

Design Prototypes as Boundary Objects in Innovation Processes

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Abstract

In our paper we focus on how design prototypes can foster communications in organizations that deal with the development of innovations. We distinguish the impact of prototypes between two different organizational levels; we first conduct the impact of prototypes at the level of organizational design teams that develop ideas and concepts for solutions. We then focus on the impact of prototypes on the level of organizational teams and departments that have not been part of the initial design phase but are responsible for further developments in the innovation process, e.g. production, financing, and marketing.

Previous research has indicated that prototypes have a significant influence on both organizational levels. Prototypes, in the best cases, can become so-called boundary objects between different domains and stakeholders and may deliver positive effects within the innovation process. However, the successful management of stakeholders in this context remains highly challenging. In this paper we want to address these difficulties as well as the current state of research in this field. We propose that a prototype does not only stand for an important design technique but should moreover be regarded as a management tool that can be integrated into a structured dialogue between stakeholders. We provide first insights on what a structured dialogue, based on prototypes, can mean and what it thereby should imply. We will synthesize prior research findings and begin to develop a concept on how to utilize prototypes as boundary objects from a management perspective.

Keyword: *prototypes, boundary objects, innovation process*

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Developing prototypes has always been considered to be a major part in design. Non-Designers often perceive them as new products that illustrate the next generation of a series of products, while designers create them for different purposes: not just as a result of but as a manifestation of design ideas during the design process.

Prototypes are artificial manifestations, thus our research does not look for an objective nature of the invention, but for the role they may fulfill for organizations that deal with design-specific challenges. We assume that a prototype can be characterized not only as a medium or by its form, but also by its impact on team-internal and organization-wide communications. As Houde and Hill (1997:2) state, prototypes can be defined as “any representation of a design idea, regardless of medium”. However, the prototype is always a limited representation (Brandt, 2007), identifying only limited aspects, because of its restrictions in form and medium. Lim, Stolterman, and Tenenberg (2008:2) present an extensive overview of the nature of prototypes as manifestations and filters for design ideas in which they describe prototypes as “means by which designers organically and evolutionarily learn, discover, generate, and refine designs”. They conclude that there are prototypes of different qualities and that “the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable” (Lim et al., 2008:3).

Furthermore, prototypes are often described as boundary objects (Star and Griesemer, 1989, Neyer, Doll, and Möslin, 2008, Brandt 2007, Doll 2009) that have an impact on the understanding and the exchange of design ideas in organizations and are therefore crucial for the success of social interactions within the design team. The concept of boundary objects has been developed within sociology and was introduced by Star and Griesemer (1989:393):

Boundary objects (...) are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation.

The term has later on been transferred to various other scientific disciplines like for example computer science and management studies. According to Wenger (2000) there are three categories of boundary objects: artifacts (tools, documents, models), discourses (languages that can be shared across communities) and processes (routines and procedures that facilitate the coordination of communities). Obviously, boundary objects are of explicit relevance in organizational innovation processes, as Star et al. (1989:393) further describe them as

objects which are both plastic enough to adapt to local needs (...), yet robust enough to maintain a common identity across sites. (...)The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds.

Boundary objects have the ability to couple different social worlds (Doll, 2009) in order to converging perspectives and give them meanings. Not only multidisciplinary design teams interact with each other but also social worlds within the organization (other teams, departments) and outside the organization (users, customers, clients).

This specific impact of prototypes as boundary objects between team members and between organizational teams needs to be further explored. Thus, after a review on

previous research, we begin to develop a concept on how to improve the prototype's capability to foster communication processes.

Prototypes as Boundary Objects in Design Processes

The first level of organizational teamwork that is affected by prototypes is the design team which develops the initial design idea. They develop prototypes for various reasons. With regard to our research interest, we identified three major aspects from previous research: (1) the role of prototypes as a manifestation for user feedback, (2) the role of prototypes as a tool to improve team experience, and (3) prototypes as a force to converge thinking during the design phase. To start with, a single prototype might be able to have an impact on all three aspects.

Prototypes as a manifestation for feedback

Prototypes are considered as a manifestation for different sources of feedback in design processes. We identified four major forms of feedback from the research literature with regard to the design process: (1) design teams can compare their understanding of the design task with clients from the beginning of the design process; (2) design teams empower users to reflect the design idea, (3) to actively elaborate the design idea, (4) and also to further iterate the design idea within the design team.

Involving the client in the very beginning of a design project can support the process of identifying the given problem field and developing a first specification. Clients oftentimes are not able to specify the requirements of complex products right from the start, given that something genuinely new and innovative is being required. Design teams therefore often start with a prototype that builds a shared space (Doll, 2008) for continuative discussions with the client. Debating this first prototype with the customer is likely to lead to a clearer picture about what customers actually want. This function of prototyping is mainly to be found within software development: prototypes are understood as instruments for the clarification of system specification, to support decision processes and to gain practical experience with a planned software system before actually starting the implementation of system components (Doll, 2009).

The relevance of prototypes as a medium to communicate client wishes to the design team is well understood in software engineering: Frederick Brooks already pointed out in 1978 that „it is really impossible for clients, even those working with software engineers, to specify completely, precisely and correctly the exact requirements of a modern software product before having built and tried some versions of the software they are specifying” (cited in Doll, 2009:150). The client's feedback offers the possibility to get in concrete touch with a design idea and to give important feedback, which can be integrated later on within the further work of a design team. Referring to this praxis, Buchenau and Suri (2000) coined the term “experience prototyping”.

During the design process, design teams develop prototypes to get feedback from users on how they perceive the underlying design idea: "Visualizing and prototyping play a significant role in designing. Early sketches and mock-ups, however rough or rugged, allow ideas to be shared and discussed" (Junginger, 2007:60). Dow, Heddleston, and Klemmer (2009:31) describe the role of prototypes for "designers (to) embody creative hypotheses" that also help to observe the outcome. Designers do so by sharing and discussing (Junginger, 2007) manifestations between each other and also by testing their usability with users (who can also be customers, depending on the context). The users' feedback can help to understand whether the design idea is desirable or even understandable to outsiders: "Prototypes too often confirm that what we wish for is unrealistic or ill conceived. Conversely, prototypes can reveal that the designer's wishes

were not sufficiently imaginative” (Schrage, 2006:3). Prototypes are considered to be tools for evaluating successes and problems of a design idea by showing them to potential users: User feedback can be played back to the design team so that critique and comments can be integrated (Brandt, 2007). Prototypes with this purpose may be called “integration prototypes” (Houde et al., 1997): they are built to represent the user’s experience of an artifact and may focus on role, look and feel, or technical implementation. That means, if prototypes within user interaction are designed to answer questions, one has to be mindful of the different purposes prototypes can serve. In order to receive feedback, prototypes are a powerful medium for designers to communicate their ideas and rationales with each other and to other stakeholders (Lim et al., 2008) and to evaluate them (Houde et al., 1997). For these purposes the development of multiple prototypes for a single design challenge is a common practice among designers. Research has shown that it is often useful to develop not only a series of prototypes but various prototypes in parallel to receive better feedback (Dow, Glassco, Kass, Schwarz, Schwartz, and Klemmer, 2010).

Moreover users and clients not only reflect ideas, but are also asked to elaborate the idea by actively modifying prototypes. As part of a user-centered design, prototypes are regarded to be helpful to evolve a shared “language-game” between design teams and users (Brandt, 2007) therefore fostering “human-human interaction” (Schneider, 1996). Users thereby not only reflect points of interests that the design team mentions, but also raise new questions. The quantity and kind of questions that generate prototypes may change with the dimension of a prototype. Different questions can require different kinds of material, prototyping media or differentiation (Schrage, 2006:5). As Leonard-Barton (1991) has stressed, models and prototypes are “inanimate integrators”, which support people in and outside organizations to communicate about a certain product beyond boundaries of discipline or domain. For example, prototypes can be applied in order to actively involve customers in the testing of innovative business ideas by using high or low fidelity prototypes (Virzi, Sokolov, and Karis, 1996).

A prototype is less regarded as a result of a process, but rather as an evolving manifestation. Furthermore, the prototype is both, the result of an intermediate step and the starting point for the next step within the design process. A first version of a prototype usually represents a very rough idea to be tested in order to come up with new ideas within the team. The feedback may change the perception on the design idea and leads to an iteration: “An iterative prototyping practice oscillates between creation and feedback: creative hypotheses lead to prototypes, leading to open questions, leading to observations of failures, leading to new ideas, and so on” (Dow et al., 2009:43). Within this iterative process, prototypes are able to reduce different uncertainties, e.g. in terms of viability and feasibility of business ideas (Doll, 2008).

The focus lies on the creation of a shared understanding why a design idea might work or might need to be reframed; it is therefore not important whether the prototype provides an elaborated look or functionality. Design teams, which require fast and iterative feedback, focus on simple prototypes that are just elaborate enough to manifest the design idea properly. Thus the prototype is to be seen as a means of generative and evaluative discovery (Lim et al., 2008). Junginger (2007:63-64) points out:

An organization that employs design thinking and design methods inquires into the organization’s problems from a user’s point of view – from the perspective of someone who has little understanding about the complexities involved but who needs to have a clear path of action.

Prototypes to improve the team experience

Research has shown that prototypes also can have a positive impact on the team experience. Doll (2008) mentions teams of founders that perceived the development of prototypes as a tangible experience that also leads to emotional changes. Prototypes reduce uncertainties and thereby improve the confidence and the bonding of the team (Doll, 2008). Dow et al. (2009:172) also assume a positive effect on both "individual emotions and team dynamics". They mention that it is important for the teams to not only receive feedback on prototypes individually but to "perceive and interpret feedback collaboratively" (Dow et al., 2009:172). They learn together and realize what they can achieve and what not, thereby developing a team identity (Doll, 2008). Doll (2008) also conducted a correlation between the usage of prototypes in teams and the quality of the overall team performance.

Prototypes to converge thinking

If we look for explanations why prototypes can improve team experience and performance, one major aspect has been identified in previous research. While teams develop prototypes, they seem to intuitively converge their thinking. The prototype as a model helps to visualize the focus of exploration (Houde et al., 1997). The effect has been described as a shared mental model (Neyer et al., 2008) within the team. This implicit model is a result of the communicative interaction along the development of the prototype. Once developed, the prototype acts as a sender that delivers a signal to team members about the process being made (Neyer et al., 2008). Prior somehow diffuse ideas and vague models either turn into a prototype that the team can agree on (which indicates the existence of a shared mental model) or that leads to further discussions and conflicts (which indicates that there are still divergent perspectives that do not match with each other).

Prototypes and Innovation Processes in Organizations

As described in the former chapter, research literature from the past twenty years explains various positive impacts of prototypes on social interaction processes of design teams. Beside these descriptions of prototypes as manifestations for design teams and their communications, various authors also focus on the role of prototypes as a boundary object between design teams and other organizational teams (Verlinden and Horváth, 2009). From this point of view, prototypes are a means to answer questions between designers, but also between designers and others (Lande and Leiffer, 2009). We focus on the role of prototypes as boundary objects in innovation processes. We assume that a prototype can potentially deliver a design idea in a way that other stakeholders are able to further develop these ideas based on their individual knowledge without overseeing the designer's initial intention.

Knowledge transfer by prototypes

Prototypes are often communicated during the design phase, but are also being handed over after the design phase is done. During the design phase, designers and design teams show prototypes to their supporting organizations (such as project managers, business clients, or professors) to indicate progress and direction (Houde et al., 1997). One group of relevant stakeholders during the design phase might be technical writers who are responsible for document ideas and findings: "Since technical writers often need to start their work long before a working version of the product is available, having access to a prototype can be valuable in helping to develop an understanding of exactly how the product works, as well as providing easy access to details such as specific prompt wording or screen designs" (Virzi et al., 1996:242). Junginger (2009:33-34)

emphasizes the importance of prototypes as boundary objects during the design phase as well:

Prototypes allow both the design team and the members of the organization to see the emerging work. At the same time, early prototypes serve as explorations of new possibilities since they provide the space and place to approach and visualize problems in a somewhat noncommittal and thus less threatening way. Scheduled review sessions of prototypes are one way to involve members of an organization in the development process.

Not only technical writers, but also other domains become actively involved during the innovation process. Virzi et al. (1996:242) point out:

Prototypes are effective in communication with marketing departments, and here the high face validity of high-fidelity prototypes can be critical. Marketing can also use the prototype as part of early demonstrations to their clients.

Developers and engineers can be directly targeted with prototypes in order to further elaborate the design idea, e.g. in terms of its technical feasibility: "A corollary to this is that the process of building a high-fidelity prototype always helps to identify weaknesses and omissions in a user-interface specification" (Virzi et al., 1996:242).

Organizational redesign by prototypes

Using prototypes across organizational teams does not only influence the development of a product but also the whole organization. Different approaches to utilize prototypes in this sense can be found. David Kelley argues that organizations can either develop specification-driven prototypes or prototype-driven specification and both approaches can be suitable (cited in Schrage, 2006:4). It is nevertheless important to combine both in order to further develop design ideas (Schrage, 2006). This indicates that design teams cannot solely rely on a prototype as a manifestation when prototypes are rotating within the organization and along the innovation process.

Often prototype-driven organizations experience a redesign as an effect on their innovation processes:

Each individual product can serve as an 'intermediate act' that collectively and successively transforms the organization. Organizations tend to see products as ends, not as intermediary acts. Thus, a number of products have been mislabeled as 'failures' instead of being recognized for their role as necessary intermediaries without which an emerging radical new approach would not have been possible (Junginger, 2008:34).

Schrage (2006:9) calls a prototype a "medium for interdepartmental integration" that is potentially capable of deconstructing organizational flows and structures. Especially management starts to become aware of incremental changes by looking at the "flow of prototypes" (Schrage, 2006:10) through the organization and the questions being raised by that: "Who—insider and outsider—get to see what when? When are modifications made? Who requests them? Which requested modifications are ignored?" (Schrage, 2006:10).

Outlook: Prototypes as Management Tools

In our outlook we emphasize the importance of prototypes as boundary objects within both design teams and organizations. A lot of design teams have proven to be successful by integrating clients and users within the design process by utilizing prototypes. Nevertheless we assume that the integration of organizational stakeholders is yet underdeveloped in most organizations. We further assume that management needs to

take advantage of prototypes to a greater extent in order to foster the knowledge transfer between organizational stakeholders. Until now, little research indicates the successful exploitation of prototypes as a future management tool.

Shortcomings in the Usage of Prototypes in Organizations

We have seen that prototypes can be used not only as boundary objects within design teams but furthermore within the overall innovation process of an organization. Prototypes are therefore attractive to many organizations in order to pursue innovation processes. Nevertheless, research has shown that prototypes are often not self-explanatory. Not every prototype develops the quality of a boundary object in organizational innovation processes. Simply handing over prototypes from design teams to developers or engineers does not seem to adequately tackle the complexity when dealing with design ideas and knowledge.

As previous research has shown, design teams become aware of the complexity and thereby pursue to actively integrate clients and users within the design process. However, the design process is only part of the overall innovation process in organizations and various organizational stakeholders must be involved. The involvement of stakeholders based on a shared design idea is a highly challenging task with regard to knowledge management:

Good ideas may be rejected by ill-informed executives based on what is perceived as inadequate execution of the prototype. Top management may find it difficult to see beyond prototype roughness to the ultimate product. As a result, many engineers conceal provocative prototypes from senior managers until the models have been polished appropriately (Schrage, 2006:7).

The Role of Management

With a focus on organizational innovation processes, we assume that management is the key domain that is nesting between organizational stakeholders (teams, departments, business units) to make sure that loose couplings between them can be tightened or released, depending on the context (Orton and Weick, 1990). Management thereby acts as an active observer of design teams and other stakeholders within the organization.

Management has the authority to connect design teams and further stakeholders into a knowledge transfer after the design process. In our view, many chances are being scattered if design teams have to “polish” their prototypes in order to present them to management. However, scenarios that could contribute to this problem field have only started within the existing research literature. We want to build on the thought of Schneider (1996) who suggested that a prototype needs to be interconnected with a structured dialogue. We assume that a dialogue at the interface between design teams and e.g. developers cannot be taken for granted, simply by introducing prototypes. Management may take advantage of the prototype as a promising enabler for a structured dialogue.

Reconstructing the Evolution of a Prototype

The need for a dialogue becomes clear when we understand that every team and every part of the organization has access to a very limited knowledge which determines its perception of the prototype. We are aware of the fact, that other stakeholders have a different knowledge that can enhance our perception in order to further develop the prototype but we do not know what knowledge this might be - otherwise it would be already part of our knowledge. Most of this knowledge is implicit and hard to grasp by observation or common dialogues, because both dialogue partners are in a similar

position, not knowing what the other partner does not know, even worse: often not knowing what oneself does not know (Nonaka, 1997). Designers may be experienced in reflecting their actions towards themselves during the design phase (Schön, 1983) but they hardly reflect their actions explicitly towards other stakeholders after the design phase.

As described above, any prototype is always a limited representation of a design idea and therefore often in the need for an explanation to external stakeholders:

Most confusing, it often remains unclear which of these questions are actually addressed by a demo, and the big question is: What point does the developer make in showing this prototype? What does the developer prove, falsify, or demonstrate? (Schneider, 1996:522)

Management can make a difference by providing space and time not only for the presentation of the prototype but also for the reflection on what happened during the design phase and the externalization of implicit perceptions on both sides.

Since the final design prototype can be regarded as a product of the design phase, it is oftentimes helpful to not only present the final result of that discourse (Rambow and Bromme, 2000) but also to reflect the evolution the prototype went through. As we have seen in previous research regarding the active integration of users and clients, prototypes lead to further iterations based on an elaborating understanding of the underlying design challenge. We assume that understanding these iterations is as helpful as understanding the final manifestation in order to transfer the knowledge. In this sense, a prototype can be described as an evolution of arguments that were convincing enough to make an impact on the final result. This evolution of arguments is implicit and oftentimes not documented. A structured dialogue should reflect the evolution of a prototype in order to externalize the design idea and the underlying knowledge.

A promising approach that could help define further research in this area may be seen in the research field of concept-knowledge-theory (C-K theory). C-K theory is a design theory that was introduced by Hatchuel and Weil in 2003 and reflects the assumption that

design can be modeled as the interplay between two interdependent spaces with different structures and logics: the space of concepts (C) and the space of knowledge (K) (Hatchuel & Weil, 2008:1).

This theory delivers a model of dynamic knowledge- and object-development that is likely to support the documentation of a dialogue about the final manifestation of a prototype.

Our further research questions what kind of structures management can provide in order to set up a promising dialogue between stakeholders. We are currently designing an experiment to empirically validate our assumptions.

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