert review in the second co-design project with Mr Chapple.

The surgeon simulated the operational procedure and showed it to the designer during the first half of the session. While doing this, he also commented on the surgical simulator's design e.g. he showed the proper position for some parts incorporated in the surgical simulator so that it can better replicated the human anatomy (row 1 to 5). He did this also to test the usability of the surgical simulator and he showed that by doing this, he could demonstrate to me the operation procedure smoothly.

In the simulation session, the surgeon mocked up the rectal clamp which he was normally used by adding plastic straws to an available clamp (row 6 to 7). He then used it to show the designer the current way it was used in operations and the problems he experienced during the particular surgery (row 8 to 9). The designer observed this demonstration and took a focused recording of this with the camcorder.

The surgeon did not explain all the steps in the procedure but during the simulation, by using verbal descriptions he defined certain of them. For example, he just simply described the incision process on the external abdomen verbally and then moved on to the next procedure, clamping the intestine by demonstrating it physically. From my observation, the surgeon did this to stress focus on the main design problem. This was also demonstrated before the simulation session when he suggested a cut out of the proposed incision size in Meeting 02 (Fig. 8.14) and it was executed later but before the simulation session (Fig. 8.20).

The surgery simulator not only worked as a mock-up to make available the surgeon's experience working with his instruments but also supported the concept development of the new surgical instrument. In the second half of the session, I moved the activity from simulating the current situation into developing the surgeon's idea for a new concept of rectal clamp (co-designing). This is where we used mock-up kit that I developed through a series of pilot studies (6.4.2 and 6.4.3).

The rectal clamp's mock-up was built initially by the designer using the surgeon's sketches (row 11). He made it as a block mock-up to represent the new design of a rectal clamp where the mock-up only suggested the size and shape of the new design. The designer thought that the function for the new design could be understood without showing it more fully mocked-up. But the surgeon took the mock-up a stage further and modified it to make it functional (row 12) and this mock-up was used on the surgery simulator to test its concept (row 14).

The surgeon reflected on his design in the test and discussed the design specification with the designer. He reconfirmed his concern by repeating the test on the simulator (row 14 to 16). The designer and the surgeon moved on with the mechanical concept for the rectal clamp design by producing sketches and to the mock-up (row 17 to 18).

At one point, the surgeon was not satisfied with the material used for the rectal clamp mock-up and switched it with a material we found from the room (which is not included in the mock-up kit). He wanted a more durable material for the mock-up so he could have a firm grasp on it (row 19). Then he tested the mock-up again with the simulator.

The focus in the co-design session was moved from developing the rectal clamp into developing the surgical simulator when the surgeon saw a further use for the surgery simulator when demonstrating it to the designer. He suggested the simulator could be used as a training aide on manual suturing in anastomosis. He took a suturing instrument from the room and used it on the surgical simulator, while explaining generally to the designer about the procedure. He did not

explain exactly how he performed it but, just by demonstrating, the designer could understand the current procedure (row 22 to 24).

Here, the surgeon suggested that the designer could change the material that replicated the intestine to a more suitable material as he made a more detailed description of the feeling and characteristics of the real intestine (especially about the colon and rectum).

Towards the end of the co-design session, the surgeon altered the surgical simulator by taking my fleece sweater and putting it into the medical model to replicate the human internal organ and test it (row 25, 26). He suggested that this is important as in real operation this has been one of the obstacles that surgeons need to face when they try to reach the colon and rectum (as they are at the back of small intestine). The designer was able to understand this on the spot because he had the experience from reading an anatomical textbook and also viewing a physical model e.g. skeletal and anatomical model.

In conclusion, this first project showed several interesting points in carting out collaboration with an expert user, in this case a surgeon. First, it shows the benefit of having contextual immersion e.g. a surgery simulation and a co-design session together seems beneficial in developing ideas. This goes far both the concept of the rectal clamp and the surgical simulator.

This may happen with the use of mock-ups as indicated by Ehn & Kyng (1991) and their suggestions about the use of mock-up in the design process (4.3). Another element that I believed supported this was also the 'making' of the mock-up. As shown by Vaajakallio & Mattelmäki (2007), users can propose products by using mock-up kits provided (4.4). In contrast to their 'tool kit' (ibid) , my kit was raw and gave the surgeon freedom in what and how he wanted to use from it e.g. using a plastic straw and attaching it on to the current pivoted instrument (row 6 to 7), even though, most of the making was initiated by me and then was taken over by the surgeon. So, based on this evidence and then from the pilot studies (6.4.3), I used the same mock-up kit again in the second co-design project with Mr Chapple (8.4).

The surgeon exhibited a significant example of an outcome arising from the use of the design strategy e.g. changing his idea from developing the rectal clamp into the development of a surgical simulator. This related to Cross's (2007) description of designers reframing a problem along the way during design process (4.6).

8.2.5 Outcome of co-design process and further development of the surgical simulator

The surgeon and I agreed that the outcome of the project produced:

1. A new concept for a rectal clamp and

2. Surgery simulator for training purposes.

We decided to continue developing the surgery simulator as the surgeon believed that it has the potential to be marketed in surgical training. Thus, I made the second version of the medical model using the same mock-up material such as cardboard, stuffed condoms and foam sheet. The reason for making another mock-up was because I needed a presentable mock-up suitable for design evaluation.

The previous mock-up used a diaper box with graphics and holes, which may distract the experts and may raise unnecessary questions in evaluations. The new version avoided these things and was made from clean, neutral material, e.g. unprinted cardboard (Fig.8.24).

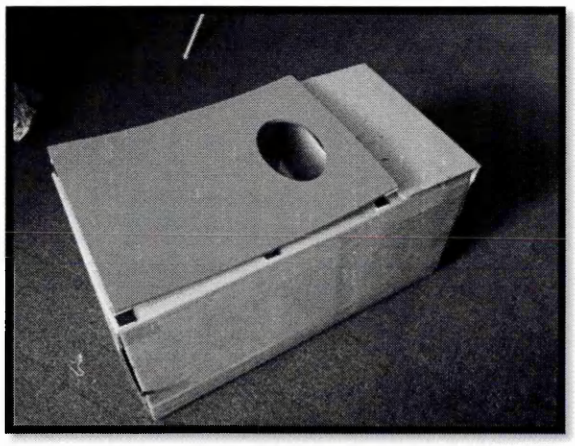


Figure 8.24. *Type 2 mock-up of the surgery simulator.*

The surgeon was not present when the model was made. Still, it was built according to the surgeon's requirement and the designer's observation. Through the making of the model, the designer realised that the material used in making the mock-up, especially cardboard, might be used as material for the marketable product. He also saw the possibility of the product packaging and also how the product could be assembled by the user. A video recording of the product assembly was taken as a reference for design purposes (Fig.8.25).

Figure 8.25*.Snapshots of a video recording on how to assemble the surgery simulator.*

The model was given to the surgeon for evaluation by him and his colleagues. Feedback from the surgical experts was given verbally by the surgeon to the designer, together with some notes drawn on the mock-up to suggest further modifications. Some considerations suggested by surgical experts are listed below:

1. More durable material or structure to be used.
2. Semi-deflated ball to be used to replicate the bladder. The surgeons suggested the training using this model may include retracting the bladder, which is practised in this particular surgery.

3. Pelvic arch suggested on the model needs to be altered and this was drawn on the model.
4. Thicker material to be used for replicating the colon and rectum.

At this stage, the surgeon suggested that the model needed to be built suitable for initial evaluation and the model design may be suitable for training purposes. The evaluation would be performed among his colleagues, and would be an imitation of the particular surgery, which includes using the current instruments to demonstrate clamping, suturing and retracting.

8.3 Co-design process in action 02: Fistula model project with Mr Keith Chapple (Fistula project)

The second design project was developed with Mr Keith Chapple, a consultant colorectal surgeon base at the Northern General Hospital (NGH), Sheffield. He has more than 20 years' experience as a doctor and 5 years specifically as a colorectal surgeon. He did his PhD study in molecular biology in a major university in Leeds and trained as a surgeon in South Yorkshire. As a head of department in colorectal surgery at NGH, his job involves dealing with surgeons' problems and needs. One of the major problems the department is facing is to understand Magnetic Resonance Imaging (MRI) reports for acomplicated colorectal disorder, fistula-in-ano.[17]

The collaboration started with communication through email and later meetings with the surgeon at his workplace. The first meeting was arranged to introduce myself and the research. Then I met him again for a semi-structured interview to understand the context and establish the collaboration. Later, we cooperated in a design project where I was enlightened further about the context and undertook design collaboration using the same approach with a mock-up kit as in Mr Brown's project.

Mr Chapple's aim in the project was to develop his idea for a fistula model inspired by a game call Kerplunk while he was playing it with his children. This

[17]Fistula-in-ano is an abnormal communication between the anus and the perianal skin.
Source - http://fitsweb.uchc.edu/student/selectives/Luzietti/Painful_anus_fistula_in_ano.htm

would be used by radiologists to show the complicated 3D paths of fistulas, identified from MRI scans which will help him and his colleagues to understand better about the complication.

8.3.1 Contextual immersion in action 02

Fistula-in-ano and the problem of the Radiographer's MRI Report

Experience gained from a previous MA design project (1.2) had made me familiar with the colorectal disorder and its treatments. Initial communication (7.2.2) and interviews with the surgeon (8.1.1) provided further understanding about how the type of fistula identified and how to understand its structure can be complex.

Fistula-in-ano (Fig.8.26) is an irregular connection between the internal bowel system (anus) and the surface around the outer anus (perianal skin). Current technology such as MRI has been used in the UK to scan the tracks of fistulas. Currently, MRI scans are transferred into text reports without images, since the reports are combined observations from many images and radiologists have specialist expertise in interpreting the MRI images. The reports, which consist of descriptions of the fistula on coordinate grids and layers, enable surgeons to understand how the fistula tracks emerge and to decide the best treatment for it (Fig.8.27).

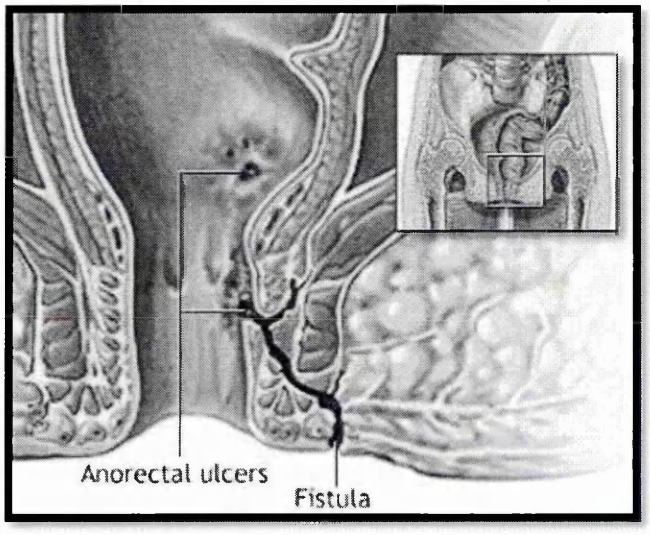


Figure 8.26*.Fistula-in-ano.*

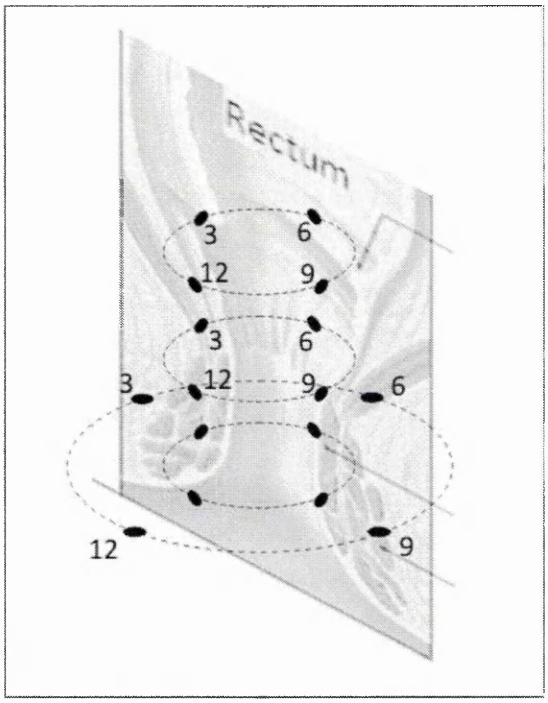


Figure 8.27. *Coordinate system used by radiologists to indicate fistula track in the MRI report. Researcher impression.*

Reports for simple fistula-in-ano are easy to understand (for the surgeons). However the surgeon explained that he and his colleague had a problem in understanding reports for complicated cases of fistula-in-ano; they had difficulties in visualising these complicated tracks through reading the MRI report. Some alternative has been attempted in order to visualise the fistula tracks, such as further explanation from the radiologists in weekly meetings with surgeons and by using digital 3-dimensional images of the fistula tracks. They worked well for some cases, but the issue has become a routine problem in this particular domain.

From the surgeon's explanation of his colleagues' feedback, digital 3-dimensional images helped the surgeon to understand the tracks. However, the surgeon believed that a hands-on model may work better when referring to the use of images and models to understand human anatomy, which is familiar to him from his professional practice. A model may give a more direct experience than images.

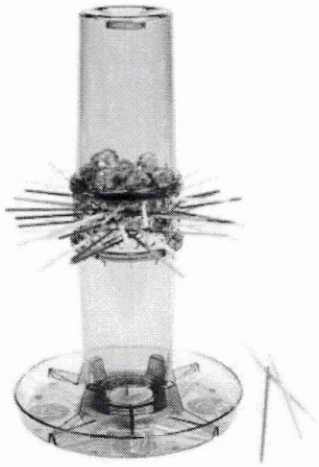


Figure 8.28.*Kerplunk*™.

He explained that he may also have the solution for this issue by taking an idea from a children's game called Kerplunk™ which he played with his children. The game starts with a complex network of plastic sticks passing through a tube (Fig 8.28) and this seemed to be analogous with fistulas which pass through the anus although the fistula is a single 'snake-like' object rather than the many straight sticks in the game. He discussed this idea with radiologists and they agreed that this idea may be useful. Being aware I was a designer, working together on this would give him opportunities to take forward his idea for further development. So we agreed to collaborate in a design project and proceed with a co-design session.

8.3.2 Practical design session 02: Fistula project

The objective for the session was to continue the evaluation of the methods started in rectal clamp project (8.2) which were contextual immersion and working with mock-ups. This was a live design project and could show how the design method worked in action and how expert users responded to this. In the rectal clamp project, the surgeon showed that he was actively involved in the making and showed that he could use some design strategy such as reframing a design problem (4.6) e.g. changing the project focus from designing a rectal clamp into developing a surgical simulator.

From that, I hoped to see whether Mr Chapple would follow a similar pattern. As this project did not involve a patient or the simulation of surgery such as the rectal clamp project, it was set up in a design environment i.e. a room containing

a table and chairs, included with a mock-up kit located on the table, reachable for the participants to use.

The design objective for this session was to develop the surgeon's idea of a model of fistula-in-ano using the mock-up as a co-design tool. The agenda was to discuss initial ideas and move on to mock-up building. This session was set-up in the meeting room and lasted for two hours.

A mock-up kit was used in this session, together with basic sketching tools such as papers, pencils and a digital sketch pad. The mock-up kit used in this session retained the same openness as in the rectal clamp project, but had some different main material e.g. cardboard, papers, pipe cleaners and tapes (6.4.2 and 6.4.3a) to suit the project. The surgeon had outlined his idea in the earlier meetings and described it by making sketches, which gave the designer ideas about the materials to be used (8.1.1). The mock-up kit was set on the work table within easy reach of the surgeon.

This session started with the designer briefing the surgeon about the plan for the session including offering the surgeon to use the mock-up kit whenever needed. Then we continued with some contextual immersion, e.g. the surgeon describing the context of the issue. The surgeon did this verbally, through sketching, and using the mock-up kit to model the particular anatomy which was also the design concept.

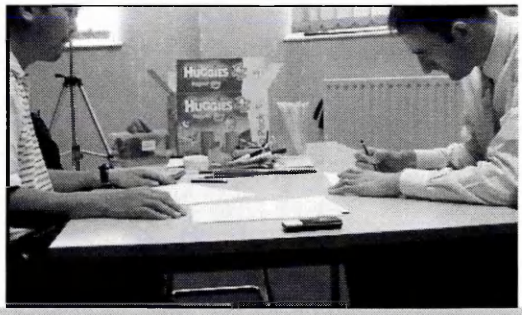
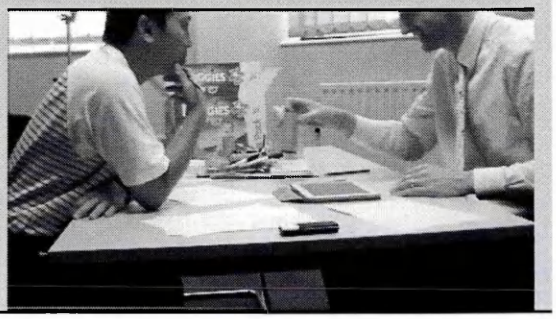
The designer then continued the mock-up 'making' by providing the main construction of the mock-up. The surgeon took part in the making by altering and annotating the mock-up with details. At the end of the session, the designer asked the surgeon for his opinion of the session and the designing process. Then the designer also briefed the surgeon on further planning for the project.

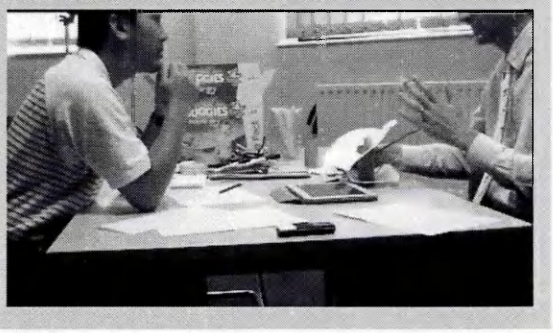
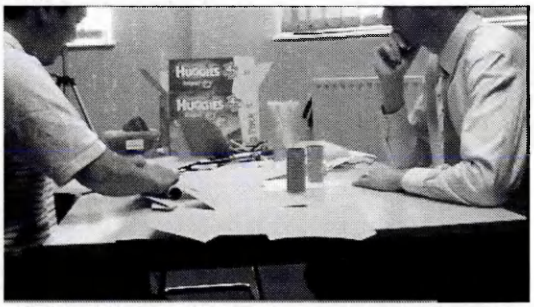
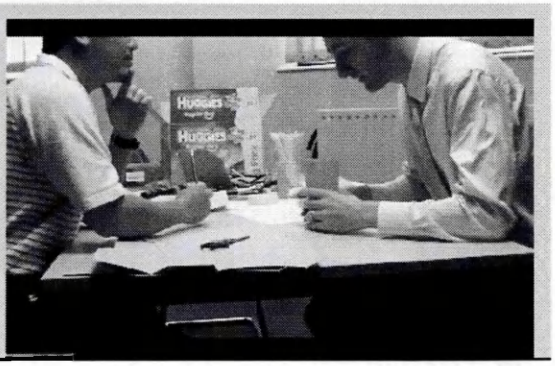
Two digital camcorders were setup. One took the overall view of the session, while the other focused on the making of the mock-up. In the previous project (6.3), the camcorders were easily manoeuvred in order to change the view taken. However, in this project, manoeuvring the camera was unnecessary as I had learned how to get a good camera view from Mr Brown's project. Also the

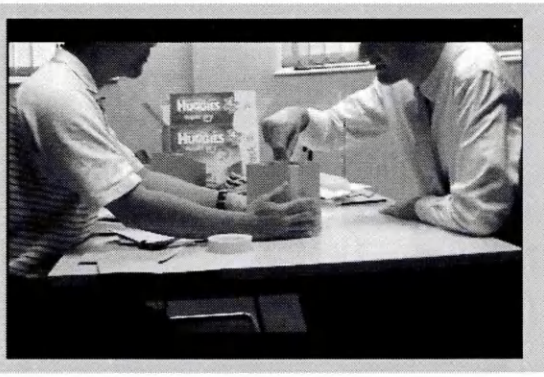
configuration of the meeting room allowed me to get better view of the co-design session.

The video recording was transcribed using qualitative research analysis software (Nvivo) and the main actions were listed (Table 8.02) in order to start the analysis. The table below was simplified from Nvivo and significant clips (images) have been extracted as shown.

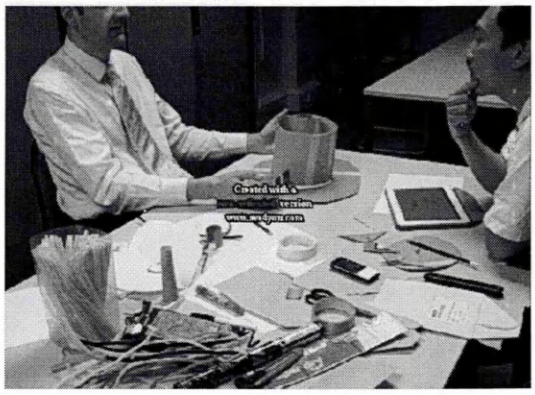
***Table 8.02**. Actions by collaborators in the fistula project.*

No	Minutes	Actions	Images
01	00.00 – 25.01	The designer explained the agendas for the session. Surgeon explained the process of obtaining the MRI report and relevant issues.	
02	25.36	The designer and the surgeon discussed the design. The surgeon made sketches for the design.	
03	27.43	The surgeon took a material (toilet paper roll) from the mock-up kit while discussing about the design.	

04	30.00	The surgeon continued to show his idea by making a mock-up. He used the mock-up to explain the anatomy to the designer.	
05	33.29	**The surgeon also explained briefly how the product will be used. He did this by taking a pipe cleaner to show how this will replicate the fistula** track.	
06	47.17	The designer moved the session into making more robust mock-up and started by building the second cylinder (first cylinder was using the toilet paper roll)	
07	48.00	**The designer handed the cardboard he'd cut for the surgeon for him to decide the size of the cylinder.**	

08	39.05	The designer and surgeon made the mock-up together. The designer constructed the main component and the surgeon put in the details which are mainly small circles that represent holes with coordinate.	
09	1:00.33	While putting the mock-up components together, the surgeon explained the representation of the mock-up components with the particular anatomy.	
10	1:06.37	The designer reminded the surgeon about another component for the mock-up which is pelvic sink *(refer to row 04, where the surgeon made it with a white paper on top of the first mock-up).* However the surgeon decided not to include it.	

11	1:10.32	Completing the mock-up with the last piece of component. The designer cut a square base using a cardboard and put it at the bottom of the mock-up. Then the surgeon drew a circle of the desirable size.	
12	1:12.67	The surgeon drew small circles that represent holes with coordinate on the base.	
13	1:14.79	Designer completing the assembly for the mock-up by attaching the base to the other part using pipe cleaners.	
14		The designer dissembled the mock-up as the surgeon decided to make a hole in the middle of the base. The designer cut the hole.	

15	1:51.50	The surgeon used the completed mock-up to demonstrate how to use the product. He did this by punching a hole at every layer of cylinders and put a pipe cleaner through them.	
16	1:53.98	Then the surgeon annotated on the mock-up with sphincter muscle's names and layers.	
17	1:55.00	The surgeon informed the designer that after seeing a complete mock-up of his idea, he decided the base which represented the buttock, to be flat as the mock-up. This contradicted to his first idea of making it near to real anatomy.	

18	1:57.92	The surgeon altered the mock-up after evaluating the mock-up by simulating the use of the mock-up for the second time.	
19	1:59.03	The session ended with the designer and the surgeon reviewing the development process and the mock-up. Then the designer briefed the surgeon about further plan of the collaboration.	

8.4.2a The designer's and the surgeon's actions

The designer briefed the surgeon about the session's agenda. The surgeon then produced sketches and made a diagram to explain the context, problems and needs at the beginning of the session (row 1 and 2). As shown below (Fig.8.30), the surgeon's idea was to have layers of cylinders which would indicate the layers in anal sphincter, and something to be positioned at the bottom of the model to represent the perianal region (the buttock). Every layer would be provided with holes, which would be used as a passage for a wire/wires put through and between them to reproduce the fistula tracks.

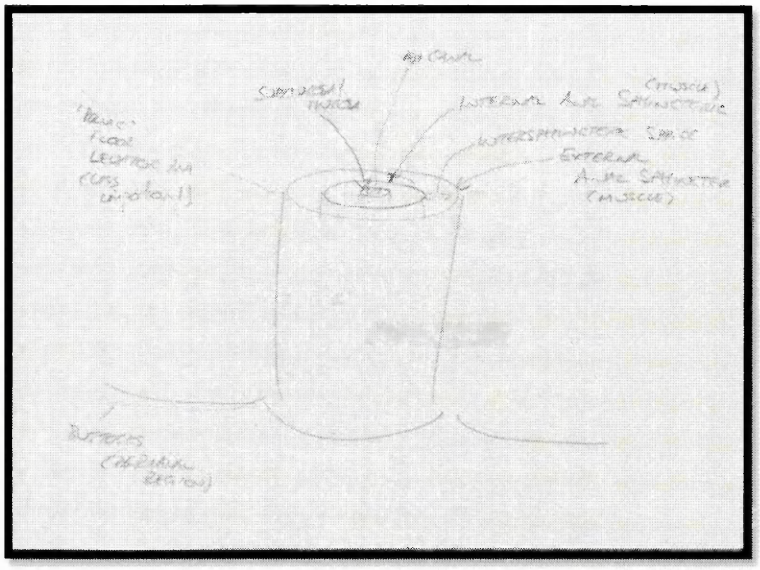


Figure 8.30*.Sketch by surgeon showing the initial idea of the fistula model.*

Then the surgeon took a toilet paper roll and continued to describe his idea using the material (row 3). The surgeon then tore up some sheets of paper and shaped them into a circle to represent the perianal area (the buttock) and pelvic floor (row 4). Using this rapid mock-up, the surgeon also explained about the particular anatomy as well as a brief idea about how to operate the model (row 4 and 5).

They continued the session with the making of a more precise mock-up. The designer started this by building the second cylinder as they agreed to use the toilet paper roll as the first cylinder (row 6). Then the designer handed over the second cylinder to the surgeon to decide the best size (row 7). This process was repeated for the third cylinder. In this process, the designer took the responsibility to build the structure and the surgeon annotated the details (row 8). Then they put together these three cylinders in layers to review the design before these cylinders were fixed together (row 9). After they were fixed, the designer reminded the surgeon about another part to be included but the surgeon suggested that this part can be abandoned for now (row 10).

The session continued with the participants completing the mock-up by applying a base to it. The base was cut and fitted to the mock-up by designer but the surgeon who decided on the size and the detail annotated on the base (row 11 and

12). This was similar with the previous process on the cylinder. Then the designer fixed together the base with other part of the mock-up (row 13). The surgeon then decided to add a hole on the base. The designer dissembled the mock-up and fulfilled the surgeon's request (row 14).

Next, the surgeon used the mock-up to demonstrate the use of the product. He did this with making a hole in the annotations on every part of the mock-up (row 15). Then he took a pipe cleaner to replicate the fistula track by putting it through the holes he made. He also labelled the cylinders with particular names, e.g. "internal sphincter" as this will inform where the fistula occurred (row 16).

He did this evaluation process twice in the session and the second test was more subtle, as at this stage, he tried to compose the operation procedure more precisely. In the first test, the surgeon commented about the desirable size of the product as he found difficulty in operating the mock-up. He also decided that the base that represented the buttock should be flat as we were designing the mock-up. The surgeon commented that it "sits nicely on the table, rather than having a realistic buttock, but maybe not free standing" (row 17).

After the surgeon reviewed on the mock-up, he explained that he realised the hole made on the base was wrongly designed because as this hole replicate the anus, it should be the same size of the smallest cylinder on the mock-up, not the biggest one. So the designer took the cut out section from the base, made the suggested size of hole and applied it back to the base with adhesive tape (row 18).

At the end of the session, the designer did a 'post-mortem' where he briefly reviewed the session and asked the surgeon about the co-design process (row 19). The surgeon indicated that he was satisfied with the outcome (mock-up) as it made the surgeon's idea tangible. Details of the surgeon's comment can be found below (8.3.3d).

8.3.3 Analysis and discussion

I had two responsibilities in this session. As a designer, the aim of the session was to seek design concepts for visualising a fistula-in-ano MRI reports using mock-ups. For the research, the aim for the session was to look at the process of co-designing using the method identified in pilot studies. The basic design

concept was proposed by the surgeon before the session set-up; this gave opportunities for the designer to add materials to the mock-up kit suitable for the surgeon's idea.

As in Mr Brown's project, the analysis was based on my reflections on the experience as a participant and also on my observations of the video recording of the session. The focus was to look at how the designer and the surgeon used the mock-up kit and how they reflected on their actions and the artefact (Fig. 8.29) they made. I will use above Table 8.02 to support my discussion below and refer to it by the numbers of 'rows' in it.

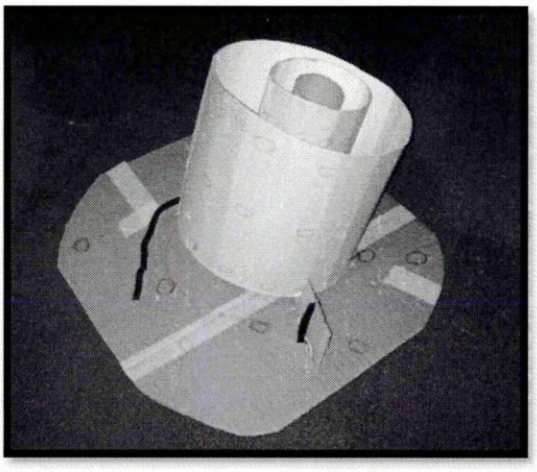


***Figure 8.29**. Type 1 mock-up. Built during co-design session with the surgeon.*

I will use the term 'simulator' to describe this product that I and the surgeon developed. The term 'mock-up' will be used to describe the paper prototype that we built in this session.

8.3.3a How did the creation of the mock-up work in this session?

This mock-up building activity provided a simple schematic way for me as the designer to understand the bowel anatomy; for example, prior to this session, I had not realised that the bowel has three layers, despite studying several anatomical diagrams. This was shown by the surgeon when he made a simple mock-up to demonstrate his initial idea as the main concept of the design. Using materials such as paper and a toilet roll without fixing them together this was also used this to explain the anatomy (row 04).

Then, by taking the idea from that first 'rapid' mock-up, the designer and the surgeon built another reliable mock-up that showed the size, assembly procedure as well as evaluate the usability of the model (row 6 to 19).

The model (proposed product) was designed as a manually-operated product so, once we made the mock-up, it was simple to undertake a usability test (row 15). From the evaluation, we found some aspects of the product could be improved. We did on-the-spot changes to the mock-up and then tested it again (row 12). This was similar to Ehn &Kyng's (1991) project, where mock-ups of computer system were altered by users during enacting their way of working.

8.3.3b The designer's reflection

As explained in 8.3.1, I was familiar with the surgeon's context due to my experience in my previous MA project. I examine on anatomical models during that project which gave me some understanding on bowel anatomy (8.2.1b). So, in the co-design session, I could understand what the surgeon meant when he explained the basic structure of the bowel anatomy, especially when he used the mock-up for demonstration purpose (row 2).

Building on this, I gained more understanding of the surgeon's context through making the mock-up, especially from the three layers of cylinders, and this helped me understand the significance of the design features proposed. Notably, the surgeon avoided using medical jargon and rather used general terms through the co-design session.

From this experience, I suggest that repeated cycles of engagement in the user context may be necessary in order to increase the designer's understanding, and to enable them to seethe needs from the expert's point of view. It may also indicate that there cycles can emerge from the mock-up building process.

I built mock-ups together with the surgeon using his idea. However, the observations showed that the surgeon and the designer made different contributions to the mock-up. This can be seen from Table 8.02, e.g. the designer constructed a cardboard cylinder (row 06), then the surgeon took over to decide the size (row 07) and drew small circles to indicate holes (row 08 and 12). This

was a tacitly agreed cooperation which appeared to play to each participant's respective strengths and experience.

From the video observation and reflection on my experience during the session, the designer and the surgeon altered the mock-up immediately after evaluate it e.g. at first the surgeon decided to cut a hole on the base (row 14) but revised the hole size after he simulated the procedure using the mock-up (row 18). This may show that the designer and the surgeon reflected on their decisions during the building of the mock-up, this includes evaluation. This is not new as Ehn & Kyng (1991) describe that this also occurred in their research where their participants annotated changes on the mock-up through enacting their work, however, in my case, the alterations were made during the designing and influenced the final design as well as the designer's understanding.

8.3.3c Surgeon's initial feedback.

As the researcher, I asked the surgeon's opinion of the process of designing using mock-ups during the co-design session. At an earlier stage of the session, the surgeon explained that he had never been involved in any product development project such as this one, and this was the first time he'd designed and built a mock-up. He then expressed his opinion about the method during the session.

> *'...I only had a rough idea in my mind for what it was and then seeing it, actually bigger than I thought. In my mind I thought it will not be as big as this. Now I see it in real life, this is the right size to do it. In my mind it was half the size of this, which is a bit wrong. It made me think about my clinical knowledge and then to explain to someone who was not a clinician and then to make a schematic of it, it is something that you think. Because a lot of what we do is we don't think about it, it's like a nature, and then step back and think, o yeah, that's the basic bits. So, that's made me think, and then you know that three layers, actually now looking at it, you do need all three layers, so it makes me think about all the basic problems in the wider context, yeah definitely...' Minutes 1:46.00*

My interpretation was, by designing with mock-ups, the surgeon would experience the physical appearance of the design; for example, the overall size of the product as well as the components of the product. The surgeon commented that it is difficult to explain their tacit knowledge to other people who lack a clinical background. However, through the mock-up building, he was able to stop and evaluate his action by reflecting on his clinical knowledge of the mock-ups and acted on these reflections e.g. the surgeon confirmed his decision to make three layers of cylinder to represent sphincter muscle layers, after he had the mock-up to hand.

8.3.4 Outcome of the co-design process and further development of the fistula simulator.

The idea proposed (fistula-in-ano model) had been discussed between the surgeon and radiologist before my involvement. They agreed in principle to having the design made for evaluation. Interactions with the designer opened the opportunity for the surgeon to express his problems, needs and ideas and the designer help him to realise the idea in the co-design session.

So, the co-design session undertaken was to take the surgeon's idea and build it with the use of a mock-up kit. Problems, needs and ideas from the surgeon were noted for the next mock-up. As the surgeon agreed that the mock-up of the fistula model may have a place in the market, we extended the project for further development.

In the co-design session, the mock-up was roughly built without applying exact details, such as holes and suitable fittings for the parts. So, the next development was to include these details in the mock-up. Cardboard is cheap and easy to handle, and therefore it was chosen as the material for this stage-2 mock-up.

Stage-2 mock-up was made away from the surgeon's direct involvement because it took a longer time to make and this was not suitable for the surgeon's work schedule. I used laser cut technology to get the details cut on the cardboard (Fig.8.32). A pipe cleaner was used in the co-design session to represent the track of the fistula and it worked well, so we decided to retain the use of this material. Numbers from 1 to 12 were written under the holes to indicate the coordinates for

the fistula tracks which based on the surgeons explanation for the coordinate system used by radiologists and surgeons as well as the annotations on the first mock-up. Then the mock-up was given to the surgeon for self-evaluation.

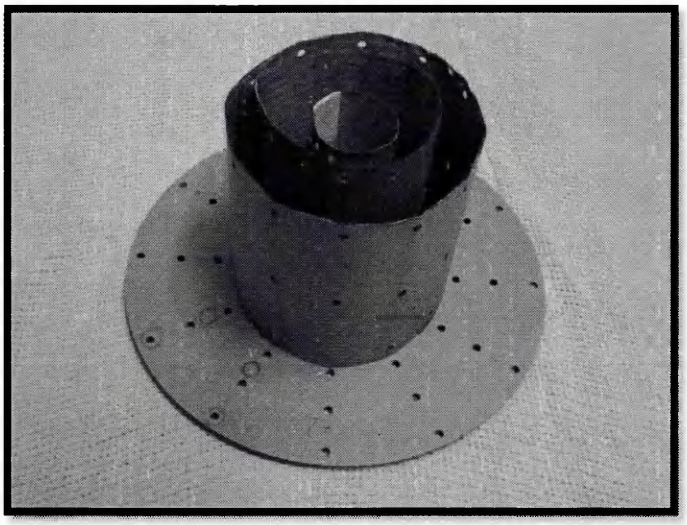


Figure 8.32.*Type-2 mock-up. Built without the presence of the surgeon.*

At this stage, we refined the model operation procedure after the surgeon 'played' with the mock-up several times. We suggested,

1. To start using the model, the second and the third layers needed to be detached from the model.
2. Then, using a tracker (something to replicate fistula track) start at the first layer as a starting point.
3. Continue with the tracker on the second and third layers and attach it back to the model, one after another.

The surgeon also came back with comments which he'd written on a post-it note, as well as drawing them on the mock-up. He suggested that the tracker needed to use any cable-type wire which had a memory or retained its position after being bent; it may also need to be bigger than a normal electrical power cable. The holes on the mock-up need to be bigger and the surgeon drew on the mock-up to suggest the size.

He also wrote the numbers with the desired size on the mock-up. He took the Stage-2 mock-up to the radiologists to evaluate the initial design. They decided to have the pelvic floor included on the model as the surgeon proposed in the co-

design session. The designer took the users' concerns and revised the design by building the Stage-3 mock-up.

Stage-3 mock-up was built to fill the surgeon's requirement from the Stage-2 mock-up and cardboard remained as the main material (Fig.8.32). As with previous mock-up, this one was also given to the surgeon to be evaluated. An evaluation questionnaire was provided, together with the mock-up. From the surgeon's and radiologist's feedback, they agreed the initial design was promising.

However, they could not interact thoroughly with the design as it was built using cardboard. They thought the mock-up was good enough to show the overall idea and confirmed the use was realistic. To evaluate the design, they suggested a sturdier prototype may be more effective.

An ideal co-design project would include the radiologist in the mock-up session as they will have the job of placing tracks in the simulator. However the aim here was to explore collaboration between designer and surgeon, rather than develop an ideal process for this particular design project.

8.4 Expert review: enriching the data from video recording evidence

A session was set up where relevant experts was invited to watch the video recording evidence as a post hoc method to confirm and identify what happened in the co-design session. This was also to enrich the data collection for the research.

Participants invited were as follows:

- Two practical designers who had experience collaborating with users in the medical domain.
- An interaction design expert.
- A design professor who had experience with design in medical and healthcare.
- A design researcher with an engineering background.

- A design researcher with a graphic communication background.

The participants were also selected because they may benefit from adopting the methods explored in this research and can compare them with their own experiences. Participants were exposed to the video (Fig.8.33) and they reflected on the issues in the video regarding methods used within the co-design session (Fig.8.34).

Figure 8.33. *Experts watching the video of co-design session between designer and the surgeon.*

Figure 8.34*. Discussion between the experts regarding the issues raised from the video.*

The equipment used in the session was a video from Mr Chapple's project, the mock-ups made by the surgeon and me during the co-design session, and the game, Kerplunk, which the surgeon got the idea from. This project was chosen because the data shown in this project was more consistent and richer. This session was video-recorded as a reference and the participants' comments in the session were compared and analysed with the observations I made before. They were asked the following questions:

- How does this relate to other experiences they have had?
- What are the important events in the video?
- Could they adopt any ideas from the process in their own work?

At the beginning of the session, the experts were briefed about the design project and the needs for the research. In this briefing, they were told that they can stop the video at any time if they needed to make instant comment on certain part of the video. Then they were exposed to the video for observation.

As they were given some question as above as an initial idea of how can they comment the data, they observed more on the interaction and actions undertaken by the collaborators from the video. They made an observation on the 'designerliness' of the surgeon by looking at the process of making and the mock-up as the interaction tool between the designer and the surgeon but did not comment anything about the design including form and shape of the artefact. I listed below issues they raised during the session.

- The use of general terms by both collaborators to replace specific jargons.
- The engagement of the surgeon in the making.
- The use of mock-up kit during the design process.
- The quality of the mock-ups made during the process.

Comments given by the participants will be used in Chapter 9: Discussion to help develop the outcomes for this research.

8.5 Summary of the practical work

The practical work contained two separate collaborative design projects with two surgeons, both in the colorectal surgery domain. The first project was to find a new concept for clamping the rectum in surgery. The other project was to design a visual tool for the surgeons and radiologists to use when visualising complicated MRI scans in bowel disorders.

These projects were the main source of the research data. In them, mock-up kits were used as a collaborative design tool between designer and surgeons. Different materials were used in the mock-up kits due to different needs and issues. The mock-up kit for Mr Brown's project was a box of everyday things containing eclectic materials with assorted shapes. On the other hand, Mr Chapple was provided with cardboards, plastic straws and pipe cleaners chosen following reflection on Mr Chapple's design concept.

In Mr Brown's project, a mock-up of a surgery simulator was built together in meetings before it was used in the simulation/designing session. This simulator was built as a tool to share the surgeon's experience and knowledge in a particular surgical procedure. It was also used as a tool to develop a new surgical instrument in the co-design session. The preparatory work in the clamp project took a long time, but this gave the designer more time to understand the user's context.

The co-design session was undertaken with the surgeon in conjunction with the simulation session. In this session, the surgeon used the surgery simulator to show the designer the surgery procedure: anastomosis. Then they moved to the co-design session and used the mock-up kit containing eclectic materials to design a modified rectal clamp. The surgeon refined the mock-up using another type of material he found around the room and made it functional and then tested it on the simulator. He also made some changes on the simulator and agreed that the simulator itself worth developing as well as the rectal clamp.

Mr Chapple was introduced to the designer by the university enterprise centre. The interview was undertaken with him in a meeting long before we engaged in the co-design session. It was simpler to set up than the clamp project because the

context and activities did not directly concern patients. This resulted in the need to have two meetings and one co-design session. Through the co-design session, contextual questions that were asked in the meeting were asked again to generate the momentum during the co-design activities.

Sketches were used by the designer and the surgeon at the beginning and during the building of the mock-ups, which were initiated by the surgeon. Through the mock-up building, the surgeon did the design and detail for the mock-up and the designer built the main form of the design according to the surgeon's requirements. They tested while they built the mock-up, which stimulated the design development. This then provided firm decisions on the size, details and usability of the product.

The projects were video-recorded, to act as the reference and data collection for the research. They were transcribed and coded using Nvivo and analysed to seek significant action which may indicate the approach used was a valuable method that might be used by other researchers in a similar setting. These were discussed in the analysis sections (8.2.4 and 8.3.3).

Three products were proposed as a result of these two co-design projects. They were:

1. Rectal clamp – this proposal was put aside for the time being as the surgeon preferred to develop the surgery simulator.
2. Surgery simulator – a recreation of a human abdomen containing simplified organs that related to the operation. To be proposed as a training aide for training surgeons.
3. Fistula simulator – a 3-dimensional visual aid used to recreate fistula-in-ano from the MRI scan.

Participatory design methods explored in these projects showed some findings in conjunction with the use of lead user characteristics. Contextual immersion undertaken by the designer showed that by doing this, allowed him to feel and understand the surgeon's propositions. This contextual immersion also happened through the making of mock-ups and the making showed that it allowed the surgeons to use some strategies designers use in designing.

An expert review session was undertaken to confirm and identify the data collected in the co-design session. Comments from the experts will be used in Chapter 9 as support for the research's claims.

Chapter 9: Discussion

9.1 Introduction

In this chapter, I will explain the method I developed and used in two design projects using my own reflections and also those from the experts review (8.4). The method which I termed as 'Mocking Up' was developed from exploration of participatory design methods in a co-design setting. This will be followed with a discussion of related issues which influenced the method.

Most examples I will use are from the fistula project as this project generated more data and the methods were better established after the previous rectal clamp project. The video of this project was also used in the expert review session to enrich the data collection through experts' comments and discussions. This expert review session was also become method to validate the process where they provided external expert views to balance my single participant observation method. This is important to my research and I propose it become part of my research process.

The first section of this chapter will discuss the proposal of my method 'Mocking Up' developed through the research. The surgeons are creative users and using Mocking Up, enabled the surgeons to use 'designerly' strategies or in other words work like designers. The development and evaluation of this method is my main claim for contribution to knowledge in this research. I will discuss what is

'designerly' and give the examples from the practical work to show the evidence for this.

Secondly, I will discuss the designer and the surgeon partnership in the design project to position them in balancing the power in collaboration. Thirdly, I will discuss how the making of the mock-ups is significant in the method developed. This section will be ended with discussion on the conditions needed for Mocking Up to be undertaken.

The research found out that the collaborating surgeon was closely matched to the characteristics of Von Hippel's lead user (4.5.3). However, the research was not exploring Von Hippel's lead user innovation approach, but having lead users as collaborator may be a topic for further investigation. The chapter will end with discussion of the surgeon's position as a lead users and their relation to 'Mocking up'.

9.2 'Mocking Up': enabling users to employ designerly strategies

I have investigated the concept of 'Mocking Up', which is a design setting used to understand user's contexts through simulating their professional activities. It is built on the two key concepts of "contextual inquiry" and "mock-ups" in participatory design. 'Mocking Up' was undertaken as design a collaboration between designer and surgeon.

Mocking Up is a creative collaboration between designer and non-designer. In the projects, through the making of mock-ups, the users were actively involved in the development of concepts by exploring their ideas, turning them into something they can physically see, touch and play with.

This may be considered as a co-design approach. It fits Sanders and Steppers (2008) co-design definition of co-design or co-creation as collective creativity between designer and persons who are not trained as designers. Their examples from design projects (ibid) and methods used in co-design project (Sanders 2000) indicate that co-design is a relevant method for the fuzzy 'front end' of the design process.

The mocking up design project followed on from this research and this was explained to the surgeons at the beginning of the projects. If the surgeons remain involved in the design projects this may provide further opportunities for research into collaboration in the later stages of designing.

The 'Mocking Up' approach includes three main activities:

1. Users come with proposition.
2. Contextual immersion by designer.
3. Co-evolution of problem and solution through the making of the mock-ups.

As showed in (8.2 and 8.3), the surgeons came with problems, needs as well as ideas. They proposed ideas at the beginning of the project that they thought may solve their problems and needs. We focused on these ideas and explored them through the co-design sessions and developed them into 'products'.

As discussed in 5.8.1, 'contextual immersion' means the designer immersing themselves in the user's context by undertaking practices that may gave them understanding about the users and related issues. The designer made a review of the users' context by reading relevant scientific publications, studying relevant anatomy and the disorder by means of images and medical models (8.2.1) and also undertaking contextual interviews with the stakeholders (8.1).

The designer acquired only a superficial knowledge of the users through these activities. Nevertheless, these activities allowed him to empathise with the surgeon's professional work. Contextual immersion was also continued during the idea development through the making of the mock-ups (8.2.2 and 8.3.3a). Surgeons informed this process by using their tacit and explicit knowledge gained from years of training and practice in the same domain and demonstrated this through making and using the mock-ups.

In Mocking Up, mock-ups became both the communication and the design tools. They became the vehicle for the designer and the surgeon in designing. Its potential usefulness was identified originally in the review of methods (4.4) and was confirmed in practice through the practical projects (6.4.3, 8.2, 8.3)

The process of making the mock-up was important for the method developed. This process allowed the designer and the surgeons to develop their understanding of the problem and the solution through the making process. In Mr Brown's project, the surgeon radically changed his design aims during the mock-up process. In Mr Chapple's project, the surgeon remained focused on his original idea and indicated the impacts of mock-ups on his evaluation as the design developed. I will discuss further for this below in 9.3.

The various activities were not segregated but overlapped and contributed to each other during the process. This can be show as diagram below (Fig. 9.01),

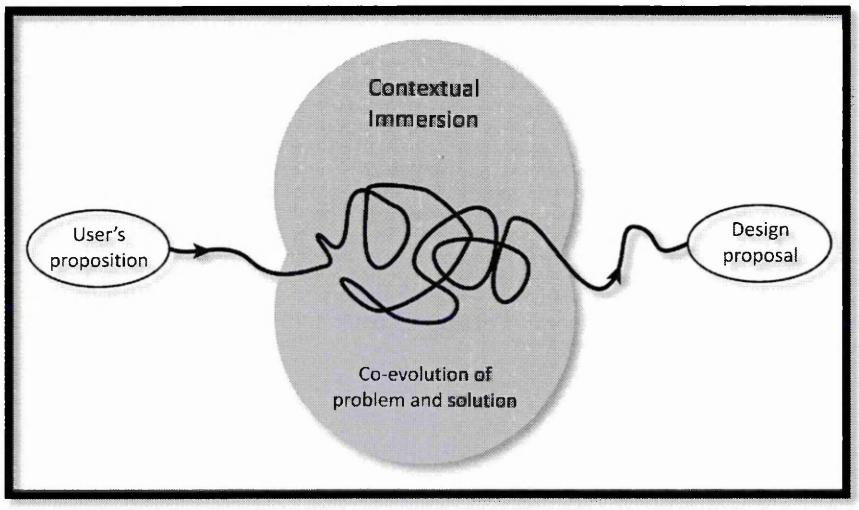


Figure 9.01*. Diagram of Mocking Up illustrates the user's proposition becoming a design proposal developed through contextual immersion and co-evolution of the problem and solution.*

My main observation in this research is that, by undertaking Mocking Up, as a designer, I enabled the surgeons to use 'designerly' strategies in developing their ideas with me.

Earlier researches have explained 'designerly' by describing what designers do and the reason behind it (Cross 2007, 2011; Stolterman 2008; and Gedenryd 1998). In this research, I have found evidence which may indicate the surgeons worked like designers through collaboration with the designer. I will discuss this further below in 9.3 in conjunction with review from the experts to support my

claim that this method is a useful practical tool for designers to use with surgeons and other expert users more generally.

Cross (2007) suggested that everybody possesses design ability including non-designers, at least in some aspect. As discussed in 4.5.2, Sanders and Steppers (2008) suggested that everybody in this world has a latent creativity. Sanders and Steppers used daily problems and needs as examples to show that non-designers do things creatively or with design ability. As discussed in 3.1, some surgeons historically were indicated as innovative e.g. they designed their own surgical tools. A recent scientific publication (Hompes et al. 2012) and an innovation publication (Luthje and Herstatt 2007) showed that some current surgeons are innovative by designing their own surgical tools.

However, some surgeons may have barriers to becoming involved in innovation or creative activity. The collaborating surgeons informed me that they had limited time and financial resources to involve themselves in innovation activity (3.6). Workloads on surgeons are very high (Ramesh 2011) and this may prevent them from engaging in research and innovation activities. Leuthardt (2006) described how workloads were holding back neuro-surgeons from engaging themselves in innovation and research work.

The practical projects in this research indicate that mocking-up enables surgeons to use designerly strategies in short creative sessions. The designer acted as a facilitator in the projects. He provided the mock-up kit, design skills and the ability of exploring and knowing the consequences in designing, allowing the surgeon to achieve a creative result in the short time available.

The surgeons in this project showed evidence (8.2.1a, 8.2.2c, 8.3.1) that they were 'Lead Users' as described by Von Hippel (1976, 1986, 2001, 2005). Mocking Up may be a useful extension of Von Hippel's lead user innovation approach. This will be discussed further below in 9.3.

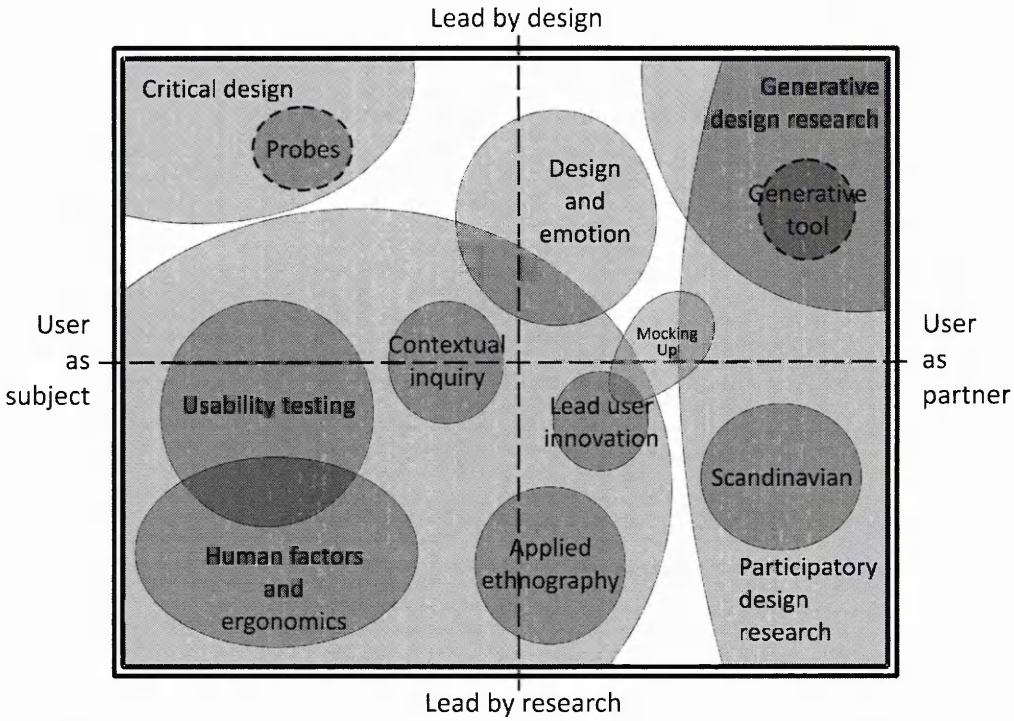


Figure 9.02*.Human centred design landscape and the position of Mocking-Up within it. Adopted from Sanders and Steppers (2008).*

This research documented and analysed a co-design process between a designer and non-designer user (the surgeons) working together in a design environment. Mocking Up is a method which is led by design and the surgeons are partners to the designer in designing. It may intersect with the 'lead user innovation approach' where it was indicated that this method involved users with Von Hippel's lead user characteristics (1976). I adopted a diagram of human centred design landscape illustrated by Sanders and Steppers (2008) to position my approach between current methods in the landscape (Fig. 9.02). A diagram of the process for the 'Mocking-Up' method can be referred below in Appendix 6.

9.3 Designerly Strategy

Using Mocking Up with the surgeons enabled them to use a 'designerly' strategy in a collaborative setting. As discussed above (4.6), Nigel Cross (2007, 2011) discussed the issue of designerly thinking and clearly described how designers think. He strongly believed that certain type of designers, e.g. industrial designers are trained to address Rittel's (1993) 'wicked problem'. Erik Stolterman's (2008) also referred to wicked problem when he discussed design methods that

developed in the area of HCI but cannot be fully utilised in the real design process became of the lack of understanding of design thinking during the development of the methods. Gedenryd's (1998) explained how this 'designerly' way of working happens through his 'interactive cognition' theory.

Such designerly strategies were observed in both co-design projects and will be discussed below. The fistula project provided the richest evidence. Nevertheless, the trajectory in the clamp project was actually interesting because it involved redefining the problem through mocking up.

9.3.1 Problem reframing

As discussed above, designers tend to reframe problems during the design process (Cross 2007 pp103) and this was indicated in the clamp project. The surgeon initially proposed a new concept for a rectal clamp which he saw as a possible solution for his ergonomic problem during surgery. But he changed his design target from designing a new rectal clamp into developing a surgery simulator through mock-ups produced to help understand the surgical procedure and test design ideas.

As discussed in 8.2.5, the surgeon started with one problem which can be described as a normal engineering problem which might be solved by methods in ergonomics but the collaboration produced a more fundamental and different problem, about communication and perception.

9.3.2 Use, test and sketching out

Cross (2007) describes how designers understand problems through the exploration of problem solutions. Gendenryd (1998) then suggests that this happens because it is the way designers use and test their knowing (problem setting + proposal of possible solution). Sketching out possible solutions is a way for a designer to see and reflect on his idea (Cross 2007) and as a way to use and test the problem setting. The artefact from making is not always the product of designing but the means of designing (Gedenryd 1998 pp 85).

This was evident in the fistula project where Mr Chapple sketched out his idea roughly using the mock-up kit facilitated by the designer (Table 8.02 in 8.3.2).

He built a mock-up from paper and a toilet paper roll to explain the relevant anatomy (Fig.9.03).

A design expert commented on this in the expert review session,

> *'I think that process of engaging in that way, enabling him to learn about his concept as it develop ... ' Minutes 56:11.*

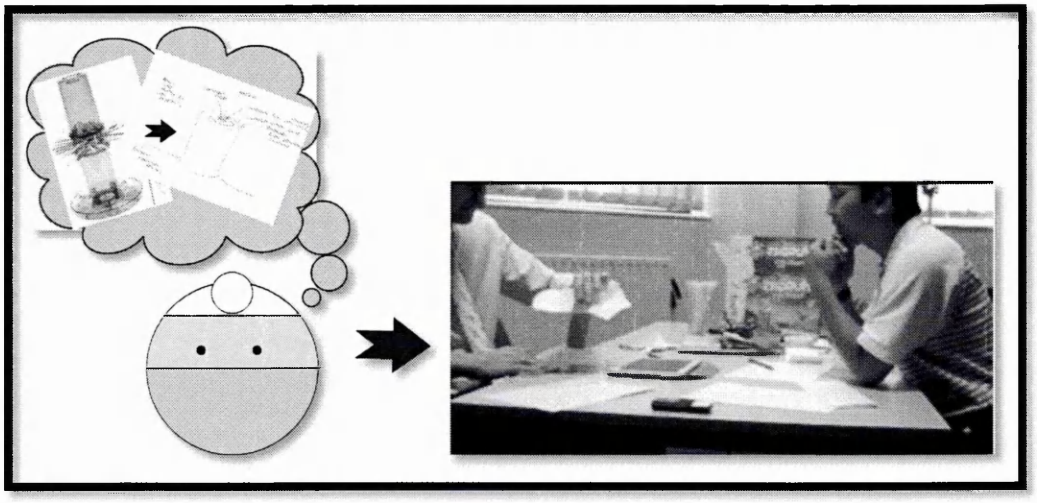


***Figure 9.03**. Surgeon sketched out his idea using mock-up.*

This sketching out continued and the designer provided the surgeon with making skills where he became the hands for the surgeon. The mock-up was built according to the surgeon's description. Nevertheless, the mocking-up or the exploration of the surgeon's idea developed the understanding of the problem and the possible solution (for collaborators). For example:

9.3.2a Setting the right size.

Minutes 35:02 – the designer hands over the cardboard he cut to the surgeon for him to decide on the size of the cylinder (Fig.9.04). The surgeon observed, adjusted and tried it out with his hand to decide on the suitable size. They continued to do this (construct the cylinders) for three layers of cylinders. Note: cylinders in the design represented the three layers of sphincter muscles.

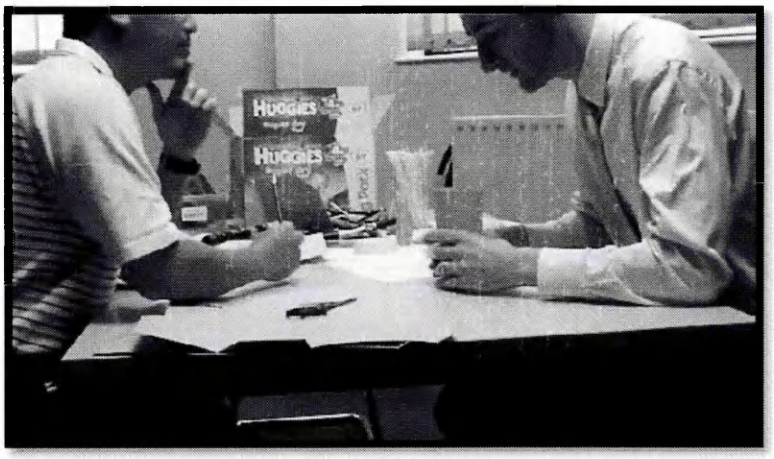


Figure 9.04

9.3.2b Simplify the anatomy

Initially the surgeon's idea was to have the exact replica of the anatomy. However through the making of the mock-up, he decided to simplify the model for ease of use (Fig.9.05).

Figure 9.05

> *'...it's not anatomically correct but it sits nicely on the table. Rather if we have the correct anatomy (hand gesture of buttock's shape), it would be wobbly, ... Minutes 1:55:00.*

9.3.2c Discarding less important part

The surgeon abandoned the part that replicated the pelvic sink (see Fig. 9.03, the top funnel shape) as he realises that it will confused the future users (Fig.9.06).

Here he also said "*having this in 3D..... ...*" He showed that by having the mock-up, made him rethink of the functionality and important parts of his initial idea.

Figure 9.06

Designer : "what about this?" (showing the funnel shaped paper to the surgeon)

Surgeon: "that one... hmm.. The more I think about it, it just going to confuse them" Minutes 1:06.37

9.3.2d Applying and revising detail

The surgeon took a long and focused look at the mock-up, turned it over and over and sketched the holes to find the best points to put the holes (9.07).

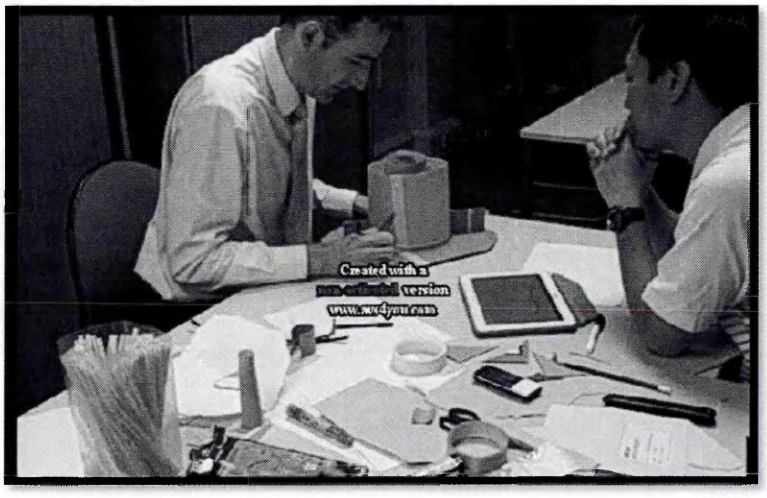


Figure 9.07

Minutes 1:57.92 – In the co-design session, the surgeon used the mock-up to test the usability by simulating the future usage of the product (this then initiated the

operation procedure of the product). This allowed him to revise his decisions on the detail of the design e.g. he put back the hole cut on the mock-up as he realized that the hole was wrongly replicated on the bottom cavity (Fig.9.08).

Figure 9.08

From these observations, I suggest that Mocking Up enables users, in this case the surgeons, to use designerly strategies in exploring their propositions. The strategies indicated in the projects were co-evolution of problem and solution, problem reframing, and making as enquiry, as well as situating strategies. However, this is not to claim that by using this approach, it will transfer the skill of the designer to the surgeon. Instead, the intervention of a designer in this type of situation and using accessible design tools such as mocking-up, enabled the surgeon to used designerly strategies.

9.3.3 The role of making mock-ups

Mock-ups are core in this approach to collaboration. However, the mock-ups themselves are not the main focus, rather than their construction that becomes the vehicle for idea exploration.

As discussed in 4.4, mock-ups were used in earlier researches and practices and they offered promising advantages in involving non-designers in the design process (Ehn & Kyng 1991; Long & Hughes 2011; Vaajakallio & Mattelmaki 2007). A number of specific effects of mock-ups can be observed in the projects (8.2.4 and 8.3.3a).

9.3.3a Making the simulators became a good tool for contextual immersion.

As described above in the clamp project (8.2.2), a mock-up of a medical simulator was constructed to answer ethical questions which prevented me from working in the surgeon's actual environment. This *simulator* became an alternative environment for the surgeon to demonstrate surgical procedures (Fig. 9.09).

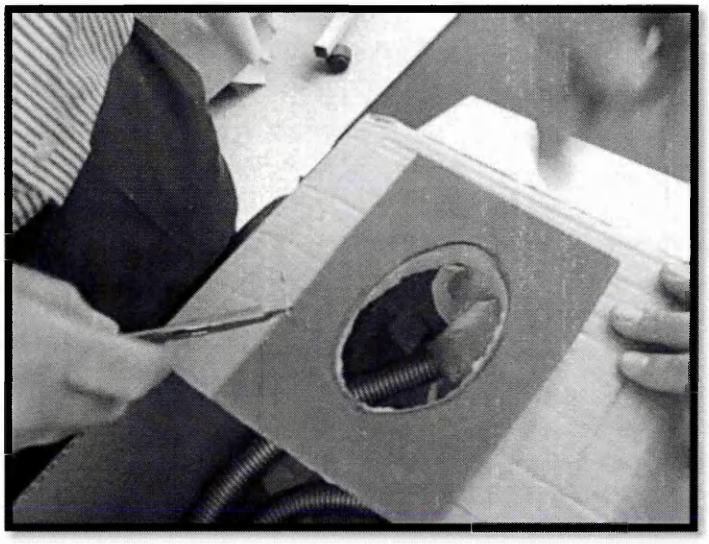


Figure 9.09. *Surgeon demonstrated suturing procedure to designer. (Rectal clamp project)*

As described in fistula project (8.3.3a), mocking-up was used to manifest the surgeon's idea of *simulating* and recreating the anatomy and the disease in a physical model which then can be used for communication between stakeholders (surgeons and radiologists). Seeing this through the 'making' process provided the designer with an understanding of the user's specific context, i.e. anatomy, operational procedure and disease, and these were transferred through the mock-ups.

In this setting, the designer became the surgeons' 'apprentice' through making and seeing (Holzblatt and Jones 1992).

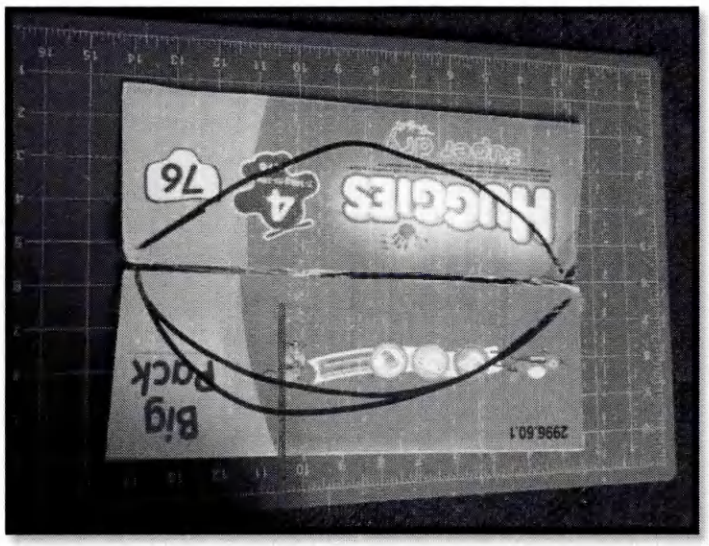


Figure 9.10. *The surgeon drew on the mock-up to represent the standard incision made to human torso for surgery. He also gave an explanation about how surgeons made this incision.*

For instance in the clamp project, the surgeon drew on the mock-up the normal incision made on the patient's abdomen and the designer used this as a template to recreate another incised abdomen using more suitable material (Fig. 9.10). In another instance, the surgeon in the fistula project constructed a simple mock-up to show his idea which also a reconstruction of the related anatomy (Fig. 9.11). This supported Ehn & Kyng's (1991) and Long& Hughes' (2011) claims that mock-ups can reveal the users' context.

Figure 9.11. *The surgeon used materials provided by designer to build simple mock-up and explain the anatomy by using the mock-up.*

9.3.3b Mocking-up allowed the surgeons to participate in the creative process

As described in both projects (8.2.4 and 8.3.3a), the designer constructed the main mock-ups in the design workshops, enabling the surgeons to experience the

creation of their idea. This then *enabled the surgeons to explore and understand the design aims* in the projects. Nevertheless, the mock-ups may not work without the designer's intercessions in the making of the mock-ups. So the mock-up kit and designer's making skill combined to allow surgeons to be involved in the designing. One of the expert reviewers agreed with this and commented,

> *'...the process has enabled a platform and creates space and time to collaborate in that way so, this only probably happens with a designer intervention...' Minutes 1:28:19*

9.3.3c Mocking-up became the communication tool in designing

For instance in the fistula project, the designer and the surgeon at some points were concentrating on the making of the mock-up and did not fully communicate verbally. Both of them continued to do their work based on the mock-up (Fig. 9.12). As an expert reviewer commented,

> *'...quite a period that when there is no dialogues in this video. But there was gestures which communicating through that thing...' Minutes 1:14:46.*

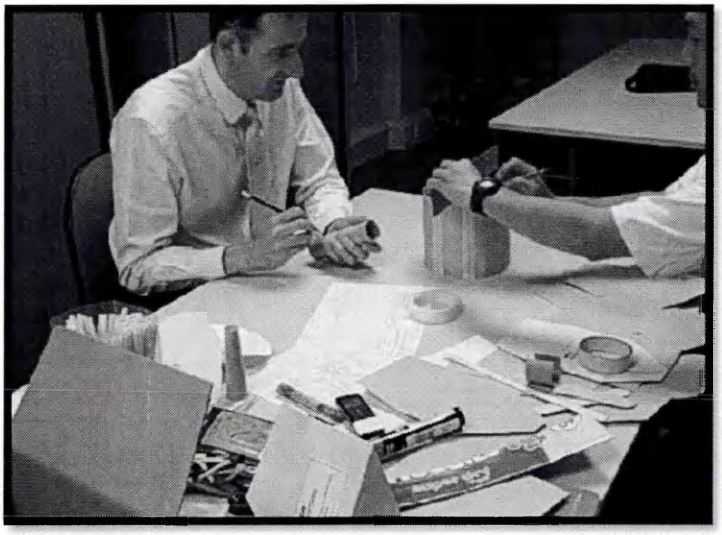


Figure 9.12*.the designer and the surgeon continue to work without communicating verbally.*

9.3.3d Mocking-up explored the surgeon's ideas by constructing it from scratch to artefact

Vaajakallio & Mattelmäki (2007) enabled their participants to become involved in designing by using a form of mock-up kit which they called a 'Make Tool'. This 'Make Tool' is used by the participants by mix and match suggested elements to propose new designs of devices and explore design possibilities by pretending to used them in the future. In contrast the surgeons explore their idea with the designer from scratch through artefacts with no predetermined elements by the use of an 'open' mock-up kit of very diverse and flexible materials.

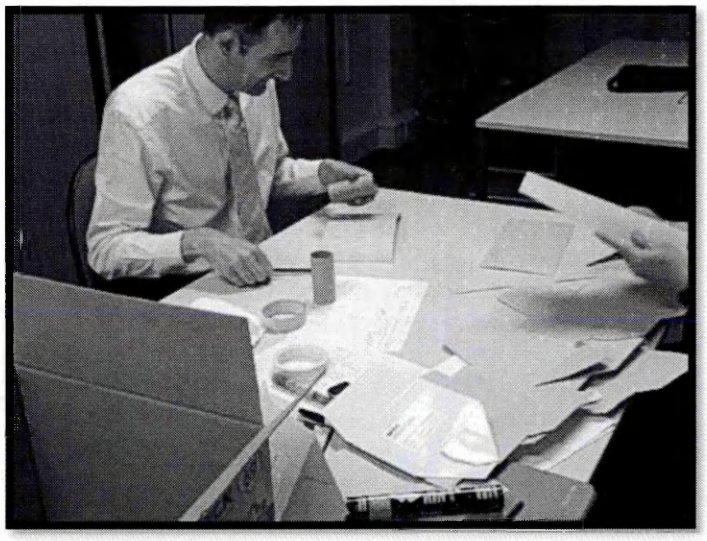


Figure 9.13.*the designer and the surgeon making the mock-up together from scratch.*

For instance, in the fistula project, packaging cardboards were used to construct the mock-ups. To use such 'raw' material, it required cutting, shaping and annotating on the material (Fig. 9.13).

So, this may suggest one of the reasons that Mocking-Up was successfully undertaken was because the designer possessed high making skills and experience of this kind of construction. He constructed a sturdy mock-up in a very short time which enabled the surgeon to test the design.

Someone who preferred drawing may focus on a beautiful drawing but the designer did not produce a beautiful mock-up in the fistula project, yet productively made a design with the surgeon. So, creating beautiful artefact is not the point for the designer at this stage of a project but producing understandable

mock-ups enables the co-design development to move forward. As the expert reviewers commented, the crudeness of the mock-up gave confidence to the surgeon and removed the designer's ego as the dominator in designing.

9.4 Partnership between designer and surgeon

Above I have described how Mocking Up allowed the surgeon to use 'designerly' strategies with the assistance of the designer and accessible materials for making mock-ups. This may only be successful when the designer and the surgeon act as partners in the design project. An expert reviewer commented on this,

> *'...in normal circumstances there are two things that that you need to overcome, (1) to make the professional communicate with you and (2) to encourage them to go into the practical thing of it. These two barriers, I think you don't face in this session' Minutes 50.06*

The surgeons may have their own interest in the projects that made them active collaborators. However, their interests in collaborating in the project were unclear and this question was not directly put to them. The designer and the surgeons had a mutual understanding at the beginning of the design projects. At the first meeting the surgeons proposed products to be developed (from their experience of the problems and needs) and I explained the benefit they could get from the intellectual property (IP) if the designs were novel.

Nevertheless, the surgeons did sometimes mention some benefit they could get from designing the product they proposed. Both of them proposed the potential for the use of the products they designed. Mr Brown mentioned how one can get a financial benefit from his proposal for a new product. Mr Chapple was more focused on a gain for his practice from the fistula simulator he proposed i.e. a shorter time to understand complicated fistula.

As discussed above in 4.2, Holzblatt and Jones (1992) suggested that to understand the user's context, one must become the user's apprentice through a partnership. As discussed in 4.5.1, Arnstein (1969) described the partnership's ladder of participation. One needs to acknowledge that the decision power is

shared between the partners and no one will be neglected in any resolution. This was the case between the collaborators in the co-design sessions.

As an expert reviewer commented,

> *'...the practical process that you gone through is a great leveller...that a kind of open door to creativity...' Minutes 1:20:54*

As described above (8.2.4 and 8.3.3), the *designer acted as the partner and also the facilitator in the design collaboration*. The designer did this by bringing the design process to the surgeons and making the design development process accessible and usable for the surgeons. This allowed them to employ 'designerly' practices, while renewing and reframing ideas through the sequence of mocking-up.

Surgeons in the projects were the users and they became the *source of contextual immersion and this was also shared through the making of the mock-ups*. They were *co-designers in the projects and they were the primary providers for the conceptual ideas* which indicated that they may be innovative users. I will discuss below this partnership by presenting the evidence of the above mentioned roles and how they occurred.

The designer and the surgeon took their specialized knowledge and skills and worked towards a common language for both of them in the session. This was shown in fistula project, at the beginning of the co-design session, where the surgeon changed his specialized term (perianal area) into a general term (buttock) when explaining the anatomy to the designer. And the expert reviewer agreed with this,

> *'it seems that the surgeon in that session knows not to used highly specific terminology, because he knew that you might not understand it.' Minutes 52:44.*

However the designer did not do this (use specialized terminology) in the session. Most of the terms he used were already familiar to the surgeon. However, he 'levelled down' his design skills by not using very refined techniques (e.g. well

prepared sketches) but made a rough mock-up and this may be the reason the surgeon was keen to engage in the creative activity (mocking-up).

The expert reviewers commented,

> *'...you are capable of sketching, intimidating by Sh! Sh! (showing sketching gesture). You didn't impose your design skill to threaten him...' Minutes 1:22:00*
>
> *'..the crudeness of the model was useful to give him (the surgeon) confidence, everything go down from you as the dominator. I think that removed the barrier' Minutes 1:23:16*
>
> *'that leveller in term of language and hierarchy and status, can come through language' Minutes 1:22:01*

9.5 Mocking Up Circumstances

The practical design sessions (8.2.3b and 8.3.2) were about exploring the surgeon's idea and the collaborators were focused on taking the idea into reality. But can Mocking Up be employed in different circumstances, e.g. exploring other solutions/ideas or having other expertise in the collaboration?

Observation in the pilot studies (6.4) undertaken with participants with different background suggested that it may be possible.

***Figure 9.15**. One of the dental surgeon constructing the idea she proposed.*

Bowen (2009a) describes how 'critical artefacts' enable potential users of future products to reflect on their assumptions and explore concepts beyond their prior experience. This seems to have been shown through the pilot studies undertaken in my research although the artefacts used were not directly comparable to Bowen's (ibid) critical artefacts. In my project, early ideas initiated by the participants, when mocked up or discussed, did spark new ideas which the participants believed useful.

In the first example, as described in (6.4.3c), dental surgeons participated in a session which started with discussing their problems and needs initiating several ideas. They constructed them using a mock-up kit and then through the making and reviewing the designs, they came up with other ideas which suggested better solutions (Fig. 9.15).

The second example, as described in (6.4.3b), suggested that Mocking Up can be undertaken with users with very different expertise from surgeons. In this session, a chemist participated in a pilot study where the approach was explored. The chemist explained his specific context, problems and needs through verbal explanations, and the use of sketches and mock-ups (Fig. 9.16).

Figure 9.16. *The chemist use mock-ups to show the concept of current practice in using a particular device.*

Both examples showed Mocking Up may be suitable to be practiced under different circumstances, yet with some common features. The clamp project, the single session, included developing the structure, size, specification and also initial test for the usability of the idea. This suggests that Mocking Up may help

and speed up the design development process if the approach includes these features.

- The project starts with user's ideas (in the example case the surgeon's) and explores them in the session.
- Issues or ideas explored are limited to the function and features that can be explored by mock-ups.
- Experienced and skilled designers provide making skills and the ability of explore and know the consequences (for the surgeon).
- Availability of a mock-up kit with flexible low fidelity materials e.g. corrugated cardboard.

9.6 Surgeons as lead users in Mocking Up.

As discussed in 4.5.3, some surgeons do innovate and could also be considered as lead users. In the main study, I did not select the surgeons using Von Hippel's lead user characteristics thus did not follow Von Hippel's lead user innovation approach. However, Von Hippel's methods often involve providing lead users with tools for innovation, and that is clearly part of the Mocking Up approach. I did attend to and observed their (the surgeons') lead users' characteristics through working with them.

In the expert review, the participants agreed that there is something about the surgeon that made him to act as he did. They said,

> *"He seems **really keen**" Minutes 52.02.*
>
> *'The really interesting thing about this is the space. The act of making in that way just seems to throw away the barriers. **If this will work with any individual I don't know**. But that, sharing common task seems to produce something useful' Minutes 1:14:16.*
>
> *'I am surprised with the surgeon's engagement in the making. Probably with this kind of professional, this method may be appropriate' Minutes 53.30*

'...however I think it is depends on how prepared the individual is to explore something tangibly, and see what is the issue it might be' Minutes 1:28:40

Therefore, this suggested that the surgeons (as lead users) participate effectively in my approach and it may be worth others who would like to use this approach, selecting participant based on their lead-user-ness.

Thus, Mocking Up can be proposed as an extension of the lead user innovation approach and may be situated within the third box of the lead user innovation process (Fig.9.17). As the main design tool used in Mocking Up is mock-ups, this also suggests that a 'tool kit' as described by Von Hippel (2001) may be a set of accessible materials that can be used to construct mock-ups. Furthermore, Mocking Up is suggested as being a useful approach that enables lead users to engage in designerly strategies to innovate. Nevertheless, designer's intervention is essential.

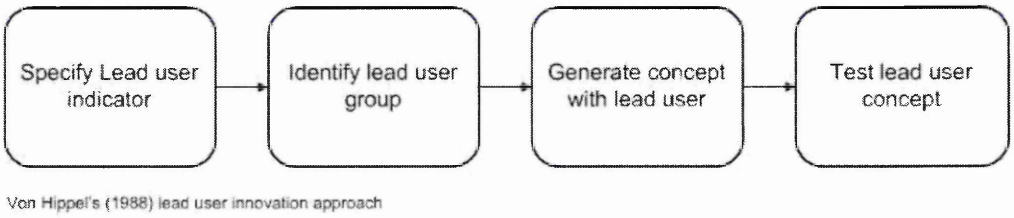


Figure 9.17*. Lead user innovation approach described by Von Hippel (1988).*

Chapter 10: Conclusion

Chapter 9 presented a holistic discussion on the design collaboration works I undertook with the surgeons. For this chapter, I will now reflect and sum up the research. Throughout this research, I found that 'Mocking Up' is a useful co-design approach that can be used by designers, engineers or expert users in design collaboration. The approach showed that it enables expert users to use 'designerly' strategies in design development process. There are three activities included in this approach. Firstly, users come with a proposition including problems, needs and ideas. Secondly, the designer immerses her/himself within the user's context. This is then followed by the co-evolution of the problem and solution happens through the making of mock-ups. This approach is visualised in a diagram which can be referred to Appendix 6, in a hope that it can benefit the designers or other stakeholders in design development. Mocking Up was developed through two design projects with two colorectal surgeons for designing:

1. A rectal clamp – this project's design aim was changed into developing *surgical model* to simulate anastomosis surgery.
2. A model of *fistula in ano* - a 3-dimensional visual tool for use by radiologists to recreate a complicated *fistula in ano* pathway model based

on MRI scanning, to be used by surgeons to understand the nature of the complication and to plan further action.

New products were proposed through the collaborations reported and the collaborators believe that these could be usable in a further conceptual development stage as they may have value in the medical equipment market place as there being a need for such item. These are also part of the outcome of this research. Nevertheless, they still need to go through a further iterative process of designing for it to become a product. Therefore, the design collaboration between the designer and the surgeons may further advanced following the completion of this thesis. The products developed in this research were:

Surgical simulator – it was targeted to be a teaching aid in the area of lower gastrointestinal surgery i.e. rectal anastomosis including operation such as clamping and suturing method on the rectum and colon.

'Fistutrek', a brand name given to the fistula model developed through the collaboration – designed to aid the radiologist in replicating a complicated anorectal disorder and in case fistula-in-ano detected through MRI scan. This model also will be given to surgeons to aid them as a way to understand the case and for them to made further plan for the surgery (Fig 10.01).

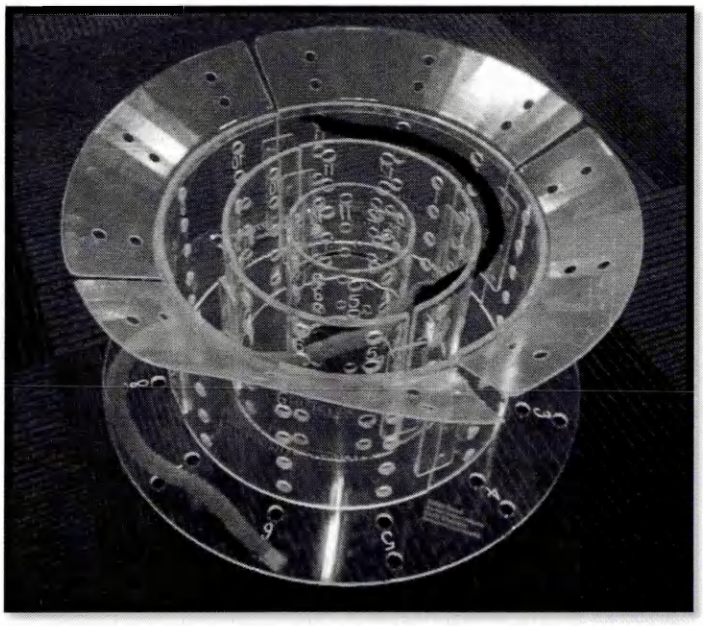


Figure 10.01*. Fistula model developed between Mr Keith Chapple and me.*

As stated in Chapter 1, my thesis set out to investigate; 'To what extent can a participatory design approach aid the development of surgical tools and improve their effectiveness?' Co-design approach developed in my research has aid the development of the respective tool through the 'collective creative activities' (Sanders and Steppers 2008) via Mocking-Up. Creative activity undertaken in this method was making the mock-ups. By doing this, the surgeons' contexts were made available and more importantly, has assisted them in developing their ideas through 'making' activities. This process is a designerly strategy normally used by designers when designing. Mocking-Up make this strategy available for the surgeons to be used in the collaboration.

'Designerly' strategies stimulated in the projects are described in Nigel Cross's (2007) discussion of the way designers work in addition with Henry Gedenryd's (1998) discussion of 'interactive cognition'. These were exhibited within the design activities of the case studies. The strategies claimed here to be usable by expert users, with the support of designer, are *problem framing*, *using and testing, solutions through making* and *proposing solutions to address the problems*. The uses of these strategies were demonstrated through the co-design project undertaken between the designer and the surgeons.

The proposed concept of partnership has become the core to this design collaboration. This was exhibited in the design projects where collaborators were able to find common ground in which they could share their expertise creating understanding and confidence when undertaking design development together.

Another element that may have contributed to the approach being successfully ventured upon was the expert users' characteristics. The design projects showed that these surgeons were open minded and enthusiastic. While being well versed in their own field, they were open to the use of technology available to them outside of their own domain.

My research also found that collaborating surgeons displayed Von Hippel's lead users' characteristics (1976, 1986, 2001, and 2005). This then suggested what motivated the surgeons to collaborate with the designer in developing products. It also suggests that Mocking Up extends the Von Hippel 'Lead User' innovation

approach by enabling lead users to engage in 'designerly' strategies in the innovation process. By building mock-ups with the intervention from designer, lead users may transform their idea into product through the design process developed. Von Hipple (2001) suggests that lead user can use 'tool kit' to prototype their idea in which this kit could be designed by manufacturer. Mock-up kits developed through this research can be one of the options for these 'tool kit'.

In developing the approach, I have tested and refined the method through several pilot studies within different circumstances. I found that Mocking Up is may also be suitable to be undertaken with various of experts and perhaps with more than one collaborator at one time. The use of mock-ups as a design tool was useful in exploring users' ideas and may also be a useful tool for exploring design possibilities.

My experience gained through this research suggests that design in the medical, surgical and healthcare domain is worth exploring as this is a huge area and may offer valuable research and design opportunities.

However, these experiences were gained in a western environment. As I am based in South East Asia, there may be a chance to apply this approach in a different cultural setting. This may give rise to further challenges which promotes further development of Mocking Up and a chance to explore other application areas.

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Appendixes

Interview questions for manufacturers

Researcher: Saiful Ramli

Objective: to understand current practice

Background

1.1 Academic background (degree level)

1.2 Years of experience

1.3 Company background (how – start, years, expertise)

Experience in medical/surgical tools development

2.1 Any experience working closely with medical experts e.g. surgeons, doctors, nurse etc.

2.2 How often/ many times working with them.

2.3 nature of working relationship (how do work with them) e.g. partners, customers.

2.4 What do the medical experts provide

-do they propose idea

2.5 challenges in working with medical experts.

2.6 any medical experts come to the company and suggested new product?

Design process practiced in the company

3.1 current practices

3.2 who do designing

-did medical experts involved directly in design development (how)

3.3 any third party involved (university, designer etc)

3.4 ownership of intellectual property e.g. patent.

Note:- ***asked the interviewee to rearranged printed and cut design process on piece of paper. Suggest them to use arrow to show the flow. Take picture of it.***

Open questions

4.1 What do you think surgeon designing surgical tools? Heard about any?

4.2 What do you think about designers designing surgical tools?

Interview questions for Surgeons

Researcher: Saiful Ramli

Objective: to understand current practice

Background

1. Can you tell me about your professional background eg. First degree till subspecialist.
2. How do you choose to be in the specific domain? Any influence

Surgical domain and instrument

1. Did you involved with any development of surgical tools before? Any stakeholders approached?
2. How do you choose the instruments use? How the hospitals choose instruments? Eg. Senior recommendation, brands, or…
3. Do you change the instruments used through times? Why
4. What do you think about the design/development of surgical instruments or any artefacts that support the surgeon in doing their work? Historical, current and future

   . *issues of surgical instrument imported from certain country with not up to the standard.*
5. Did you see any needs on new or redesign of surgical instrument in your particular domain or other domain?

Open questions

1. What do you think about other stakeholder (not surgeons) designing surgical tools?
2. What do you think the barrier or challenge may occur for designer or surgeon in designing surgical tools?
3. Through your experience, are there any surgeons you know that involved in development of surgical tool and what do think they can provide in the process?

New design / needs

1. Do you have any needs in new surgical tools or any tools that support surgeons in doing their work?
2. Continue if needed
3. Does other of your colleagues have this problem?
4. Continue if needed
5. How long have you think of this matter?
6. Continue if needed
7. Did you approach any stakeholders about your concern and idea?

RISK ASSESMENT FOR PHD RESEARCH – SAIFUL RAMLI – C3R1

Research title : Investigating Participatory Design Method For Collaborative Development Of Surgical Tools

Area assessed : Operation theatre simulation unit – Robert Winston Building

Assessor : Saiful Ramli Date of Assessment : 13th September 2011

Local manager: Janine Timms

Researcher : Saiful Ramli (Designer) Date unit will be use : To be Confirm

: Mr Steven Brown (Surgeon)

Supervisors : 1. Prof Chris Rust 2. Prof Paul Chamberlain

What are the hazards?	Who might be harmed ?	Action on assessment	With these controls the risk is H/M/L	What further action is required?	Action by who	Action by when

Injuries from transportation of medical simulator	Researchers	Appropriate trolleys have been identified and ready for use for transportation of medical simulator from vehicles to Operating Theater simulation unit. What about getting from the hospital to the vehicle?	Low – Adequate risk control	None	Designer	Date of assessment
Pathway for medical simulator transportation	Researchers	Clear pathway has been identified and pictures were taken as a reference	Low – Adequate risk control	Date and time of transportation will be confirm advance to Local Manager for arrangement	Designer	Date of assessment

Slip and Trip	Researchers	Setting points of video camera has been identified.	Low – Adequate risk control	No cable will be set up on the session. Video camera will be battery operated.	Designer	Date of assessment

What are the hazards?	**Who might be harmed ?**	**Action on assessment**	**With these controls the risk is H/M/L**	**What further action is required?**	**Action by who**	**Action by when**

Use of Sharp instruments	Researchers	First Aid procedure and contact have been identified and briefed by Local Manager	Low – Adequate risk control	Sharp instrument will be handled by trained medical staff (surgeon). They will be kept in their protective sheaf until needed. Used scalpel will be disposed at hospital facility by the surgeon.	Designer	Date of assessment
Electrical Equipment	Researchers	PAT testing procedure has been brief by local manager	Low – Adequate risk control	PAT testing will be taken before date of use.	Designer	On going

Sheffield Hallam University

SHARPENS YOUR THINKING

Information sheet and consent form

Observing design project's video

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please read the following information carefully and please ask the researcher if there is anything that is not clear or if you would like more information.

The activity you are being invited to is an observation of a video recorded during a design project between designer and a surgeon. The project was to visualized complicated MRI report of bowel disorder – fistula in ano[18]. The length of the video recording you will watch will be approximately 30min. The session will be expected to run not more than 90min. You will be expected to give comments and opinions regarding anything you see in the video which can reflect your experience and expertise in (1) the designer's and the surgeon's roles (2) design tools used in the design project and (3) 'designing' in medical/ surgical/ healthcare domain.

Background of the project

The design project was developed together between Saiful Ramli, a design researcher and Mr. Keith Chapple, a consultant colorectal surgeon base in Northern General Hospital (NGH), Sheffield. Saiful had 5 years practical experience as an industrial designer in various industries and 2 years teaching in university in Malaysia. He is currently a PhD candidate in Sheffield Hallam University with research interest in design in medical and healthcare which he developed through his previous MA project.

[18]Fistula-in-ano is an abnormal connections 'tubes' following a complex path around and between the wall of anus and buttock's surface.

Source - http://fitsweb.uchc.edu/student/selectives/Luzietti/Painful_anus_fistula_in_ano.htm

Mr. Chapple has more than 20 years' experience as a doctor and 5 year specifically as a colorectal surgeon. He did his PhD study in molecular biology in a major university in Leeds and his training as a surgeon in South Yorkshire. As a head of department in colorectal surgery at NGH, dealing with surgeons problems and needs under the department is part of his job. One of the major problem his department is facing is to understand MRI report for complicated colorectal disorder, fistula-in-ano.

The surgeon and his colleagues had difficulties to understand complicated fistula-in-ano report where they cannot visualise the relation between the textual descriptions and how the real thing occurs. He explained that he may also have the solution for this issue from a children game called Kerplunk which he used with his children. The concept of pulling sticks from holes can be used to recreate the fistula. He brought this idea in discussion with radiologists and they agreed this idea may be useful. Knowing me as a designer gave him opportunities to bring his idea for further development.

Two meetings were planned to prepare for a design session (the video). In the first meeting, surgeon was briefed about the research and the design project. An interview was undertaken in the second meeting to investigate the surgeon background, his problems, needs and ideas. Surgeon context was learned by the designer from his previous MA project and recent collaboration project with another surgeon.

What happen in the video?

The initial idea was brought up by the surgeon developed together with the designer. The session was conducted in lab setting and lasted for 90 minutes. Design tools such as sketches and mock-up kit (cardboard, paper, blue tack and adhesive tape) were used in the session. In the session, the surgeon and designer used sketch to design and built together the design using mock-ups. Cardboard were cut and shaped according to the idea sketched. Designer made the main structures and the surgeon applied the details. Then, as the mock-up was sturdy built, they decided to test the practicality on site. Some changes were made on the mock-up after the testing according to the design usability. Other concerns were annotated directly on the mock-up. The mock-up was name as Type 01. The designer used digital camcorders to record the session for research purposes.

In this session I hope to develop a better understanding of the process and interaction between the designer and surgeons, and I am asking you to comment on what you see. Here are some questions to have in mind.

- How does this relate to other experience you have?
- What are the important events in the video?
- Could you adapt any ideas from the process in your own work

What happen next?

Type 2 and Type 3 mock-ups were built away from surgeons after initial evaluations on the mock-ups for design refining and brought for further development.

Why have I been chosen?

You have the expertise and experience which can reflect my work with the surgeon.

Do I have to take part?

It is up to you whether or not to take part. If you do decide to take part you will be given this information sheet to keep and asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What do I have to do?

You will be given materials to build mock ups. The object you will create is a design of your tools (tool to assist you design work eg. mould etc) that you have done before. If you don't have any, the researcher will assist you to make one by creating scenario.
I am hoping to make video/audio recordings of the sessions. If you agree to this, the video/audio recording will be of you doing designs with mock-ups.

What will happen to the video/audio recordings?

The recordings will be in my personal control and will only be used for the purposes of the research. Part of it may be seen by my research supervisor and other close research colleague for analysis purposes. You may withdraw your consent before, during and after the recording or ask for it to be edited if necessary. You can stop the recording for any reason. You can listen to or see the finished recording.

What if I change my mind during the study?

You are free to withdraw from the study at any time without giving any reasons for your withdrawal. The video recording of you will not be used but will be kept as a reference for another expert review.

Are there any risks or disadvantages to taking part in this study?

There will be no risk or disadvantages from taking part in this project.

Will my taking part in the study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any video or audio tapes will be stored securely. The data from this session will be used in the thesis and discussion with the research colleagues within the university and you will be identified by a code rather than a name.

I understand the arrangement mentioned and I understand that I can withdraw without any reason given.

Researcher

Saiful Ramli
C3RI
Art and Design Research Centre
Sheffield Hallam University

Signature:

Name: _____

Paper presented at Eight International Conference on Design Principle and Practice in Chiba University, Chiba, Japan, March 2013 and

Published electronically in The International Journal of Design Management and Professional Practice,

Saiful Hasley Ramli, Chris Rust. (2014). *Mock-up as design tool in designer-surgeon collaboration*. International Journal of Design Management and Professional Practice, pp 13-29. Online.

Mock-up as a Design Tool in Designer-Surgeon Collaboration

Abstract: Some surgeons are capable of seeing needs earlier than other users in the same domain, and they are also able to provide the solutions. Some earlier research showed this, e.g. surgeons with lead user's characteristics designed their own tools. However, current workloads and other responsibilities hindered them from expressing their design problems and needs for new surgical tools. In this paper, the author will discuss the use of mock-up kits as a design tool and 'making' as design collaboration essence in two collaboration design projects with colorectal surgeons. This mock-up kit was developed through some other related work containing eclectic everyday material and on hand formable material, e.g. cardboard. Two colorectal surgeons were involved in separate design projects, and each of them has their own needs and purposes. The research aimed to study how mock-ups can be used in such co-design works and how this method can enhance the usability of surgical tools. It has shown that the process of 'making' allowed the surgeons to use design strategies. The activities in both collaboration projects indicated that mock-ups are valuable tools to use in such co-design projects because they enable the surgeons to be actively involved in creative activity.

Keywords: mock-ups, co-design, surgical tools

MOCKING-UP :A Collaboration Design (Co-Design) approach for Designers and Expert Users

Descriptions

Note: For page reference, please refer to the thesis below:
Saiful Ramli (2015). 'Mocking Up: Strategies to engage expert user in designerly thinking'. Doctoral dissertation, Sheffield Hallam University

A User Propositions

Expert users come up with the problems, the solutions and the ideas before engaging in the design project.
Page - 143, 171, 196

B Contextual Immersion

The designer immersing themselves in the user's context by undertaking activities that will gave them the understanding of the user's world and related issues.
Pages - 45, 73-75, 144, 172, 201, 206

C Co-evolution of problems and solutions

The designers and the expert users engage in a creative activity via making the mock-ups. This process allows the designers and the expert users to develop their understanding of the problems and the solution through the making process.

The expert users will use the mock-up kit as a communication tool in sharing their knowledge and experience. They will also show ideas by making the artifacts using the material from mock-up kit. However, the designer's intervention is needed in this process. The designers will be the hands for the expert users. So, for the method to be successful, it is crucial to have designers who have a high skill in making instant mock-ups. This design environment will make available the designerly strategies to be used by the expert users.
Pages - 60, 196, 172

C.i Designerly Strategies
In normal circumstances, design strategies are used by designers to solve design problem. However, in this approach, design strategies can be also used by the expert users with the provision of designer's intervention. Below are the design strategies used by expert users in the co-design process.

Use and test
A designer uses sketches to explore their solution / idea. In this approach, the expert users uses this strategy for the same reason. The difference in this method, mock-ups are use in this method as it more interactive and suitable for the non-design background participants.
Pages - 201-204

Problem reframing
A designer formulates problems within the broad context of a design brief . They are not limited to the given problems and restructuring new problems from the given problem is the designer's way of attempting to solve them. Expert users adopted this approach during the collaboration.
Pages - 61, 169, 201

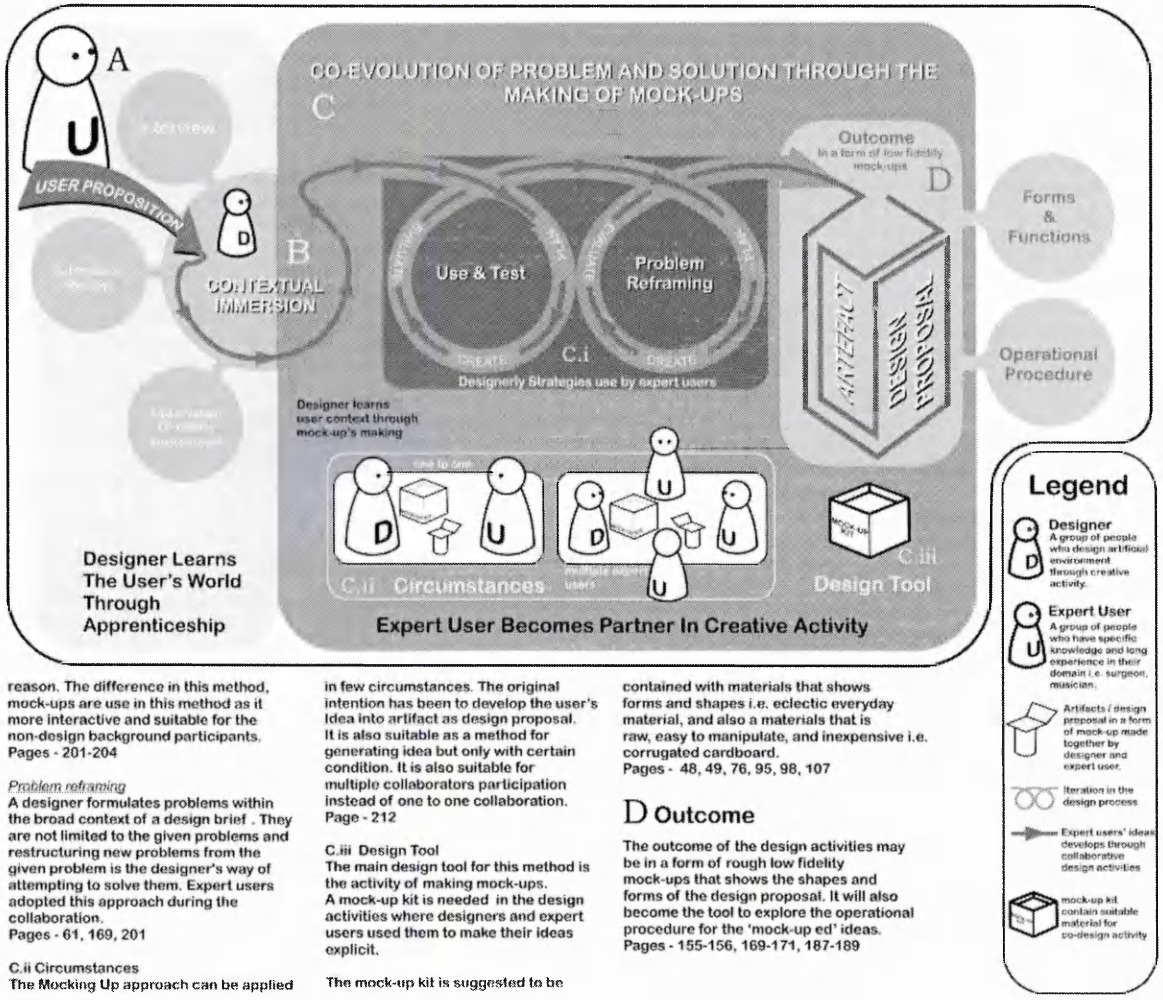
C.ii Circumstances
The Mocking Up approach can be applied in few circumstances. The original intention has been to develop the user's Idea into artifact as design proposal. It is also suitable as a method for generating idea but only with certain condition. It is also suitable for multiple collaborators participation instead of one to one collaboration.
Page - 212

C.iii Design Tool
The main design tool for this method is the activity of making mock-ups.
A mock-up kit is needed in the design activities where designers and expert users used them to make their ideas explicit.

The mock-up kit is suggested to be contained with materials that shows forms and shapes i.e. eclectic everyday material, and also a materials that is raw, easy to manipulate, and inexpensive i.e. corrugated cardboard.
Pages - 48, 49, 76, 95, 98, 107

D Outcome

The outcome of the design activities may be in a form of rough low fidelity mock-ups that shows the shapes and forms of the design proposal. It will also become the tool to explore the operational procedure for the 'mock-up ed' ideas.
Pages - 155-156, 169-171, 187-189



MOCKING-UP :A Collaboration Design (Co-Design) approach for Designers and Expert Users