PROTOTYPES AS INQUIRY, VISUALIZATION AND COMMUNICATION

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ABSTRACT
Before engineers and designers can become comfortable with the idea of building conceptual prototypes, they need to understand that prototyping is a valid method for not only for evaluation but also for exploration of concepts. This understanding depends on a deeper recognition that not all questions regarding a real product or system are amenable to mathematical analysis or simulation: there exist questions, often of a qualitative nature, that are necessary to answer even though they cannot be expressed analytically. “Prototypes as a mean of formal evaluation are a relatively small part of the entire design process. Prototypes are the means in which designers organically and evolutionarily learn, discover, generate and refine designs. They are design-thinking enablers deeply embedded and immersed in design practice and not just tools for evaluating or proving successes or failures of design outcomes”. [1]
Furthermore, as designers’ participation in the fuzzy front end of the development process increases, the definition of prototype and the activity of prototyping evolve. What is a prototype of a service? What are the materials needed to build prototypes for future experiences? How do you prototype behavioural change or transformation?

Keywords: Prototype for exploration, prototypes for evaluation, visualization, design process

1 INTRODUCTION

The word prototype is a term in need of clear definition. In multidisciplinary settings, prototypes are different things to different people. To an industrial designer a prototype may be an appearance model that represents the form of the object without depicting functional characteristics. To an engineer a prototype may be a fully functional object that closely represents the final product. To an interaction designer a prototype maybe an on-screen simulation of a user interface. The ambiguity of the term escalates when trying to find common uses or classifications within the different disciplines. There are prototypes for exploration and prototypes for evaluation in every field. There are prototypes that depict refined details of the final product (high fidelity) and others that are rough representations of one or more dimensions (low fidelity). There are also variations in terms of scope or breadth in regards to what is being represented, whether it is a mechanism, form, interface or experience.

1.1 Designing with and through Prototypes

The most common use of prototypes is to communicate ideas among different stakeholders in order to make design decisions. However, the generative or exploratory nature of prototypes is also critical to the design activity. “Design knowledge is knowledge in action, revealed in and by actual designing” [2]. In order to solve a design problem, designers need to “make” things iteratively. Clark suggests that the act of bringing thoughts into material form is not incidental to the act of creation but is itself constitutive of and essential to creation [3]. Typically, the designer works through a visual medium (drawings, models, etc) and according to Schon, “—the designer sees what is ‘there’, draws in relation to it, and sees what he or she has drawn, thereby informing further designing. In all this "seeing," the designer not only visually registers information but also constructs its meaning--identifies patterns and gives them meanings beyond themselves” [2]. Schon calls this process “designing as a reflective conversation with the materials of a situation”. He also believes that the activity of knowing-in-action involves sensory, bodily knowing. Drawings and sketches play an important role in this process, but physical models provide even richer visual information and a more concrete sensory experience with an artifact or a given dimension of an artifact.

One important consideration is that all visual representations have a level of ambiguity and inevitably imply some compromise from the original intent. This can be an asset as well as a hurdle. Drawings, sketches, physical models and computer models have inherent characteristics appropriate for different reflection and communication tasks at different stages of the design process and are subject to multiple readings, particularly within multidisciplinary settings. “The achievement of a convergent, collective reading of prototypes depends on reciprocal reflection among designers--reflection on objects, moves, and descriptions-which may be subverted by the participants' attachment to particular readings and their defensive reactions when their readings are called into question” [2]. Therefore, defining criteria for development of a given prototype is a design challenge within itself. Design teams need to consider prototypes as a complex design problem that encompasses use, usability, materials, processes, audience (the ‘makers’ and ‘readers’ of prototypes) and context of use.

1.2 Disciplinary perspectives

1.2.1 Product Design Engineering

In the context of Product Design Engineering, prototypes are defined as “an approximation of the product along one or more dimensions of interest” [4]. While this definition encompasses sketches, drawings or physical models, the concept of ‘prototype’ is primarily understood as an evaluative tool “used to identify and satisfy requirements”. [4]

Figure 1 depicts the generic product development process that starts with a concept development phase. This initial phase is driven by identified consumer needs and product requirements. Prototypes, sketches and drawings are tools that assist in evaluating how well the ideas generated in this phase meet the defined required needs. Often times, these prototypes are called “proof of concept” prototypes. Prototypes also play a role later on in phase 4 where the final product is constructed for the purpose of testing performance and reliability.

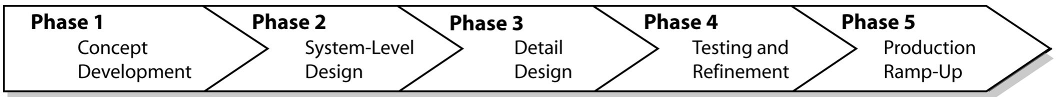

Figure 1. Generic product development process [4]

Ulrich and Eppinger classify prototypes in two categories: physical and analytical (non-tangible representations of a product, usually mathematical models such as computer simulations or computer models of three-dimensional geometry). Another dimension relevant to classification is the scope: what aspect of the design idea is represented. For Urlich and Eppinger a comprehensive model closely corresponds to the actual product represented. A focused prototype implements one or more aspects of the product. A focused prototype can be physical or analytical, but a comprehensive prototype is typically a physical model. The ‘makers’ of such prototypes are usually experts in a given material, process or technology. The ‘readers’ of these prototypes can be the design development team, manufacturing, the supporting organization or end users. The product design engineering process is typically expert- driven and the artifact is at the center of the inquiry.

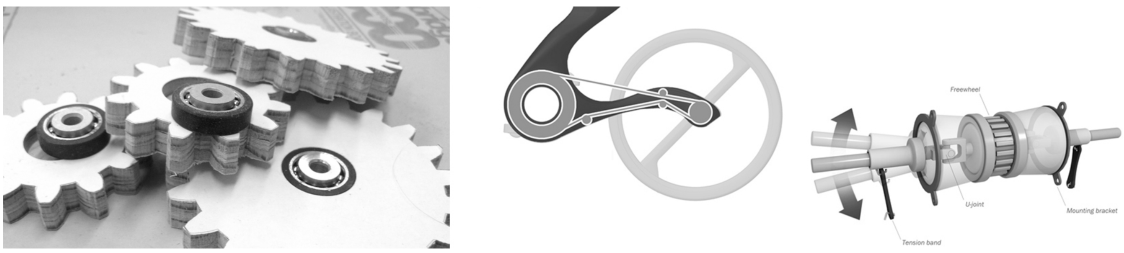

Figure 2. Focused mechanical prototype and analytical prototype of a gear system (S. Shim)

1.2.2 Industrial Design

Prototypes in Industrial Design are understood as idea generation tools, evaluative tools, and powerful communication tools. Prototypes in this context are also associated with visualization tools that reveal opportunities and limitations at different stages during the product development process. These visualizations target different sets of audiences. Figure 3 depicts a traditional product design process.

The design activity typically starts with a design opportunity identified and prototypes are built to address the exploration and evaluation of questions such as: *Is it useful? Is it usable? Is it desirable?* Issues that may be addressed in this phase include: How can this product address the users needs? What form will best support the user in performing a given task? How does the product fit the user and the activity? How can the product be more attractive?

Phase 1 is exploratory and iterative and most often multidisciplinary. Prototypes in this context can serve as tools for discovery, understanding and learning. They assist the designers in externalizing concepts in similar ways that drawings or sketches do but they also aid in exposing physical characteristics, opportunities and constraints that a drawing is unable to provide. The models at this stage are usually low fidelity models (sketch models) that can focus on one or more areas of a possible direction. The drawing, however, can range from abstract diagrams to highly refined sketches that require an advanced level of expertise. "Sketchier visual techniques for early design are becoming more and more important as product designers need to increasingly attend to the context and experience surrounding product use". [5]. The 'makers' of prototypes at this stage of the traditional industrial design process typically include the design development team. The 'readers' of these prototypes can be the designer, people on the design development team, the supporting organization or end users.

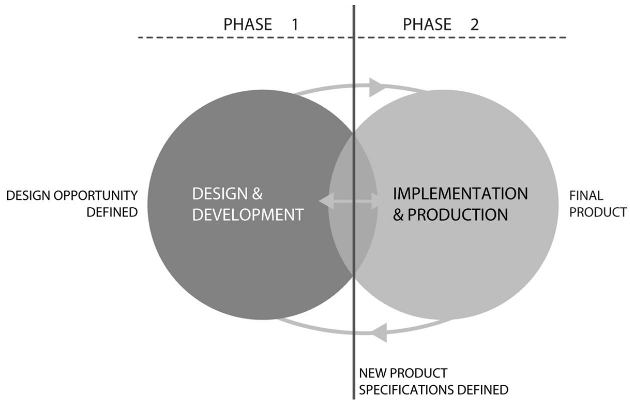

Figure 3. Traditional product design development process

Phase 2 (Figure 3) utilizes prototypes in an evaluative process that can also be multidisciplinary. The prototypes between the two phases are characterized by their evaluative and communicative properties. Depending on the type of evaluation and communication task and the kind of 'reader' (designers, management, users, manufacturing etc.) the prototypes at this stage can be high fidelity models, comprehensive models, appearance models, breadboard models, etc. The 'maker' in this stage, is typically an expert in a given material, technology or process. The industrial design development process is generally an expert-driven process (although it is increasingly recognizing the user as an expert and contributor) with the user at the center of the inquiry.

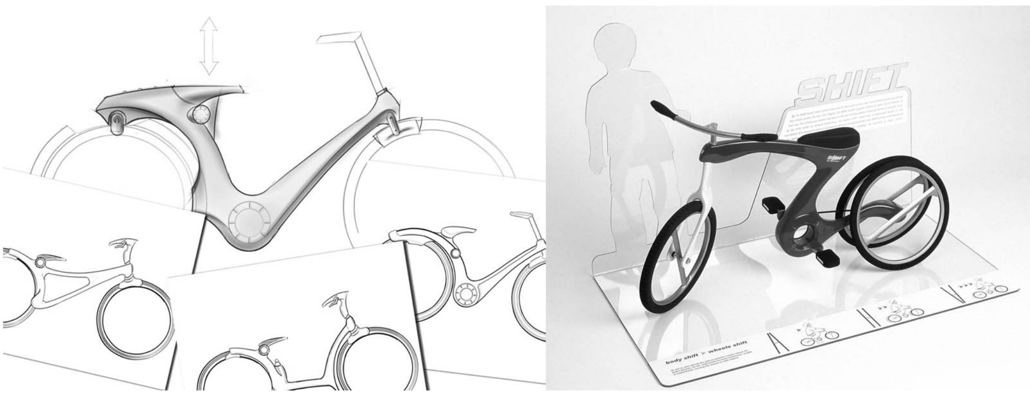

Figure 4. Sketches and a high-resolution appearance model of the Shift Bike (S. Shim)

2 PROTOTYPES AND THE EXPANDING DESIGN DEVELOPMENT PROCESS

Design has undergone radical transformation in recent years. The traditional design process is still alive and well but a new phase (Phase 0) has emerged at the front end of the design process to address the exploration and discovery of answers to questions such as: *What is useful? What is usable? What is desirable?* Issues that may be addressed in this new phase include: How can we improve people's lives? What is meaningful to people? What do people value? What do people desire?

Design in Phase 0 at the front end of the design development process is not just about visualization and the application of individual creativity anymore. The challenges are far more complex. But we can address these new challenges through co-creation, i.e., collective forms of creativity [6]. Co-creation in design requires an expanded understanding of what prototypes can be and who uses them. In the fuzzy front end of the design process the 'makers' and the 'readers' of the prototypes are very likely to be the same people. And these people probably come from many different backgrounds and disciplines, well beyond design and engineering. We need the Phase 0 prototypes to be useful for everyone so that we can explore together. What are the characteristics of prototypes needed to assist in the process of externalizing ideas from a group of people?

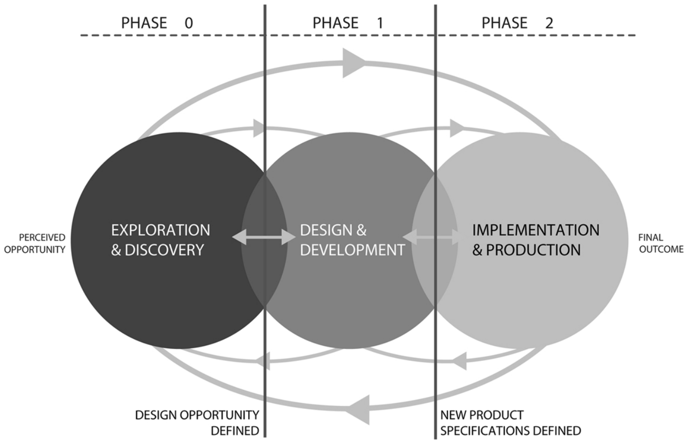

Figure 5. Expanding Design Development Process

Design embodiments that emerge from the exploration and discovery activities that take place in Phase 0 include behavioural change, organizational transformation and social transformation. Clearly, new types of prototypes for imagining, expressing, visualizing and communicating will be needed to navigate in these new design spaces. Figure 6 shows two examples of prototypes that support collective idea generation.

Figure 6. Prototypes for collective idea generation (using maketools)

What are the characteristics of the materials needed for collectively prototyping in Phase 0? It is the ability of the materials to reach (through remembering) and to touch (emotionally) people regardless of their background or experience. Therefore the ambiguity of the materials is key. Ambiguity can be tapped and used to evoke memory, provoke emotion, stir imagination and support expression of the provoked ideas. A wide range of materials is needed so that different kinds of people can work in their preferred "mode". The materials need to be both concrete and abstract. And the materials need to be both visual and verbal because the connection to meaning is different in the visual and verbal domains.

3 PROTOTYPES AS A DESIGN PROBLEM

In a sense, a prototype is a “product” that needs to fulfill the needs of a given audience. It is constrained by materials, processes and needs to be defined in the context of use. The challenge in developing the effective prototypes lies on defining the function that the prototype is to perform while acknowledging the need for establishing design criteria. The development team, whether discipline-based experts working individually or multidisciplinary teams working collectively need to spend time “designing” and planning the appropriate prototype for the appropriate task. In order to define what is appropriate, the development team needs to consider the following criteria: purpose, audience (prototype ‘makers’ and prototype ‘readers’), scope, resolution and materials.
Figure 7 summarizes the general characteristics of prototypes based on their purpose throughout the three different phases of the design process (Figure 5): exploration and discovery, design and development, and implementation and production. It also depicts relationships and appropriateness for different purposes.

CHARACTERISTICS OF PROTOTYPES

	PHASE 0			PHASE 1			PHASE 2		
	Exploration	Evaluation	COMMITMENT	Exploration	Evaluation	COMMITMENT	Exploration	Evaluation	COMMITMENT
PURPOSE	Identify the problem or opportunity.	Describe the problem or opportunity. SELL		Externalize and generate multiple ideas.	Confront constraints. Validate direction. SELL		Address constraints. Validate final product features.	Test performance. Lower risks. Integration of components. SELL	
AUDIENCE ‘makers’	Makers =Readers Low expertise in making models. Multiple disciplines. Collective expertise.	Expertise in visualizing and moderating.		Low expertise in making models. Multiple disciplines.	High level of expertise.		High level of expertise.	High level of expertise.	
AUDIENCE ‘readers’		Stakeholders Funders Clients		Individual and collective expertise	Multiple perspectives. Technical expertise.		High level of expertise.	High level of expertise.	
SCOPE	Wide scope. Multiple dimensions.	Prioritize and select area of focus.		More focused. Conceptual.	Focused. Functional and physical.		Focused. Functional and physical.	Comprehensive.	
RESOLUTION	Ambiguity is a resource. Low time/ investment.	Future scenarios. Actions over products. System level.		Low fidelity. Low time/ investment.	High fidelity. High time/ investment.		Higher fidelity. Higher time/ investment.	Higher fidelity. Higher time/ investment.	
MATERIALS	Conceptual. Emotion provoking.	More tangible. Evocative. Visual.		More tangible. Low tech.	Physical or analytical/ digital.		Close to actual materials and processes.	Closer to actual materials and processes.	

Figure 7. Summary of characteristics of prototypes throughout the expanded designed process

All three phases of development have an exploratory and an evaluative component. The scope describes the breath of the subject (system, experience or product) represented by a prototype (specific dimensions or a fully integrated artifact). The audience refers to the ‘makers’ and ‘readers’ of prototypes. These can be individual experts working in isolation or multidisciplinary teams generating and/or evaluating prototypes. They can be end users, organizations, communities, company partners, manufacturers or technicians. Resolution and materials are closely related criteria. The level of fidelity required dictates the choice of materials, processes and technology. Inconsistencies between the materials, level of fidelity needed, the skill level of the ‘makers’ and the needs of the ‘readers’, can negatively impact the success of a project. Due to these interactions it is possible that a prototype may fail to answer the question asked whereas the concept or idea behind it maybe sound. On the other hand, prototypes may actually answer questions that seem acceptable whereas the production or implementation of the design may be flawed since prototyping materials and processes may occasionally outperform their production counterparts. This can be the case particularly with computer models. Another example of an inconsistency would be high fidelity scenarios of future experiences for phase 0. Often times, digital models force the "makers' to make premature decisions.

4 FUTURE WORK

The framework presented in figure 7 can serve as a reference framework for a development team or for design and engineering education. At a glance, exploration prototypes are mostly low fidelity models that may or may not require high level of expertise in the 'making'. In contrast, prototypes for evaluation require higher levels of fidelity, expertise, time and cost investment. Evaluation prototypes are often communication tools between the different groups and serve as "bridges" between phases. Inconsistencies between fidelity, materials and expertise levels can lead to misleading prototypes. This is often the case in academic environments. Quite often we have seen students' ability to conceptualize new solutions to a problem be handicapped by attempting to build a high fidelity model with low fidelity material when attempting to explore a solution. Students with no real education or training in prototyping often select a candidate material based on their own limited experience, without considering how well it will answer the question. In other cases, students confuse their failure to work with a specific material with a failure of the idea itself.

We have presented a preliminary framework and intend to refine and develop it into a guideline for use by practitioners and educators. We plan to provide methods, cases and visual examples to assist, guide and inspire future users.

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