How Experiments in the Fuzzy Front End Using Prototyping Generates New Options

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ABSTRACT

The fuzzy front in product development is frequently mentioned as the most critical phase of the innovation process, and the five cases of successful design innovations here indicate that experiments and an experimental approach are generating positive outcomes. The experiments in the cases can be characterized as various forms of prototyping. Interestingly the prototyping and experiments took place in the very early phases of the innovation process, rather than later as often advised and interestingly experimentation in the cases here appears to be a vehicle for creating new options. Furthermore, the analysis demonstrates that prototyping can be considered as a punctuation device, as it offers those involved the option of opting out of ongoing processes, routines and engage in playful behavior by allowing for a freer experimentation with materials, processes, methods to challenge existing knowledge and explore potential solutions. In science, by contrast, experimentation generally is carried out to support, refute, or validate a hypothesis, in other words it seems to be associated with testing options rather than creating them.

Keywords: Fuzzy front end; experiments; prototypes.

INTRODUCTION

Innovation is the driving force behind superior business performance (Utterback, 1994) but how do organizations develop and manage innovations at the early stage of the innovation process? Multiple avenues have been proposed, but from the accounts of IDEO (Hargadon and Sutton, 2000), experiments seem to be crucial in the initial phase of the innovation process, namely the fuzzy front end (FFE). This phase is frequently mentioned as the most critical phase of the innovation process (Frishammar et al., 2012, Frishammar et al., 2013, Koen et al., 2001). In this paper, we analyze experiments in the fuzzy front end, defined as the early phases of the new product development (Khurana and Rosenthal, 1998, Verganti, 1997). Interestingly, there are not many studies on how experimental approaches unfold in this stage. We will provide some insights based on the analysis of five projects in a company. The projects used various forms of prototyping to experiment, and we conclude that prototyping acts as vehicles for generating alternatives and new options, rather than to 'test' already know alternatives. Thus, we propose two contributions to the literature. First, we suggest that the prototype should be used as vehicle for exploring and experimenting rather than testing options; second, we assert that prototyping should be used already in the fuzzy front end, rather than towards the end of the innovation process, as proposed by the innovation literature.

THEORETICAL BACKGROUND

Past research on the fuzzy-front divides the processes into phases: ideation, scoping the project, defining the product, and building the business case. The front end is divided: Pre-Phase Zero, Phase Zero and Phase one (Verganti, 1997). The front end is "complete" when a business unit either commits to the funding and launch of a new-product development project, or decides not to do this.

Research departing from a sequential view on the fuzzy-front end processes has pointed to different types of activities that needs to be undertaken, such as idea identification and selection, identification of potential markets (Verganti, 1997, Reid and de Brentani, 2004); the handling of uncertainties (Brentai and Reid, 2012); the managing of knowledge using information technologies or organizational structures (Thomke and Fujimoto, 2000) and balancing internal and external collaboration (Christianse et al., 2013).

Controversies can emerge in the fuzzy front end (Christiansen and Gasparin, 2016), which directs the attention of actors. The struggles for closing the controversies represent a stepwise attempt to deal with what is required from the situation, rather than executing a carefully laid plan. Thus, the fuzzy front end is not only searching for information (as already demonstrated in Thomke and Fujimoto, 2000), but also the process of

taking account of the situation which includes also activities directed at initializing trial-and-error processes, engaging in experimental behavior, rather than focusing on analytical approaches.

The role of prototyping in the innovation literature

Existing literature suggest a wide range of ways of understanding prototyping.

Prototyping has been increasingly considered a central element in corporate innovation processes (Sherman et al., 2005), especially if used in the early phases and including external stakeholders (Terwiesch and Lock, 2004) and used as a cross-functional approach to bring together people from different functions (Luo et al., 2005), which supposedly reduce uncertainty (Sherman et al., 2005). It is also used to involve users and ask their feedbacks early in the process rather than towards the end as usually prescribed by the innovation process (Bosch-Sijtsema and Bosch, 2014). In product development processes, the prototype is suggested to start after the product specifications are proposed, thus typically after the fuzzy front end (Rosenthal and Kapper, 2006), although this has been contested by development in the software industry (Gassman et al., 2006). However, in other industries, physical prototyping can be expensive and thus used only in the late phases, and in some industries the physical prototype has been substituted by virtual prototypes, which has enabled improved product development performance (Fixson and Marion, 2012). In situations with lead-user communities, the prototypes are presented when the product is ready to be tested and offered to the final users to try out, as for example within sport equipment, the prototype is offered to the athletes to try (Hienerth and Lettl, 2011). This is not common for developing products at the bottom of the pyramid: concept and prototype development coincide (Viswanathan and Sridharan, 2012). Four different generic purposes of prototypes for product develop has been suggested: Learning, communication, integration and to mark progress milestones (Eppinger and Ulrich, 2012) while others mention a range of purposes related to evaluating various features (weight, structure, architecture, form, usability, interaction) (Elverum and Velo, 2015). Different classifications of prototypes have been suggested such as: Proportional model, ergonomic model, styling model, functional model, models close to final product (prototypes) (Gebhardt, 2003).

Prototypes can be used to engage with collaborative process with stakeholders and can improve the functionality-usability (Bogers and Horst, 2013). However, since it is often developed towards the end of the NPD process and to interact with customers, some authors suggest developing a narrative before the prototype: an easy-to-apply product narrative that explains a technology application to a customer before prototypes have been completed (Hende and Schoormans, 2012).

The development of ideas such as rapid prototyping and design thinking has fostered research on the role of prototyping within the context of new product development, in particular by being considered as a problem-solving tool (Bogers and Horst, 2013). This extend the prototype to be considered as representing shared knowledge, based on learning (Brown, 2008), a socio-material design whose main quality is its permanent 'beta' condition and being in mutual suspension allowing collaborative effort (Corsin Jimenez, 2014).

Prototypes can be useful for deciding whether or not to produce a product and by using prototypes early in the process, the risk of innovation can be reduced (Barkan and Iansiti, 1993); as a way to reach consensus about a design (Shilton, 2012); as a test for consumers to develop the ''perfect'' product (Marion and Meyer, 2011); as an actor which partakes in the production of a non-linear model of innovation (Henderson, 1991). Sometimes it has been used as inherent part of the effective concept development (Viswanathan and Sridharan, 2012); to resolve uncertainty in the early stages of the development process, validate evolving user requirements and pre-train users or to create a marketing demonstration (Liou, 2008).

It has been considered an artifact that facilitates the decision making process (Simon, 1969); an object for problem solving; an object to involve customers (Gruner and Homburg, 2000); a test for consumers to develop the 'perfect' product (Marion and Meyer, 2011); something that helps managers to make sense of what the product will be or to test it with sales managers (Perks et al., 2005).

In our study, we understand it as something different, that has not been addressed before: as vehicle for new options.

METHOD

This paper is based on analysis data from an ethnographic study in a Danish Design company, Fritz Hansen, based on Actor-Network Theory (ANT) (Latour, 2005). Using ANT imply that the research focus is on following the human- and non-human actors, in their controversies, struggles, collaborations and negotiations trying to assemble new designs by making their networks stronger. Furthermore, departing from this perspective means that observations are not considered 'final' or closed for further investigation, but can always be opened for further inspection and analysis if needed. The focus of the analysis from this theoretical departure, thus became to analyze what human- and non-human actors participated in the construction of the network, that lead to the prototypes for the chairs, and what processes and struggles emerged during that process, and how actors managed to overcome these.

Data stems from site visits, interviews in and outside the company, access to company documents and the company museum. Three researchers participated in the study. The second author stayed 60 days in the company over a period of 18 months, mostly physically located near the marketing and design department. The company's museum has a rich historical collection of prior prototypes, products, and documents, such as the minutes from board meetings, scrapbooks, leaflets and marketing material. Structured and ad-hoc interviews was conducted during site visits. Three rounds of scheduled interviews were conducted, guided by a structured set of questions developed from theoretical and preliminary findings by three researchers. The 22 structured interviews lasted between one and two-half hours. Five of the interviewees were interviewed twice. Besides, numerous informal conversations with employees were conducted during the site visits, e.g. during lunch-breaks in the company canteen. Additional background information was collected from recorded radio, television documentaries, and documents collected in the design museum in Copenhagen, the Victoria and Albert Museum in London, and Catherine College in Oxford.

Data were entered into a project database, first coded using thematic coding by one researcher and then checked by another to ensure validity and then analyzed using the Dedoose qualitative analysis application, before constructing the networks and writing up the narratives. Networks and narratives was externally validated in meetings in the project steering committee, with two managers from the company, who meet with the researchers every 4–6 months over a period of 2 years, and by the frequent site visits. Four formal presentations of the analysis in the company also served as opportunities for feedback and comments from other employees.

ANALYSIS

Five cases are analyzed. The cases are the chairs: Ant, the Serie7, the Egg, the Ice and the Ro chair, presented in chronological order.

The Ant chair

In the 1950s, the management of the case company Fritz Hansen was looking for new opportunities to develop industrially produced chairs to become a mass-manufacturing company rather than remaining a cabinet-maker. The company was aware of new industrial possibilities and international developments. At the same time, a Danish designer and architect - Arne Jacobsen – approached Fritz Hansen because he was looking for a modern chair to furnish a new factory canteen that he just designed. However, the chairs he saw did not satisfy him. Thus, he discussed the possibility of developing a new chair with Hansen. Together with the architects in his studio, he produced some sketches and he chose one to send to the factory for a full-size prototype. However, he was not satisfied with what he received, as he considered the design to be utilitarian and lacking aesthetic innovation. He started to experiment with it. The team realized that they were constrained by the limitations of the bent wood technique. The CEO showed the architects some chairs he brought home from America, designed by Eames and Saarinen, made of plywood, a new material. They decided to try to use it. Several experiments were carried out aimed to understand how to shape the new material, while the manufacturing department was exploring ways of producing and bending a plywood made from beech, a common native wood in Denmark. As the bending technique was new and experimental, the design team proposed a prototype with the seat and the back made of a single piece of molded plywood. Simultaneously manufacturing, based on the shape of the new prototype, developed a machine able to press the double-curved seat in one piece by bending the wood in the third plain. The resulting prototype was based on experiments made by the design team together with engineering, the smiths and the manufacturing department in a tight collaboration; only a minimal part of the work was done at the drawing table.

The Series 7

When presented in a trade show, the Ant chair received many positive and enthusiastic reviews from critics. The customers, however, were not satisfied with the three legs and the lack of an armrest: they wanted to have the same chair with four legs and armrest. Arne Jacobsen, the architect, refused to add the four legs and an armrest. *Why should it have 4 legs when 3 are enough?* he declared in an interview. Adding the armrest would have required to change the backrest to support the weight; thus, rather than compromising the Ant, he proposed to develop a new design.

In the process, the design team (Arne Jacobsen, his design studio, the CEO and the manufacturing department) again experimented with different prototypes. It was agreed to use the plywood, add the armrests and legs, make it stackable, make it ergonomic and organic. The new prototype had an initial shape inspired by the DAN chair, manufactured by the company many years before. The second prototype was made more dramatic by Jacobsen, emphasizing the curvature of its back. The designer Verner Panton commented (in the newspaper *Politiken*)*:*

> The craftsmen would often joke about him (Jacobsen) because he was so difficult to work with. Once we were working on the chair which was to be reproduced about 50 km from the drafting office, and that meant that when he had new suggestions, workers came to fetch the chair and returned it the next morning. Several times, the changes were drawn on

the prototype and then sent back for a new one, immediately after delivery.

The series 7 became (and still is) a market success, and according to some the most sold chair in the world.

The Egg

Following a similar experimental process using prototypes in the initial phase of the innovation process, the design team, together with the architects/designers and craftsmen of the company, launched a new icon design some years later: The Egg.

The architect - Jacobsen is interested in designing a lounge chair, and the company Fritz Hansen acquired the license for a foam material, and suggested Jacobsen to use it. The foam flakes offered new possibilities for construction. Jacobsen, after few preparatory sketches, started to work on a rough prototype in plaster, while the manufacturing unit simultaneously experimented with production techniques and tools suitable for the new foam material. The process was a continuous back and forth process between the designer, the various craftsmen's and the manufacturing unit in the company.

In an interview, Perjesi, an artist assisting Arne Jacobsen in molding the prototype, described the prototyping as a sculptural process:

> We began to cut things out in the cardboard and work with plaster, always in scale 1:1. For the first half years I stood there working with a single chair and put plaster on and off. It was like making a sculpture, and Arne Jacobsen took it to his summer house over the weekend a few times and continued to work on it. I remember the first time we drove to his summer house, to work on the Egg, we had put the plaster model into the back of my car, and then the whole weekend we added and removed plaster. Back and forth, like classical sculptors. […] Arne Jacobsen had a very concrete and physical way of working with objects. That does not mean that his idea wouldn't clash with what was physically possible - he would order a prototype to be sawn apart to take a couple of centimeters off in the middle, not bothering whether the model could be put back together again. In fact, he did just that when the Egg was almost finished. […] To me, he was a sculptor handling a form.

Fig. 1. The experimental prototypes.

The prototypes emerged from the experimental workshops, followed by a model in full-size plaster, and then one in foam. A craftsman from shipbuilding helped in one workshop to sand the material, as it was similar to

the material used in the maritime industry. That ended in the prototype of the shell, which was supposed to be filled with foam flakes in the development process. The Egg, once introduced in the market, was considered was an innovation in terms of design forms, materials, and representing a successful combination of art and technical features.

The Ice

The third chair is the Ice launched in 2002, made of metal, aluminum and a light synthetic plastic; its particularity is that it can be used both indoor and outdoor.

The company decided to hold a competition between invited designers. The CEO and the design manager presented the selected designers with a design brief, and engaged with them to develop their first individual prototype. Based on it, they selected the designer Salto. The winning designer, Salto, expressed his concern for the materials he was asked to use. He had difficulties in advancing the prototype, since he did not previously work with aluminum and plastic, due to their cost.

> I could do whatever I wanted to, of course in collaboration with the company, so we had a lot of discussions where to go, how to do, how this product should look like, how should it be... costs and price.

The last prototype, however, ended up costing four times the forecast. The company's management was asking for an ultra-modern, lightweight, strong, comfortable and stackable chair that could be used in outside cafes, but also in canteens, private homes, and meeting rooms.

The many requirements challenged the development of the prototypes: an outdoor chair should be durable, resisting the rough Scandinavian climate; an indoor chair should be soft, smooth and warm, it shouldn't be too heavy, nor too cold. Salto experimented with the prototypes in his studio while constantly interacting with a development team at the manufacturers headquarter, using the prototypes to mediate the discussions and explore new possibilities. Initially, the prototypes were made in wood and steel to reduce costs; when the models were becoming more advanced, they were molded in plastic. Ten prototypes were made in the early design phase.

The Ro

The last example concerns the development of the Ro, an "easy chair" launched in 2013. It was intended to be a comfortable, relaxing, and affordable easy-chair, to supplement the famous Egg chair. Also in this case, prototypes were developed in a close relationship between the company design manager and the designer and a small development team at the manufacturing unit.

The development team worked at the manufacturing unit in Denmark, and the Spanish designer Hayon moved to Denmark to work closer on the development of the prototype. At the beginning, the designer and the design manager developed eight different prototypes to explore the different options within the frame given from the company, presented as a design philosophy: pure, honest and long-lasting products, without too many unnecessary ornamentations, emotional, serene, calm, serious, Danish and original.

The eight initial prototypes were narrowed down to a few ones and the designer and the manufacturing unit developed a few selected prototypes into full 1:1 scale size, but not complete or aesthetically beautiful, constructed using rough material (cut-board, wood, foam). They were in full scale because the design team needed to feel, sit and see the prototype to evaluate and make decisions and consider how to develop and manufacture it. The prototypes, thus, was constructed to understand how the design will work out, and make cost and production calculations.

Conclusions

Although very different, the cases each has critical situations where the fuzzy-front-end processes are punctuated and bracketed (Weick, 1979), dragged out into an experimental space with many parallel simultaneous ongoing activities, that address the challenge from various angles, all at the same time: The shape, the values, the functions, the materials, the tools, the materials, the manufacturing technologies, the designers values, the blacksmiths competencies, the shipbuilders knowledge, the sculpturer' experiences, the design briefs and the mock-ups.

Table 1. Analyzing the cases

Case	Experiment focused on	Outcomes
Ant	Exploring the qualities of material, the industrial manufacturing options and the design of a new shape	New methods, tools and machinery for pressing the plywood into a new shape
Serie7	Expanding the bending possibilities of plywood	New organic shape and new manufacturing skills
Egg	Exploring the qualities of a new material, create a unique shape and explore manufacturing techniques	An iconic design, mastering a new material and new manufacturing techniques and tools
Ice	Explore what is the right designer, explore new ways to collaborate and learning to combine new materials	Using a competition approach to select designer, prototypes and mastering new materials
Ro	Develop a broad range of alternatives to explore what is possible within a certain design philosophy	Interaction with development team, managers and designer producing mul-tiple alternatives.

DISCUSSION AND CONCLUSIONS

The process for doing experiments with prototypes in the cases can be characterized as a process going constant back and forth between the different human and non-human actors - simultaneously. Innovation and experimentation is not an isolated concept of the individual, but emerges through the collective. In the cases, the prototypes were used in the fuzzy front end, rather than towards the end as much prior research has suggested. In this, the prototype seems to acquire a new function: rather than being a test, it becomes a vehicle for creating new options. The ANT analysis helps us to analyze how relationships can be re-organized in the process and stabilized - for a shorter or longer period - to create a network (Callon, 1991) - a proposed prototype, how the prototyping processes makes it possible to relax some of the assumptions - deliberately removing some relations, introducing new design elements (actors) test how they might connect to new experimental prototypes.

In the processes, many actors were involved: managers, designers, craftsmen, manufacturing, sculptors, new and well-known materials and production techniques. The prototype is used to reflect on the process and look for alternatives to the courses of action. The prototypes seem to ignite the fuzzy front-end process and make it explorative. The prototyping changes the experiment into an option generator, as expressed so elegantly by Corsin, "it is a temporal construction that tolerates uncertainty as a reasonable and feasible outcome" (Corsín Jiménez, 2014). Indeed, the prototype accepts and even provokes interruptions, during which assumptions are challenged, questioned, tested and new avenues explored. Through prototyping, the design teams get involved in various forms of explorative activities that provides sources for thinking about alternatives, rather than a structured sequence of decision making. The experimental prototyping postpones decision making, and allows for a freer production of multiple alternatives, generating options, and suggestions and putting the goal oriented decision-making to a point as late as possible. The prototyping behavior allows the processes to be stopped, reframed, and questioned, often involving new external partners, materials, and trying to incorporate and understand external information. Rather than being decision oriented, the cases here indicates that an experimental design attitude that stimulates to the generation of many alternative prototypes is adventurous and maybe even one that should be used in management as suggested by some (Boland and Callopy, 2004). Thus, further research is needed to explore the process of stimulating the FFE using explorative experiments and prototyping. For example, it would be relevant to explore with designers and managers - setting up an experiment - to carve out a space for in-depth exploration of various alternative designs, that are created to test various ideas, and then used for dialogue with others involved in the product

development process. This process could be run several times. This process should be monitored and later analyzed for getting knowledge about challenges and information about which situations and/or products this approach is most beneficial.

Using this approach would also be beneficial in training innovation students and designers to apply some of the ideas from this punctuation method; e.g. by using some type of creative space as IdeaSquare to work on ideas generation through rapid prototyping, and then ask students to step back and reflect on the prototype and the process. They should envisage future directions and new possibilities from the prototype, and build a scenario for the idea that was generated in this critical front end phase. In this way, they would have an appreciation of punctuation and the role of prototype through learning by doing.

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