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ACTION RESEARCH IN PRACTICE

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ABSTRACT

Action research might be one of the best strategies to undertake a PhD research on design. This method has been increasingly promoted recently within the design community in different fields such as human behavior, communication, new product development, etc. However, few researchers tempted to put themselves in the loop for exploring the design process. This paper provides a descriptive account of action research employed for studying the design process of user-centered new product development during a PhD research, and summarizes our main observations and return on experiment: 1) There are two distinct patterns for design and research in practice, 2) Transaction paths among action research steps are non negligible and need formalization, 3) Analysis should be added to the main steps, to take input from observation and to provide results for the reflection.

Keywords: action research, modeling, design practice, innovation

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1 INTRODUCTION

Design as a discipline has various characteristics, and as the body of literature confirms it has been a challenging subject for researchers to identify, characterize, and prescribe design activities from the problem statement to the final solution. Design is a human activity, so to drive from one step to the next for instance from the requirements to the functions, it is necessary to distinguish human operations by their orientation in time, target, share, etc. Design models could not always determine how these steps happen. They may not always propose a best general strategy for moving forward, basically because of the dissimilarity in subjects, contexts, or environments of design. There is much to know and learn about the design, and a way forward is the design research.

According to Blessing (2009) design research can be considered to have passed through three overlapping phases: Experiential, Intellectual, and Experimental, but in all phases, a theoretical framework has been largely missing. In this respect, it is required to design a general experimental and validation methodology for both design research and design support.

Can a design research be limited to the theoretical studying and establishing models? Does such a strategy work for interpreting any design context? One can imagine that those questions have been asked and re-asked many times and caused a turning point in the design research. That may be the reason why the interpretive nature of the design became important, and as a result, the epistemology of practice based research formed the movements like “action research”.

The action research arises from a problem, dilemma, or ambiguity in a situation in which the practitioners find themselves (Swann 2002). It is a practical research methodology that usually is described as requiring three conditions to be met. First, its subject matter normally is situated in a social practice that needs to be changed; second, it is a participatory activity at which 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 (Kember and Kelly 1994).

The action research was first conceptualized by Lewin (1952) and further developed by Kolb (1984), Carr and Kemmis (1986) and reoriented to design by Swann (2002). Swann explains action research as a spiral of cycles of action and research consisting of four major moments: plan, act, observe, and reflect. These steps are shown in the Figure 1.

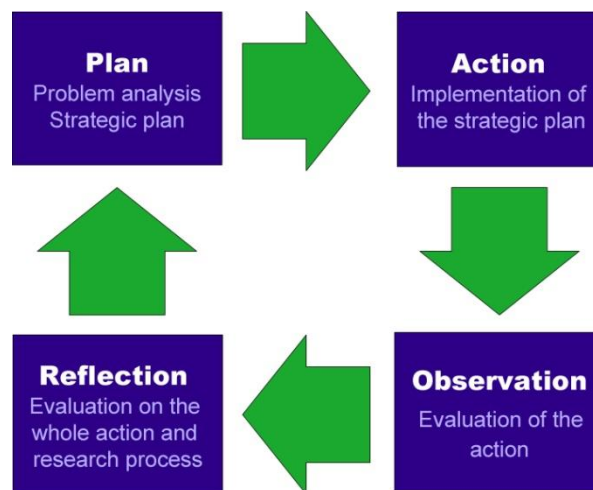


Figure 1. Action research diagram (Illustrated by the author based on (Swann, 2002))

In this approach, the plan includes problem analysis and a strategic plan; action refers to the implementation of the strategic plan; observation includes an evaluation of the action by appropriate methods and techniques; and reflection means reflecting on the result of the evaluation and on the whole action and research process, which may lead to the identification of a new problem or problems and hence a new cycle of planning, acting, observing and reflecting.

Swann (2002) points out that the action research and the action of designing are so close, thus it would require only a few words to be substituted for the theoretical frameworks of action research to make it applicable to design. A very similar idea to action research was promoted by Bruce Archer, termed out as “research through design” and “evidence-based design”. For design practice he argued that there

was a need for method and rigor, and for decisions to be recorded and explained so they could, if necessary, be defended and explained (Archer 1984).

This paper provides a descriptive account of action research which I choose to employ for PhD research, which basically was defined as “looking forward a design methodology for innovative surgical instrument design”. The PhD took place in a design center with strong mechanical engineering background where people looking for an overture toward new disciplines. I have started my research with the question of how surgical instruments are designed, and looked into the different literature in medical, engineering, and design. Next section presents a summary of this research. With many ideas and no clear answer in hands, I decided to, and had the change to be able to, be a part of a design team including two surgeons, with the objective of designing a new surgical instrument to change a particular back surgical procedure from open to minimally invasive. The context of this 3 year project is depicted in section three, along with the four steps of action research which I had chosen to follow. Finally, practicing the action research gave the opportunity to step back and look at the design research through the detail steps and tasks of experiment, and sum up a reflection on the action research, which explained in the forth chapter, before the conclusion and some ideas for further research.

2 INVESTIGATING THE DESIGN PROCESS

Surgeons have historically been idea generators and creative practitioners within their craft (Riskin et al. 2006). However, in modern days no surgical instrument is designed and manufactured by surgeons. The design of a surgical instrument is the result of the teamwork of a several actors in different disciplines including medical and technical, and thus is a complex process. GBI Research predicts the global surgical equipment market to surpass \$7 billion by 2016, with a 6% compound annual growth rate (GBI Research 2010). This successful business implies the success of design in surgical instruments within companies, but does the research know about design process in this field?

2.1 Domain based research

The research on design process of surgical instrument began with the following question: How the innovative surgical instruments are designed? To answer this question I performed a systematic review on two area of publication: First, the publication in medical or surgical product design, and second, the publication on the innovation in surgery. The objective was to identify if the designer of surgical instruments follow a process, or a set of distinct steps to go from an idea to the final product. Then, the second question emerged to see how those steps (if any) are followed and what importance they have been given by the designers and engineers.

In result, four focuses in view of design process are identified from analyzing the search of surgical instrument design in the ISI Web of knowledge. Over more than 1170 records in 94 journals I used the “Refine Results” to narrow down to 573 results in surgery and then to 37 results in MIS (3 journals) and Laparoscopy (3 journals). These six journals have been selected due to the correlation of the subject to design for less invasive surgeries.

Those four steps are identified as 1) Requirement analysis, 2) Conceptual design and prototype production, 3) Experiments on in-vitro Study, 4) Clinical evaluation in OR. To be mentioned that some of the papers had more than one focus. Table 1 shows the result of analysis.

In addition, some interesting points were found. The papers in the first category showed some research techniques such as surgeon interviewing (Berguer et al. 1997), surveys using questionnaires (Bergner and Hreljac 2004; Van Veelen and Meijer 1999) and the systematic literature review (Magdy and Eric 2003). Concerning the design, among twenty papers focusing on design, in nine cases, the design was followed by an in-vitro experimentation, while six others have reported the OR evaluation. This implies that almost a half of the evaluations in OR papers (eight out of seventeen) proposed a new operational technique using a conventional instruments.

The question of surgical instrument design has also interested the design community. However, apart from many examples to explain a unique design approach in the literature, only a few attempts to draw up the maps or the model of the design process of surgical instruments. Researchers, however, reported their research techniques; for example, direct observation (Mondada 2002), questionnaires and interviews (Trejo et al. 2007) has been reported on the anticipation of the users’ behavior for the requirement definition and the product evaluation. Two studies stand out because of providing a generic approach and the attempt to describe the sequences of activities in the design of the surgical

instruments: workflow analysis (Jalote-Parmar and Badke-Schaub 2008) and engineering for patient safety (Dankelman et al. 2005a).

Table 1. An example of systematic review: analysis of published papers in surgical journals according to the design process; Data extracted from ISI Web of Knowledge, May 2009

	# of papers	% of 37	Design phase			
			Study, re- quirement identifica- tion	Design	Experiment	OR evalu- ation
Journal of the American association of gynecologic laparoscopists	13	35.1	4	7	5	4
Minimally invasive neurosurgery	7	18.9	1	6	2	3
Journal of minimally invasive gyne- cology	6	16.2	1	2	1	3
Minimally invasive therapy & allied technologies	4	10.8	1	2	1	2
Surgical laparoscopy & endoscopy	4	10.8		3	2	2
Journal of laparoendoscopic & ad- vanced surgical techniques	3	8.1				3
Total			7	20	11	17

Nonetheless, the question of how to design a surgical instrument remained unanswered. Literature shows some fundamental problems and difficulties concerning the design of the surgical instruments: There often exist communication gaps among the surgeons (users) and the engineers during the product development process (Dankelman et al. 2005b), new technologies are imposed rather than what the surgeons would require (Patel et al. 2001), and in result many new surgical products do not integrate in the hospital usage (Gross 1993). For example, surveys on minimally invasive and laparoscopic instruments showed many difficulties and problems for surgeons using the new instruments (Bergner and Hreljac 2004; Berguer et al. 1997). There is need for a more systematized approach to the design, the evaluation, the implementation and the general release of new surgical procedures or implants (Gross 1993).

In summary not only the road of design is particular and unclear in this field, but also no evidences confirm an appropriate outcome in case of using certain methods. That is the tentative question behind our research: What does the generic design process of innovative surgical instruments look like? What should be acquired to make a successful design? The answer to this question might be found in the engineering design literature, where the researcher try to formalize the design as a process, including main steps, inputs and outputs, and tools and techniques.

2.2 Engineering design research

In the engineering design, the nature of the design process is identified as the coordination of the single acts of the designer, and the collaboration of a group of the actors using interaction tools to solve a problem, or, to shift from a problematic situation, in which the needs are unsatisfied, to an objective situation in which they are. This group is not consisted only of the engineering designers, and as a result there are many activities and interactions that would overtake the technical design tasks and activities. Thus, as Brissaud in (Brissaud and Garro 1996) point out, the design activities are distributed in particular among the different actors involved in the product life-cycle, and the integration of those actors from the earliest stages of the design is explicitly intended. It is critical to the success of a company to understand and to meet the requirements of their customers and end users, in the product design. Moreover, almost all of the engineering design methods begin with a defined problem and/or defined tasks to accomplish, which is not the case in many medical and surgical design assignments. The knowledge gap between engineering and medical professions involved in the design development implies the necessity of user integration, and an integrated design process to provide the multi designer reasoning. The technical or conceptual design in surgical context needs to be

communicated and evaluated with the user (surgeon or OR technician) and this communication shows difficulties and requires intermediary objects and methods. Thus, choosing an engineering design method and a systematic approach, at least with respect to these definitions are not straightforward issues. It would thus appear that the methodological options to design should be opened to other approaches.

3 ACTION RESEARCH IN PRACTICE

The design of the new instrument under study (named Protige) is for a novel application of a specific type of surgery called minimally invasive surgery (MIS). MIS is a new kind of surgery in which the operation is performed through a small incision. Thanks to this smaller incision, the surgeon does not have to cut through muscles and only merely needs to separate them. This implies that the patient suffers from less pain and bleeding and recovers quicker. Despite the advantages for the patient, MIS operations are more difficult to perform for surgeons in comparison with the usual open-surgery techniques, and require special instruments.

The specific case studied here is an application of MIS in conventional spine surgery. The operation procedure consists of placing three pairs of screws and two implants (called rods) on three adjacent vertebrae. The procedure normally requires a large incision (12–15 cm) to provide enough space for implementation

To carry on with the action research, a practice-led study is designed to provide an environment of research, and also a specific case to analyze. This approach makes the research process visible and capable of being analyzed from different points of view. The four steps of action research in practice, with a complementary step for analysis are explained as follows.

3.1 Plan

The subject of the project is the design process of a surgical instrument for the transformation of a specific open surgery to a minimally invasive form. The context of the project is explained in detail in the next section. In brief, the project is about finding a solution in the form of a new product, to help surgeons to perform traumatic spinal operation, which actually is an open surgery, using a minimally invasive technique. This project has not only the design objectives, but also the research objectives. The design objectives are set to conduct a real design project with tangible results. On the other hand, this project serves as a support for the research, so the research objectives according to the methodology (action research) should be provided.

Design objectives:

- To design a new surgical instrument from A to Z, starting from the problem identification to realization and clinical evaluation,
- To make a scientific contribution to innovative instrument design
- To promote the results, and eventually to apply in the form of a patent,
- To communicate the designed solution and the product in the form of a publication, presentation, etc. with the industry and the hospital

Research objectives:

- To observe, capture and document the design process and activities
- To analyze the design activities and procedures
- Devise improvement in the design methods, following one or some methods and to develop the modifications or new design procedures, information, organization, priorities, etc.
- To propose a new methodology for design in this discipline supported by the appropriate tools and techniques
- To communicate the research contribution and to publish in the design community

3.2 Action

The action of this project is simply to design the aforementioned instrument. To do this, we decided to follow the process model resulted from the literature, as a guideline for the project progression. This initial process is shown in Figure 2. Figure 3 shows some example of design progression.

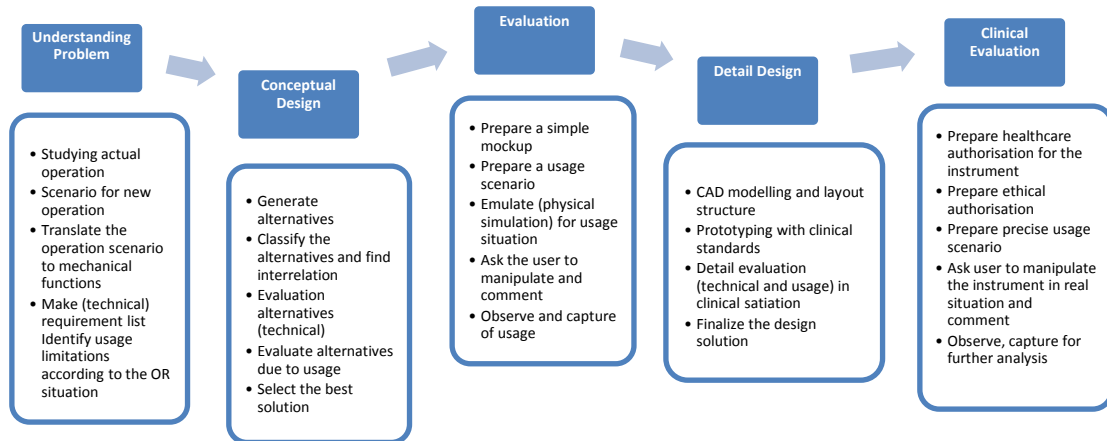


Figure 2. Design process model for the Protige project

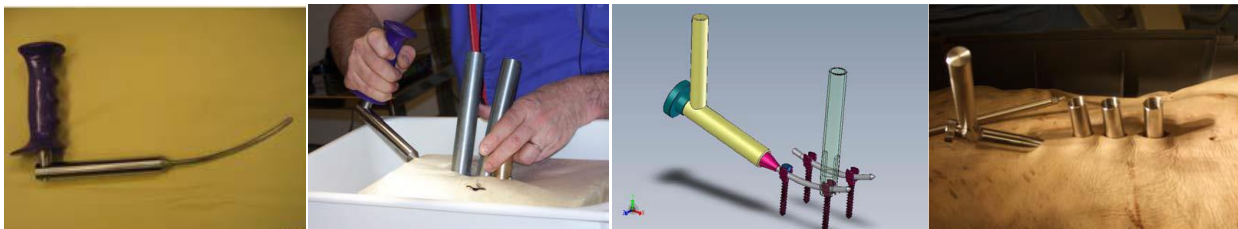


Figure 3. Design progression of Protige. From left 1) First simple prototype, rigid and one piece. 2) prototype in usage situation, 3) Detail design of product 4) Final prototype in usage situation on cadaver for clinical validation

3.3 Observation

The objective of this observation is to define the phases of the operation, to decompose the actions into the tasks and to provide complementary information about the tasks like actor, time of action and task alternatives. Environment of the research, the operation room, was carefully observed. Figure 4 shows one of the ORs in Hospital of Grenoble, fit out by fluoro-navigation system. Surgical operation room is a complex system, and there are various systems and actors interacting during an operation. For the lumbar fusion surgery, which is the subject of our study, have participated in several surgeries, and captured some of them, to provide further study and analysis.

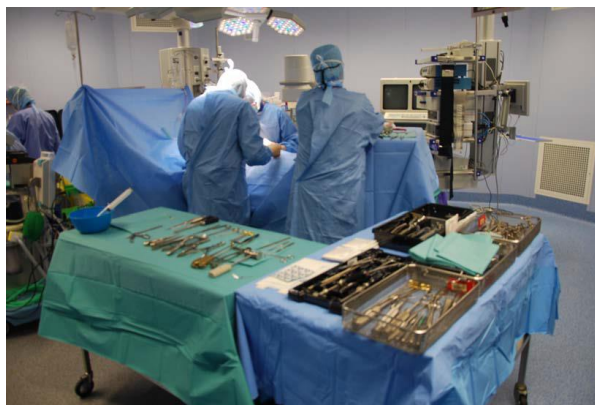


Figure 4: OR at Hospital of Grenoble, surgical team performing a spinal fusion operation

3.4 Reflection

Reflection, according to Swann, means “reflecting” on the result of the evaluation and on the whole action and research process, which may lead to the identification of a new problem or problems and hence a new cycle of planning, acting, observing and reflecting. I interpret the reflection as two main activities, one inside the other. First the internal reflection is on the action, which means here the

design process of the surgical instruments. In this step by using what has been observed, analyzed and learned, I can describe, evaluate, justify or propose the modification for the strategy of the action (here the preliminary design process). Then, on the external reflection, I look out the whole approach of action research and in the same way justifies or proposes modifications.

Table 2: A summary of design meetings during the Protige project

Date	Subject	Collaboration tools	Duration	Observation
19/06/2006	a)Preparation for the first emulation in the OR, b) phantom preparation	Simple prototype	1:10 h	Camera
30/05/2007	a) Explanation of the surgery, b) comment on another surgeon's operation, c) Discussion about prototype	CAD model	2 h	Camera, Eye tracker
13/12/2007	Discussion on the new solution, Preparation for cadaver emulation	CAD model, advanced prototype	1:30 h	Camera
1/10/2008	Detail design meeting	Annot' Action	1:40 h	Camera + Software Logfile
17/10/2008	Finalization of design, Preparation for real operation	CAD model	1 h	Camera

In the context of our research, a phenomenon of co-evolution has been observed: the co-evolution of the new instrument prototype, and the new operation procedure throughout the design progression. In other words, the evolution of the instrument prototype showed interdependency with the evolution of the usage scenario.

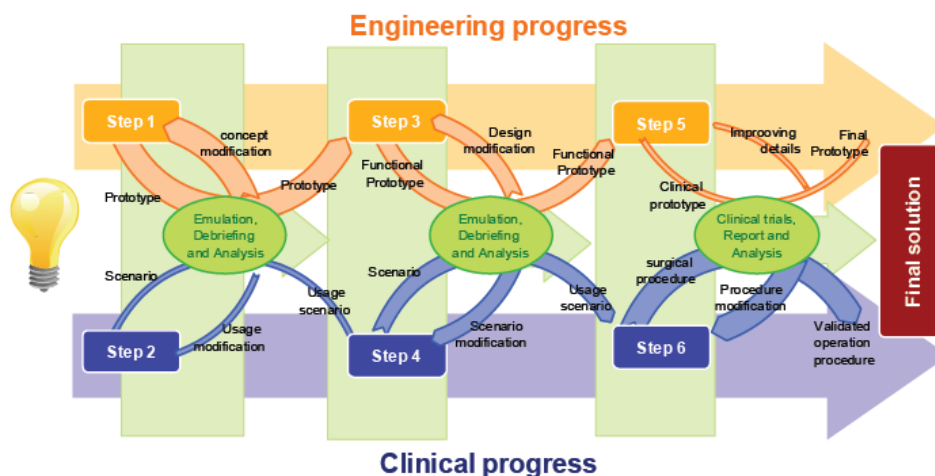


Figure 6: Co-evolutive design process model for surgical instruments

Prototype brings together all of the requisite knowledge appropriate to a specific usage scenario, and is a tangible trace of what the designer have understood from the requirement of the user. On the other hand, the user examines the prototype to evaluate whether or not, the design solution satisfies what he desires. Naturally, the user evaluation is not limited to planned usage scenario, and he tries to find out what is possible to do. This moment is very similar to what the designers do in producing design alternatives. In this way, a modified usage scenario appears from user's idea and discussion with the designer. As a result, prototype and usage have a co-evolution during the project.

4 PROPOSITION FOR A NEW ACTION RESEARCH MODEL

The three years of bringing an idea to a product in parallel to research on how the design moves on step by step and goes from a number of alternative ideas to a functional prototype in hand of the user, gave the opportunity to take a step upwards and look at the action research experience.

The action in the action research method is usually a design project, a part or the complete process, and is supposed to be directed by the researchers who take action research method for their research study. Alternatively, the design projects need to have well defined and clarified objectives. For this reason, I trust for a researcher who looks into the method and the process of design rather the design artifact, it is necessary to set up separately the research objectives and the design objectives in the plan step of the action research method. An example for this proposition is the research and design objective is given in the previous section.

When the design project is in action, the researcher observes naturally the project progression. In other words, observation couldn't really be a separate step after the action is finished. In the same way, the reflection step requires the intellectual works based on the observation, such as different analyses. For example, in the Protige project the analyses had an important contribution to reflection on design method for user designer collaboration. Analyzing communication between surgeon and designer in conceptual design meeting and design validation meeting revealed interesting details of the nature and characteristics of information exchanges, shown in detail in (Farel et al. 2013). Accordingly, the action research demarche can be reorganized as depicted in figure 6.

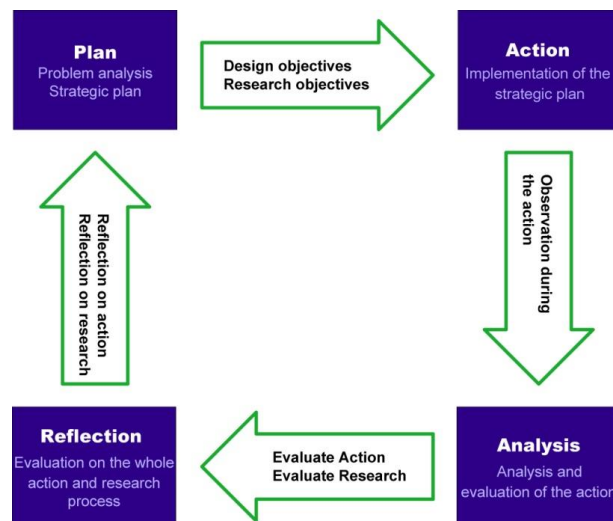


Figure 6. New proposition for action research

5 CONCLUSION

This paper took a step upward of a four year collaborative design experience of working together with engineers and surgeons, to reflect on research method. The designed surgical instrument is being used over all the project timeline as source to investigate the design process. The question of “what design methodology is needed to design innovative surgical instruments?” was given important efforts in literature study, field investigation, teamwork, observation and analyses.

In result, I came up with new contribution to the design process: the co-evolutive character of the design, the concept and application of emulation step in design, the role of expert user in the design process. I chose the action research demarche as my research demarche, and followed the steps: Plan, Action, Observation, and Reflection. Nonetheless, it is necessary to argue whether the action research was a convenient research method for this research. Here is the discussion based on Kember's three conditions for the action research.

First, the subject of innovative surgical instruments design is a collaborative practice when the actual situation needs to be changed. In other words, as it is explained in detail in the first chapter, the problematic of the innovative design in surgery could no longer be studied in an isolated field of engineering or surgery. So the design in surgery is a developing social activity in which many actors take part.

Second, concerning the participation of research, the high rate of innovation and publication in the field of surgical instruments design shows that in this context the role of designer does not really vary from the role of researcher (in contrast with designing a car, furniture, or industrial products). Thus in a design project, researchers have a participatory activity and also a fair collaboration with designers.

Third, like the surgery itself, design of surgical instruments is a spiral cycle of planning, acting, observing and reflecting. The project is documented by sketches, 3D models and also operation protocol and clinical data.

Altogether, the action research method suits well enough this research, and it provided a scientific approach to self participation in the action of design, observation and reflection. In return, the design experiment helped to apply and examine the action research method, and provide feedbacks and a new model for action research.

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