Effective Framing in Design

by

Jonathan Henry Grenville Hey

MEng (University of Bath) 2002

A dissertation submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

in

Engineering – Mechanical Engineering

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Alice M. Agogino, Chair
Professor Sara L. Beckman
Professor Paul K. Wright

Spring 2008

The dissertation of Jonathan Henry Grenville Hey is approved:

_____ Date _____

    Chair

_____ Date _____

_____ Date _____

University of California, Berkeley

Spring 2008

Effective Framing in Design

Copyright 2008

by

Jonathan Henry Grenville Hey

Abstract

Effective Framing in Design

by

Jonathan Henry Grenville Hey

Doctor of Philosophy in Engineering-Mechanical Engineering

University of California, Berkeley

Professor Alice M. Agogino, Chair

Successful New Product Development (NPD) is a challenging activity with only 30% of new products making it to their second year on the shelves. My goal in this thesis has been to improve the success rate of new product introduction. One way NPD teams improve their chance of success is by creating a product for unmet user needs. These user needs are best identified through primary research with potential consumers by the design team. NPD also requires a diverse range of skills including business and marketing, engineering, manufacturing and industrial design. Yet team members with these skills bring with them different values, perspectives and interests that cause them to see different things as important. Although the diversity of skills is key to developing the product, the different perspectives cause difficulties when the team is still deciding on what it is that users really need and what it is they should make.

In this thesis I characterize these two important challenges facing design teams in their struggle to develop successful products: 1) the team must frame the design challenge around real user needs – to figure out what people want; and 2) the multidisciplinary team must come to agreement about this framing. Through studies of over 60 graduate NPD teams and

an industry case study I characterize the role that this design team framing plays in successful NPD and propose a model to help understand how design teams negotiate towards a shared understanding of the design situation. Through a better understanding of these two dimensions and an investigation of an important framing tool, metaphor, I am able to present a set of guidelines and practices to help NPD teams navigate these difficult design phases.

_____

Professor Alice M. Agogino

Dissertation Chair

for

Maria

Table of contents

List of Figures

List of Tables

Preface

I didn't set out to study framing. I didn't even set out to study design teams. As a designer and engineer I was interested in creative design. To me, creative design was what was exciting, and most of the magic, I thought, happened within the mind of an individual. Yet as I studied new product development in practice it became clear that studying only individuals couldn't hope to really understand what design teams produced. And creative design, seemed to matter less than whether or not someone actually found your product or service useful. And so I studied framing rather than creativity, and user-centered design rather than engineering design. And I studied teams rather than individuals. And it turned out to be a lot more complex, fuzzy and interconnected than I had expected, rather a lot like new product development itself. I tried to heed my own advice of learning not confirming. The result is, I hope, a thesis that is relevant and important, and provides insight into a topic that really matters.

Acknowledgements

01 Introduction

Thesis and research questions

Summary

In this chapter I introduce the primary thesis of this dissertation based around helping design teams come to an effective framing of the design situation to enhance New Product Development (NPD) success. I motivate my thesis through a discussion of personal examples and industry cases. After outlining the primary contributions of this thesis I introduce the structure of the remainder of the dissertation.

Thesis

This thesis is about how New Product Development (NPD) and design teams [1] can successfully make products that people want. It is partly motivated by the reality of 30,000 new products hitting the shelves each year but only 10-30% of them lasting into the second (Gavetti and Rivkin 2005). The vast majority of new products, in other words, fail. Given that companies rarely manufacture and release products that simply don't work, one major cause

---

[1] While design and New Product Development can be seen as different entities NPD invariably involves some design and the outcome of the design process is very typically the development of a new product. The difference is largely semantic with an emphasis on different terms in different communities. For example, researchers approaching from engineering design typically refer to it as the design process, where as researchers from organizational behavior or business strategy will typically use NPD. In this thesis I shall use both design teams and NPD teams interchangeably.

of these failures is making products that people don't really want or need. To help avoid this, the first challenge for NPD team is to frame the design challenge based around real user needs. I set out to find out how to do this better.

Yet while most NPD and design research focuses on process, I found that process alone didn't account for the difficulties NPD teams encounter. The second challenge was getting a diverse team of engineers, marketers, industrial designers and more, to agree on what they should create; the team needs to be on the same page about what customers want.

These two goals, figuring out what people want, and getting on the same page, are intertwined in the design, research and sharing activities that a team performs. In this thesis I investigate the process of design team framing, dissecting and identifying design practices and activities that both help teams build empathy with their target market, framing the situation around real user needs, and help teams build shared understanding about this framing.

Motivation

Under the Hood Design and Meaningful Design

As an engineer by training, I have spent many years making products, devices and systems to meet the specifications given to me. If something needs to be designed to withstand 300Mpa of stress and fit within a defined space then engineers harness all their creative and professional expertise to meet the challenge. Sometimes the challenge is too much and we may question the specifications. Does it really have to be 300MPA or is 200MPA enough? Can I break the system into two to allow me to free up some space? Engineering design can be a highly creative activity, though it is often overlooked as such. Less often, however, do engineers question the entire form and purpose of what it is they're creating. Do we need a device at all? Maybe a service would do? Will people feel comfortable using the product or might they be embarrassed and soon put it to the side?

These kinds of questions are usually tackled by the marketing and strategic leaders in a company. Often then, an engineer's role is more of an implementer, someone who can make it happen and solve some tough challenges along the way.

This approach can work very well. For example, when designing the guts of an engine, the engine seals say, the customer is far away. There are few customers who have bought a car because of the engine seals, but no cars that would work without them. In these circumstances an engineer's work *is* a technical design challenge. The seals need to be made to work as efficiently and cheaply as possible. I call this *Under the Hood Design*.

Yet the experience is very different when designing products that a customer touches, uses, relies on, shares, creates perceptions of and associates with. The steering wheel of a car has to turn the wheels easily and reliably yet it also has a greater meaning as something drivers touch each time they use the car. A leather steering wheel brings forth different associations than a plastic one, a pink steering wheel different associations than a black one. The choice of material has functional characteristics – how well you can grip it, whether it heats up in the sun – but it also has other less tangible attributes that play a part in the self-presentation of the driver. Leather may look sophisticated, but maybe a new plastic would perform better. Replacing a steering wheel with a joystick may prove easier to use; but would the jet plane look be appropriate for a family car? How can designers and engineers begin to make these kinds of decisions? This is *Meaningful Design* (e.g. Diller et al. 2005).

A product's success or failure rides on getting these kinds of decisions right (Zirger and Maidique 1990; Rothwell 1972). Sometimes failure is a result of not realizing the social implications of a product or a feature. Other times what people really want is unclear or misleading.

This perspective is also supported by economic analysis. Technical proficiency is no longer all that is required for businesses to compete in the global marketplace (Pink 2006). The UK's

Design Council created an index of over 150 firms recognized as effective users of design and design research. Tracking the stock market performance of these firms has shown that this emphasis on design pays off financially. The Design Index firms outperformed the standard FTSE (Financial Times Stock Exchange) 100 companies by 200% between 1994 and 2003 (Design Council 2008). There is something to be learned from firms that do design well.

Spray sugar, the Segway, the Newton and Powder Net

I have repeatedly encountered the difficulties of figuring out the right thing to make in my personal experience as a designer and through high profile cases from respected companies. Six years ago I worked on a consulting project for a sugar company who derived 90% of their income from selling sugar cubes. But sugar cube sales were dropping as people and cafés increasingly favored sugar granules in small packets. They turned to us to find out what was next – what was the next big product in sugar? Trained primarily as engineers the team approached the problem from a primarily technical perspective. We identified 'problems' with sugar cubes such as speed of dissolving and versatility in sugariness. We used trends of technical evolution from TRIZ (Altshuller 1999) to identify sugar products that would function better, solving some of these problems. A favorite concept of mine was spray sugar. Sugar in liquid form in a spray container has numerous benefits such as easy application, versatile dosing, an even distribution and instant dissolving. In many ways, technically it was superior to granulated sugar or sugar cubes. But users, and the company, didn't go for it. Spray sugar didn't feel like sugar. Sugar should be granules, not come out of a nozzle. People felt strange spraying sugar into coffee at a café; it was more what you might do with medicine or cleaning fluid than food. Though in many respects functionally superior we hadn't understood what users really wanted.

I'm not alone in having made errors of this sort. Before its official launch the Segway Human Transporter was one of the most hyped inventions of all time. As its inventor, Dean Kamen, stated in Time, "The Segway will be to the car what the car was to the horse and buggy,"

(Heilemann 2001) But it didn't pan out that way. The Segway has remained an invention, not a successful product innovation; it has not yet achieved market acceptance (except by the small number of enthusiasts of Segway polo). While time will still tell if the Segway will achieve its promise, how did the initial forecasts prove so misguided?

The Segway's disappointment can be partly blamed on the focus on technology rather than user needs. The product was built from a technology standpoint and the visions of its creators rather than by first understanding the needs of consumers and creating a product to meet them. Much of the initial hype was due to the secrecy regarding exactly what the project, dubbed Ginger, would turn out to be. Secrecy before development meant that the initial tests of a Segway were based on the experiences and use of the members of the company and close collaborators rather than real users in the context of use. As it turned out, the Segway provided mixed benefits at best to many of its initial intended buyers such as the postal service and the police. The first mail carrier to deliver a piece of mail with the Segway, for example, had this experience: "[Chris] Pesa enjoyed trying out the device, but it didn't save him any time: He couldn't sort the mail between homes as he could when walking his route. And if it rained, it was impossible to carry an umbrella, because you needed both hands to steer." And the police force in the town of its development, Manchester, "found the machines useful for downtown parking control, says department spokesperson Shawn Fournier, but that was about it. He adds that the mountain bikes his department employs to patrol certain beats 'are cheaper, and they don't have batteries that run out of juice," (Rivlin 2003).

The self-balancing technology of the Segway is undoubtedly impressive, but the user needs it was addressing were weak. In the context of use, the needs were more than just getting from place to place more easily. It was partly this emphasis on technology and engineering rather than users that led to the disappointing Segway sales. In essence, the development team

focused on the *How* of the engineering implementation rather than first being sure about *What* should be made in the first place.[2]

Analyses of product failures are harder to come by than analyses of successful products. A failed product typically doesn't make the news. One that has received much lip-service however, is the Apple Newton PDA (Personal Digital Assistant). The Apple Newton, like spray sugar, and the Segway was a technically advanced product. It was packed with features, software and some of the fastest hardware for its time. The intent was for the Newton to be a mini-computer in your pocket. Yet, the Newton didn't catch on; it remained too big, slow and struggled with handwriting recognition. Ten years after the Newton's demise, Palm Computing's Palm Pilot, learning from their first attempt, the Zoomer, took on the mantel of efficiently replacing users' paper-based personal organizers creating the world's first truly successful PDA. The designers of the Newton created a technically impressive product but misunderstood what was most important to people at the time; people didn't need a replacement desktop computer, they wanted a replacement for their personal organizers that could be synchronized with their desktop computers (Patnaik and Becker 1999). With less exacting technical specifications, the Palm Pilot was both small and fast enough to do what was needed well.

In Chapter 06 I present more detail on a fourth example, relating the story of Powder Net,[3] a company founded, and even named after, the premise of creating tiny sensors. Tiny sensors are a worthy goal and a technical challenge. Yet the company had to quickly adapt to clients for whom size was not really an issue; they were more concerned about ease of installation, long-life and reliability. Though a focus on size created buzz, what clients really needed for real applications was something quite different. To succeed, Powder Net required a readiness

---

[2] The Segway also faced other challenges that reduced their sales including a flawed sales model – launching on Amazon where people couldn't try them out – and difficulties with local regulations, for example, getting Segways permission to be rode on sidewalks. For a thorough treatment see (Kemper 2005)
[3] The company name has been changed throughout this thesis

to listen, adapt and learn from their target market to create a product that is more than a technological invention.

Each of these examples illustrates a core assumption of this research: that it's important for NPD teams to understand the needs of their target users to be able to develop a product that will be of value to them. This assumption is in many ways at the heart of the user-centered design process.

Design is performed by teams

These examples also show that the process of figuring out what a market needs, then engineering a product to meet those needs is not always a straightforward process. In reality, NPD teams are cross-functional – comprising members from the core disciplines of marketing, engineering, industrial design, manufacturing and, increasingly, members from the social sciences such as sociology and anthropology (Squires and Byrne 2002). The backgrounds and perspectives that each of these members brings causes them to see different things as important so that in a negotiation about what a product should do or how it should do it each will address their own interests (Bucciarelli 1994). Figure 1.1, from Kleinsmann's thesis, "Understanding Collaborative Design" (Kleinsmann 2006), illustrates how different actors in a team bring different viewpoints. The word 'feasible' may prompt an engineer to think of whether a product can be made, a business specialist to consider if the market is large enough, an industrial designer to question if the product can be appealing.

In the early stages of NPD when teams are performing research and testing prototypes with users there are opportunities for different team members to learn different things from these encounters. For example, in a project addressing people's attitudes and potential ways to encourage recycling the team split up to learn from potential customers. The business specialist came back from her encounter more convinced that their offering should be based around a recycling service. The engineer came back convinced that a new type of bin to help sorting was what was needed. And the information specialist felt the solution should involve

better communication about recycling. We see what we are prepared to see and different disciplines are prepared to see different things. Bucciarelli's ethnographic studies of the design process (Bucciarelli 1988) highlighted the complex and social nature of design process.
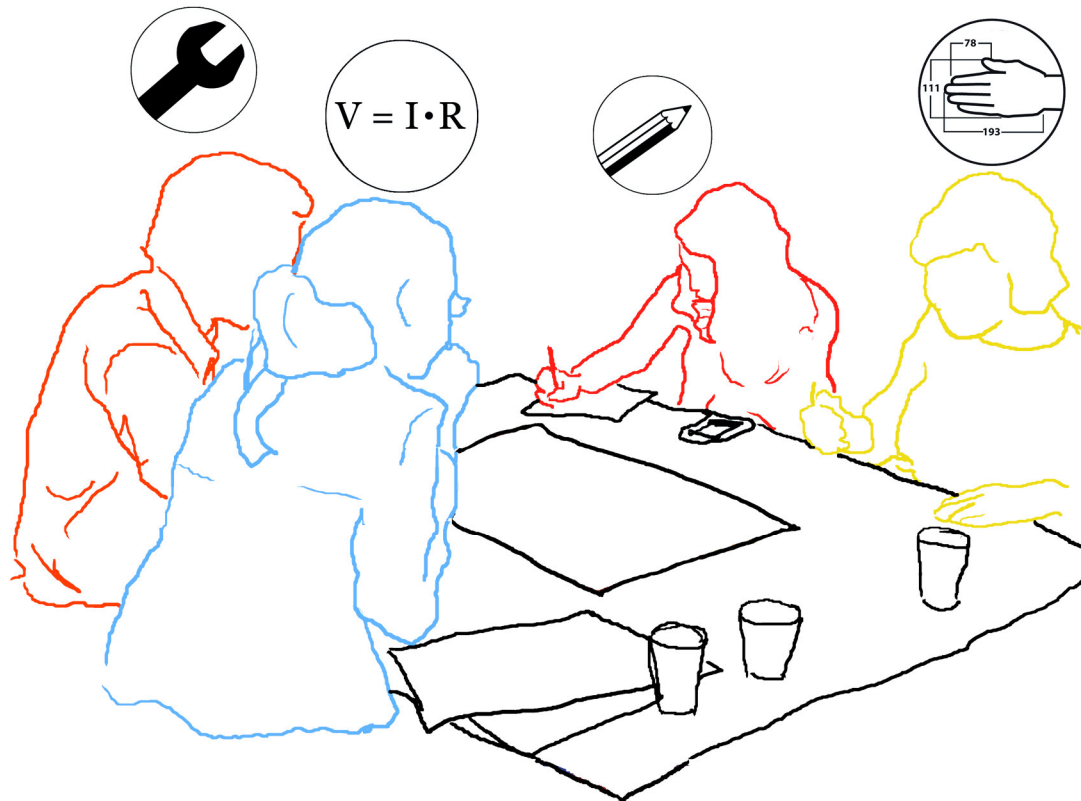
Figure 1.1 Different actors in a development team bring different viewpoints (Kleinsmann (2006), used with permission)

These differences of opinion often result in conflict and changes of direction for the project. In other words a project does not always end up being what was expected at the start. Diversity in teams can be very valuable (Page 2007) and in NPD teams diversity in skills is essential to success. Diversity in teams has been shown to enhance creativity, complex thought and thoughtful decision-making, yet it also has costs such as conflict, inefficiency, and failure to share non-redundant knowledge (Stasser and Titus 1985; Reagans and Zuckerman 2001; Nemeth 1986; Dougherty 1992; Chatman et al. 1998; Ancona and Caldwell 1992). This essential diversity creates conflict as the members of a team seek to come to a shared

understanding about who their target market is, the needs of their users, what it is they are making and how it should be made.

In this thesis I seek to illuminate how teamwork plays out in the context of user-centered design as NPD teams perform the early stage activities of the NPD process – scoping the situation, performing user research, understanding user needs, and negotiating what the team should make; in other words, framing the design situation. Some teams work together to successfully frame the design situation around real user needs and develop a project that their target market really values; others frame the situation in a way that eventually creates a product that people don't want, remains "just a gadget," or is soon discarded.

Research questions

Throughout this thesis I define framing as consisting of four primary features:

1. A desired end state or goal

2. Relative importance and relevance of features (prioritization of designers' attentions)

3. Boundaries to the design situation (problem scope, solution scope, resource constraints)

4. Criteria for evaluation (of new information, features, and possible solution concepts)

I will return to this definition in Chapter 02 to place it in context with alternative views and studies of framing in design. A team that has come to agreement on these four features is generally clear about what it is they need to do. Successful framing, I will argue, requires that these aspects are chosen based on real user needs from grounded observations with real users.

To understand the role of framing in design I gathered data from a student design setting and from professional designers to answer the following primary research questions:

5. What role does framing play in successful design?

6. How do design teams settle upon a suitable frame for their design situation?

7. What tools could help support design teams to better understand and apply the framing process towards successful design?

This thesis is roughly organized to address these questions in order.

Contribution of this thesis

The primary contribution of this thesis is to untangle the dual dimensions of framing a design situation successfully, and whether or not the NPD team is on the same page about that framing. A deeper understanding of the complexities of this process allows me to recommend a set of themes and design principles for teams aiming to negotiate the early stages of NPD.

To arrive at this endpoint I hope to also make five other contributions.

1. First, through an investigation of the lessons NPD students learn during an NPD class I highlight the value of experience working in multidisciplinary teams and the difficulty NPD teams have in effectively framing the design situation.

2. Second, I identify the primary set of activities that are themselves framing activities. To understand the influence of these activities I propose the Framing Cycle which illuminates how teams negotiate a shared frame during the design process.

3. Third, I introduce the Design Path framework built from the dimensions of framing the design situation according to real user needs, and the degree to which a team is

on the same page. I illustrate the framework by showing the three most common paths that design teams follow.

4. Fourth, I highlight the role that metaphor plays in our understanding of the design process and the contrast between traditional text book models of the design process and how design is experienced in practice. By contrasting metaphor with analogy, I show how metaphor is used as an effective framing tool early in the design process.

Thesis outline

Below I outline the content and contribution of each chapter. While the thesis will prove most readable when read sequentially I have tried to write each chapter so that it can also be read as an individual contribution.

In **Chapter 02, Background,** I begin by discussing the different strands of research that have tried to address issues relevant to this thesis. I discuss different approaches to the design process and introduce and define the notion of framing as it applies in NPD. I also introduce prior research on the formation and negotiation of shared understanding in design teams. This chapter places my work in the context of research that has come before it.

In **Chapter 03, Methodology,** I discuss the advantages and disadvantages of the research methods available to design researchers studying framing. I present the justification for my hybrid approach of gathering data from student NPD teams and interviews with industry professionals.

In **Chapter 04, Lessons Learned in NPD,** I present a study of the lessons NPD students chose as the most salient to them after a NPD course. This study provides further evidence for the importance of helping multidisciplinary teams work together and to provide tools and understanding for effective framing based on user needs.

In **Chapter 05, Finding Framing,** I build on a preliminary analysis of 22 NPD projects to understand how design teams negotiate a shared framing of their design project. I identify the key framing activities of design teams, present the Framing Cycle as a way to understand the negotiation within a team and discuss some important observations regarding team framing.

In **Chapter 06, Design Paths,** I present an extended analysis of 57 NPD teams that led to the development of the Design Path framework to understand a team's path through the early stages of the design process.

In **Chapter 07, Metaphors and Framing,** I point out the pervasive nature of metaphor as it shapes our understanding of the design process itself and key design concepts. I discuss how the metaphors in traditional design textbooks contrast with how design is experienced in practice. I also present the results from a study comparing analogy and metaphor use in design.

In **Chapter 08, Principles and Tools for Effective Framing,** I present four major themes for understanding framing and twelve design principles that NPD teams can use to approach framing more successfully. I also present a tool for helping design teams during design meetings and a method and tool for assisting metaphor use in design.

Finally, in **Chapter 09, Summary and Conclusions** I provide a short summary of the thesis together with the major results and their implications for design practice and education. I finish by naming several lines of future research.

I hope you find it interesting.

02 Background

Context of this study and prior research

Summary

In this chapter I discuss framing in the context of where it fits in the design process and how it has been studied in the past. I begin by introducing the notion of design as a wicked problem, one not easily amenable to traditional design methods. In this respect much of the important work of design is in the problem-setting rather than problem-solving. Then, I review a number of different approaches to the user-centered design process that enable us to design in spite of design's wickedness, and discuss how other researchers have understood and approached the study of framing. As design is performed in teams I then survey how researchers have approached understanding how framing plays out in a team setting. I close by outlining some of the limitations of prior approaches and views and questions still to be answered.

Introduction

New Product Development (NPD) is a multidisciplinary activity that affects business success and requires engineering skill, industrial design talent, careful management, the skills to understand people and an understanding of team processes and dynamics. As such, design

research exists in and has drawn from many fields of endeavor including the fields of marketing, engineering, software development, organizational behavior, psychology, cognitive science, anthropology and sociology. An engineer, like myself, wishing to study the NPD process must therefore begin a rapid schooling in deep and unknown fields. For example, a recent meta-analysis of papers published in marketing, business strategy and NPD journals (Page and Schirr 2008) found that studies of NPD have continued to increase over the period from 1989-2004. In particular, teams and the integration of different functional roles and disciplines continues to be the most popular stream of research accounting for 14% of the total papers published during this period. This cross-disciplinary nature of design makes the contributions so numerous it would be impossible to review them all here. In this chapter then I attempt to set the scene for this research by limiting the discussion to the most relevant prior streams of research.

I begin by taking a historical perspective on design theory emphasizing, in particular, the notion of NPD as a wicked problem. I then discuss the design process I studied – the user-centered design process, which evolved partly to resolve some of the difficulties in traditional linear, analytic design approaches. I then discuss the two core areas of this thesis, the framing of a design situation and previous studies to understand how framing is accomplished in cross-functional design teams.

Wicked Problems, problem-solving and problem-setting

Design is often associated with problem solving. The literature on problem-solving is broad and deep. A strong theme however, is that problems are readily addressed using rational, analytic techniques. In contrast to this view, in 1973, Rittel and Webber characterized the social policy problems associated with urban design as *wicked* problems (Rittel and Webber 1973). These types of problems are not readily amenable to standard analytical problem-

solving processes as they are ill structured and poorly defined. In these situations, problem setting leads just as much to the solution as the problem solving. The problem formulation itself *is* the problem. The concept of wicked problems was proposed in response to the then dominant rational problem-solving methodology as exemplified through the research of Herbert Simon (e.g., Simon 1969 and 1973). This is more than just a case of these kinds of problems being harder problems. It is an issue to do with our very conceptualization of a problem, the elements it contains, where we start, at what level we address it and how we know when we've solved it. Indeed, Rittel and Webber persuasively argue that *solving* a problem in these situations is not wholly relevant, as a once and for all solution is not possible.

Rittel and Webber provide ten common characteristics of a wicked problem including, for example, there is no definitive formulation of a wicked problem. In other words, a wicked problem is one that will be formulated in different ways by different people at different times. Dorst (1997 70) explains:

> *"design tasks may be analyzed and subdivided in a number of different ways, and there is no a priori way to determine which approach will be the more fruitful. Therefore, design task and solution are always and inherently developed together."*

Other characteristics of a wicked problem are listed in Table 2.1. Of particular relevance are wicked problems don't have an enumerable set of possible solutions, and there is no immediate or ultimate test of a solution to a wicked problem – solutions are not right or wrong, they are only better or worse. Experience in NPD may quickly tell you that many of these characteristics also apply to NPD projects. For example, an ideation session for an NPD project can never claim to have exhausted every possible option, in contrast to, for example, determining what next moves are possible in a game of chess (a classic problem-

solving challenge). Testing of NPD projects is also fraught with difficulty. For example, testing of Research in Motion's Blackberry phones most likely did not anticipate the addictive effect of their long-term use and the future nickname, 'Crackberrys'. Indeed, understanding the real impact of the introduction of a new product is very difficult when the response is affected by the uptake and attitudes of the rest of society. For example, the Microsoft Zune mp3 music player featured wireless peer-to-peer sharing between Zune users, yet the success of a such a feature is largely dependent on how many other people nearby own Zune players. Evaluating this feature is difficult and likely to be misleading in an artificial pre-product launch scenario.

Twenty five years after Rittel and Webber's original paper, DeGrace and Hulet Stahl (1990) argued that software development problems are also worthy of the moniker of wicked problems. Here I argue that NPD can also be seen a wicked problem. If NPD is wicked then problem-setting is key. According to Rittel and Webber then, traditional rational problem-solving approaches will not be appropriate for design teams trying to develop new products. To address wicked problems Rittel advocated a need for what he termed, 2nd Generation Design methods (1984). These design methods emphasize the argumentative and social nature of team design as opposed to earlier rational and analytic approaches. Yet specific details on how teams should go about these 2nd Generation Design Methods remain slim.

A key reason for the need for Rittel's approach was based on the renewed emphasis on people in the design process, as stakeholders, customers, end users and designers. If we recognize that these people will not see things identically due to different values, interests, beliefs and such, then it is no longer possible to design with a purely technical problem-solving approach. The wickedness of the design situation arises through the combination of these perspectives involved in the design process, hence the need for an argumentative approach to designing.

Table 2.1   Characteristics of wicked problems (Rittel and Webber 1973)

	Wicked Problem Characteristics
1	There is no definitive formulation of a wicked problem
2	Wicked problems have no stopping rule (there is no definitive time to stop working on a wicked problem)
3	Solutions to wicked problems are not true-or-false, but good-or-bad
4	There is no immediate and no ultimate test of a solution to a wicked problem
5	Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly
6	Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of possible operations that may be incorporated into the plan
7	Every wicked problem is essentially unique
8	Every wicked problem can be considered to be a symptom of another problem
9	The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution
10	The planner has no right to be wrong

More recently, Donald Schön's paradigm of reflective practice has been widely adopted by design theorists to understand design activity. Reflective practice is a model of design based on the study of practitioners and a framework through which to analyze design activity. It is based around the metaphor of Design As A Reflexive Conversation[4] with the situation. Designers, Schön argues, follow a cycle of Naming, Framing, Moving and Reflecting. As an example, a designer developing the layout for the inside of a new café may first name the

---

[4] In many articles and books about metaphors they are commonly represented in Title Case. I shall adopt this convention in this dissertation.

important needs the layout has to fulfill such as an area for ordering, an area for waiting, an area for relaxing, a private and communal area and so on. These named features may only become apparent in conversations with potential patrons of the café. The designer then frames the situation as a goal of providing maximum private area for relaxation while providing easy access for ordering and leaving. The designer then makes a move, maybe a sketch, a prototype, a thought experiment, a scenario or a role-playing exercise. As the designer considers the result of her move, maybe through studying her own sketch of the layout, she reflects on how well it achieved her aims. This reflection, in turn, may prompt new features to be noticed as important, maybe access to the restroom, or an alternative framing of the situation. In this context then, problem-setting is a continual process that cannot be easily separated from the development of possible solutions (moves). This co-evolution of problem and solution has also been observed elsewhere. For example, (Dorst and Cross 2001) report a protocol analysis study of industrial designers working individually on an artificial design task. In their study they highlight the co-evolution of problems and solutions where "a creative event occurs as the moment of insight at which a problem-solution pair is framed: what Schön called 'problem framing'."

In Schön's paradigm then, framing is a key skill of a designer. Other authors have also emphasized design as a problem-setting activity. For example, Lanzara (1983) contrasts the traditional view of Design As Problem Solving with a different emphasis on Design As Problem-Setting. He argues, as did Rittel, that the traditional problem solving view of design becomes relevant once much of the real work of design, the problem setting, has already been done. Much of this work is the framing of the situation by the designers and the design teams.

An example may help clarify this emphasis on problem-framing. At first blush Campbell's Soup may appear to be a soup company. For decades, Campbell's relied on their iconic canned soup for sales. Yet around 2001 when Campbell's collected research data by asking

hundreds of their consumers to complete food diaries they had a surprising insight. People didn't turn to Campbell's just because they wanted soup but often because they wanted a convenient meal that would fit into their hectic lifestyles. Campbell's were really a 'convenient meal' company with an expertise and brand recognition in soup. The traditional problem framing, "What soup do our customers want?" becomes less relevant as the problem framing shifts to "How can we provide our customers with more convenient meals?" Indeed, where Campbell's already dominated the US soup industry with a 70% market share they now found themselves in a far larger market space – that of convenient meals – where they were now competing with players like Subway and McDonalds. In this space, there is much room to grow. Campbell's still produce soup, but you can now buy it in other convenient packages such as microwaveable cups, pop-top containers, and plastic bottles, facilitating the convenience of a Campbell's meal (DX Summit 2004). An insight into how people experienced their product led to a new framing that pointed the way to a new range of products.

User-centered design

The wicked nature of NPD has meant a continuous innovation in design processes. Iteration, design ethnography, rapid prototyping methods and participatory design (e.g. Schuler and Namioka 1993; Muller and Kuhn 1993) are examples of approaches that help overcome the difficulties caused by NPD's wicked nature. New approaches and methods have helped make wicked problems tamer. For the last 30 years a large number of researchers have focused on researching and innovating on process (Dorst 2008). But design is a broad activity that means different things to different people. In this section, I want to introduce several contemporary approaches to user-centered design to explain the process I have been studying.

Stage Gate design processes

The stage gate process is perhaps the dominant model used in NPD today. The stage-gate process exemplified in Cooper (1998) and, to some degree, Ulrich and Eppinger (1995),

outlines a largely sequential design process, one in which teams perform activities with stage gates as decision points and milestones to encourage design teams to make concrete decisions and move forward. The process outlined in Ulrich and Eppinger (1995) is shown in Figure 2.1.
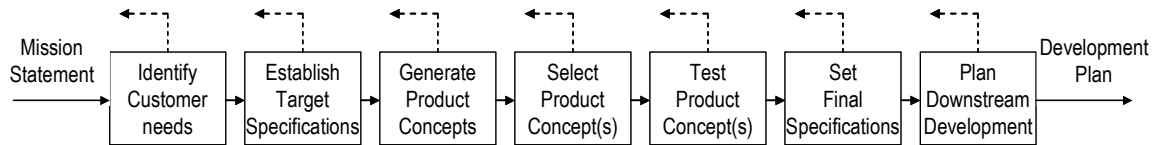
Figure 2.1   The new product development process according to Ulrich and Eppinger (1995)

While the process model appears linear it is acknowledged that design teams will perform a large amount of iteration during a project, with the result that an actual development process will not map cleanly to the stages above. Design teams follow a series of divergent and convergent phases as they iterate to a final result (Boehm 1995). In particular, the earliest stages of the design process are characterized by incomplete information leading to a high degree of uncertainty and ambiguity for product development teams (Iansiti 1995; Eisenhardt and Tabrizi 1995). Cycles of divergence and convergence and iteration are ways that allow teams to cope with this uncertainty. These early stages are commonly called the 'fuzzy front-end' of new product development (Khurana and Rosenthal 1997), and it is in these early phases that important decisions are made that have a strong impact on the project outcomes (Cooper 1998). Not only are decisions made in these phases that have important effects such as on the development cost for a new product, but it is in these phases that new opportunities themselves are identified.

Stage gate user-centered design models typically follow the generic design stages of: Identify user needs – Generate concepts – Select concepts – Detailed Design – Manufacturing and ramp-up. Distinctive at least of the user-centered design process is the emphasis on an initial understanding of user needs – to understand what needs the product must fulfill. It is generally acknowledged that a team who uncovers latent, implicit, or hidden, needs may

20

have a greater design opportunity than teams that identify surface level, explicit, well acknowledged needs. Campbell's customers' need to eat is a surface level need, but the need to maintain their pace of life over lunch may be a hidden level need (albeit only just below the surface).

Software development has developed its own variations of a user-centered design process including the Waterfall model (Royce 1987) and its successor the Spiral model of software development (Boehm 1995) (itself a facilitator of modern practices such as agile software development).

Design processes from contemporary design practice

In design practice, as design firms aim to move higher up the food chain, innovation on process continues at a rapid pace. Respected companies and researchers working in the area of new opportunity recognition have developed their own frameworks and processes for the early stages of product development. In many ways, these processes apply only to the first few stages of the Ulrich and Eppinger design process, identifying the *what* to make rather than *how* to do it. In other words, they are not so concerned with the challenges of detailed design and manufacturing that takes place in the later stages.

These processes emphasize a highly people-centered approach to design advocating intense user research as a source of insights for new product and service offerings. Frequently these processes emphasize the non-linear, highly iterative nature of the process encouraging their teams to bounce between making ideas concrete in the form of prototypes and continually testing with users the insights and concepts throughout the process.

Figure 2.2 shows examples of design processes derived from Beckman and Barry (2007) (derived from Owen 1993 and 2001), and Kelley and Littman at IDEO (2001). It can be seen that these design processes, though using different terms, have at least two common features. First, teams engage in both analysis – deconstructing and understanding a

situation – and synthesis – putting together insights to produce concrete design solutions and directions. Second, teams are expected to alternate from the concrete physical world, the world of observations, products and behaviors, to the abstract, theoretical world where frameworks, models and metaphors are used to help explain the concrete behavior.

Abstract

Frameworks   Imperatives

Analysis ———————— Synthesis

Observations   Solutions

Concrete

Abstract

Synthesis &   Idea
Meaning   Generation
Making

Learn ———————— Make

Research   Prototyping
Design &   and
Insight   Evaluation
Gathering

Concrete
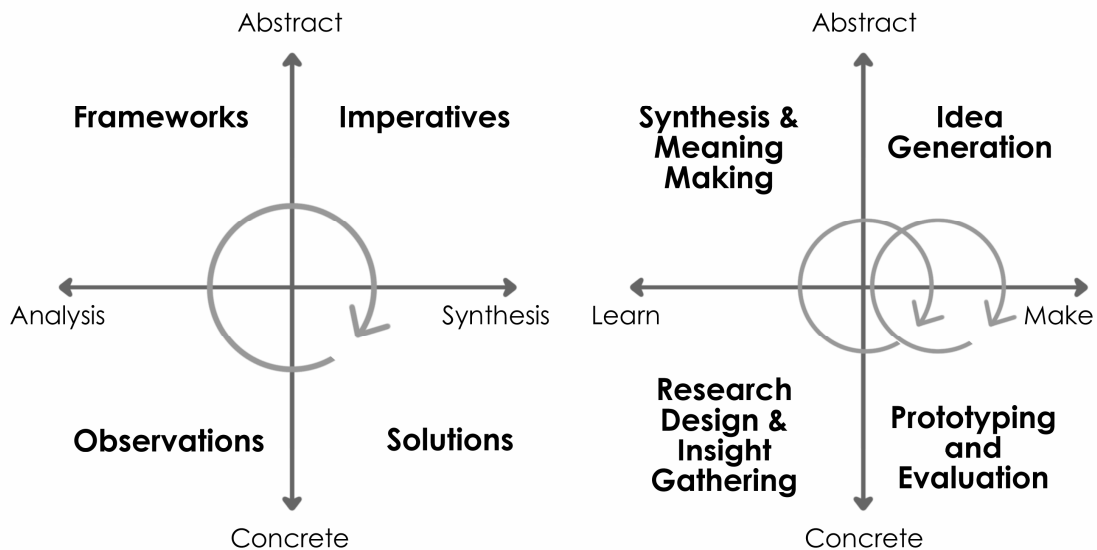
Figure 2.2   Design process models from Beckman and Barry (2007) (left), and Kelley and Littman

(2001) (right)

Beckman and Barry (2007) argue that these basic models can also be seen as one of problem finding, problem selecting, solution finding and solution selecting. They explain that, "Much of the focus of education today – particularly engineering education, but also business education – is on problem solving. The innovation process emphasizes problem finding as well. Identifying, framing, and reframing the problem to be solved are as important in this process as solving the problem or finding an appropriate solution" (Beckman and Barry 2007 44)

Design ethnography has become a widely touted method for design practices following these approaches (e.g. BusinessWeek 2006; Elliott and Jankel-Elliott 2003). Design ethnography employs methods such as in-depth interviews, shadowing and participant observation to

reach deeper insights about a target population. Mariampolski (1999 75, also 2005) usefully compares a shift of using ethnography for market research rather than focus groups to moving from black and white to color:

> *"Going from focus groups to ethnography is somewhat like moving from black and white to colour - the immediacy of the smells, textures, tastes, heat, sounds, movements, and muscular strain all stimulate an enriched level of understanding. If the research objective is to understand consumer shopping patterns, the ethnographer can tag right along at the supermarket or department store. If we need to understand home cleaning patterns and products, ethnography allows the researcher to sniff the air around the home, stare at hairballs on the sofa - actually to see the success or failure of product performance and share the consumer's look of satisfaction and pride after a job well done."*

The use of ethnography in design strongly emphasizes the skill of observation. This is largely due to some consensus that people don't always do what they say they do nor directly know why they do what they do. For example, in an analysis of data in a wide variety of settings, researchers concluded that:

> *"what people say, despite their presumed good intentions, bears no useful resemblance to their behavior"* (Bernard, Killworth and Sailer 1982 63)

When it comes to predicting long-term purchasing behavior consumers are also unreliable (Ovans 1998). Beckman and Barry (2007), give as an example a study conducted on families' TV watching habits. Parents repeatedly said they didn't allow their young children to watch violence on the TV, but when they spent time with the families the researchers saw the children were regularly exposed to violence. The parents weren't intentionally lying – as the researchers discovered, it was more accurate to say that parents didn't let their kids watch

something that would give them nightmares. Framed in this way violence in cartoons and movies can pass the parents' censorship. In other words, the observations allowed the design researchers to frame the situation in a way the behavior made sense.

User-centered design approached using techniques from design ethnography is sometimes termed needfinding (Patnaik and Becker 1999). User needs and insights from design ethnography are the foundation of the remainder of the design process. However, design ethnography takes time and resources. It is not generally possible to get close to the year or more length studies of academic ethnography. In response to this important conflict between quality of research data and the length of time available, various methods have been proposed including rapid ethnography and quick and dirty ethnography (see Sandhu et al. 2007, for a comparison of some of these approaches).

A study of modern design practice needs to study design teams as they engage in the activities of design ethnography and identifying user needs. Until now, there are very few studies of design teams performing design ethnography for NPD.

Other design process models

Readers familiar with contemporary approaches to innovation in, for example, Web 2.0[5] software startups may disagree with the kinds of design processes I have outlined above. As one MBA student commented, "It's not how I see it happening. People have an idea and they try it. If it doesn't work, they change it or try another." This approach, in essence, short circuits the NPD process by skipping the first stages of user research, analysis and even generating concepts. The startup forms based on a seemingly spontaneous idea developed by the founders based on a personal insight about a market need or a new technology. For example, based around the founder's liking for the convenience of alarm wake up calls at hotels they have the insight they could create a service to allow users to set up their own

---

[5] Web 2.0 is a term coined by Bill O'Reilly and is notoriously difficult to define but represents the move towards the combination of rich web experiences powered by Advanced Javascript And XML (AJAX) and integrated online social networking.

alarm wake up calls from the Internet. The team spends an intense few months developing a prototype site to see if it takes off. If it doesn't, the idea is simply adapted or abandoned. In some senses, this kind of approach is also in use by large web-based firms including Google. The Web 2.0 model is very much a *build it and see* approach.

Although I have not formally studied this approach I believe this approach is particularly fruitful in the world of Web 2.0 development because of a number of contextual features of this environment. In comparison to the development of physical products a number of constraints are starkly different. First, the development overhead is lower including capital expenditure required. It is generally cheaper to host a website and code some web pages than it is to get a functioning physical prototype built for, say, a new kind of bike. Secondly, prototyping is generally cheaper and quicker. A talented web development engineer can, in many cases, mock up several different at least partially working designs a day compared to the several weeks it may take to machine a new metal component. Web development projects also have the advantage of being closer to eliciting feedback from users and collecting use data through tracking user's actions on a site. In a connected world, users are more likely to provide a quick note of feedback on an online service than they are likely to return from a biking trip and call up the company who designed the bike. Finally, small web startups, until recently, often make products for users like themselves – in other words, they are a potential user of their product. When this is the case, developers can rely less on user research as they can legitimately claim to know much of what is required of their product. For instance, in a talk at Startup School at Stanford in 2006, Joshua Schachter explained how the development of the social bookmarking site del.icio.us was initially a product to help him better manage his own bookmarks. When that need is shared widely enough it is reasonable to develop based on your own perceptions of what is needed. Yet, as Nielsen (2008) persuasively argues with a typology of designers' role as potential users (The Designer *is* the user, The Designer Understands the Product, and Designing for a Foreign Domain), this is rarely the case.

Finally, the internet is also relatively new meaning customers are perhaps more likely to forgive occasional errors than they are in more established domains such as the automotive industry.

Each of these factors reduces the barriers to prototyping, testing, and getting feedback from users. With lower overheads a web development firm can also sustain itself longer on a lower budget as development continues. The factors combine to reduce the risk in failure for these products. If you build it and see that it does not take off you live to fight another day. This approach is also known as the express-test cycle. In contrast, when a working physical product requires a $100k injection mold to build it, the risk greatly increases and therefore the need to be more certain that what you are doing is correct before you do it. Finally, large product development firms cannot easily afford to develop products that may negatively affect their brand. For this reason also, the build it and see approach is more generally suited to startups. Fortunately, in the realm of physical product development advances in the speed and the reduction of cost of rapid prototyping machines (Wright 2000) are continually working to lower the cost between idea and realization. This will enable more and faster trials to be produced at less risk; to help designers fail early and often (Kelley and Littman 2001). This discussion has highlighted the important role of reducing risk in NPD. Indeed, Ulrich and Eppinger (2005) explicitly discuss the NPD process as one of reducing risk. Effective user research, design ethnography, prototyping and product trials all help reduce product development risk by increasing confidence in the final choice of product.

My research has not investigated the build it and see entrepreneurship model. Indeed, the design process models I have presented here are only the most relevant to current New Product Development. My research studies design team framing as teams follow a user-centered design process for new product development. This is as opposed to framing specifically for software development, or in any one particular domain such as interaction

design or engineering design. I now return to the conceptual notion of framing, to more clearly define it and present an overview of what we already know through prior studies.

Framing

Framing has been investigated as part of the design process, and more generally for how frames influence work in group and social settings. Researchers from the fields of sociology, urban planning, engineering, linguistics, cognitive science, management science and organizational behavior have all called attention to the concept of framing or a related construct. Yet despite the attention devoted to it, definitions of framing remain scarce (Stumpf and McDonnell 2002). Before I present how framing is understood in my research it is worth briefly reviewing prior conceptions of framing.

Bateson (1972) gives an early analysis of framing[6] where he sees the value of a frame as providing semantic context. The same action performed in different contexts can mean quite different things, for instance, the toss of a coin could be seen as a lighthearted game or result in a life or death consequence. He further compares frames to the mathematical notion of sets to help distinguish between information communicated about the frame or within the frame. In a sense he sees a frame as creating the dividing line between where objects of some type belong and others don't. In this sense, frames are a boundary-setting tool, allowing us to make decisions about what information or actions are meaningful. Goffman (1974) drew from Bateson's ideas to develop his idea of framing as it applies to social situations. In Goffman's view, frames are the rules and parameters that govern social encounters. He employs, for example, a theatrical metaphor of front stage and back stage that governs interactions in many service based settings. For instance, when an employee is *front stage* in a café they wear a uniform appropriate to the brand, treat the customers with respect and refrain from activities like smoking. However, maybe behind the building, you may find that same

---

[6] Minsky (1975) also provides an early discussion of framing developed to help understand visual processing. He sees frames as helping abstract experiences and represent stereotypical situations.

employee smoking against a wall with his shirt untucked; he is engaging in *back stage* behavior. Goffman also introduces the concept of keying which includes markers for when a frame starts and ends. Particularly instructive when analyzing social behavior are situations that result in breaking frame – someone shouting in the dentist waiting room, a teacher berated by the principal in front of his students, or simply elements of back stage behavior performed front stage, such as our café employee smoking as he makes a cappuccino (see Fisher (1997) for a good overview of the different interpretations of framing).

Framing is a process of sensemaking. In her thesis, Valkenburg defined framing as "sensemaking devices that establish the parameters of a problem," (Valkenburg 2000 174). The notion of frames as sensemaking devices mirrors the perspective of Weick (1979) who studied sensemaking in organizations. Sensemaking is closely related to story telling as stories are ways that help us make sense of the world and persuade others of our point of view (Bruner 1992; Simmons 2006). For example, a recent buyer of an SUV may justify her purchase by telling the story of needing the powerful engine and four wheel drive for trips to the mountains when really the purchase is driven by her experience of feeling safe in a larger, higher vehicle. The story forms the rationale behind their decision. Designers do this too; Stumpf (2001 71) explains that she sees frames as forming "the context of what is considered and a form of 'rationale' detailing why an artifact was designed the way it was."

Bucciarelli also touches on the notion of frames in his concept of 'Object Worlds'. He describes the object worlds of different design disciplines as "worlds of technical specializations, with their own dialects, systems of symbols, metaphors and models, instruments and craft sensitivities," (Bucciarelli 1988). In this way, members of a design team, arrive at a design situation with a readiness to distinguish certain aspects from others and to see different elements as important.

Probably the most complete discussion of frames and framing is developed by Donald Schön. Schön describes frames as *"underlying structures of belief, perception and appreciation"* (Schön and Rein 1994) and framing as an activity carried out to construct meaning. Schön sees generative metaphor as a means to frame a situation. He describes frames as a way of 'seeing-as' – seeing one thing through the lens of another. An example he gives is an urban planning problem where the framing of a slum as either a 'blighted area' that needs to be cured, or as a 'natural community' that should be preserved, significantly changes the design situation itself. The choice of metaphor – the Slum As A Blight or the Slum As A Community – evokes a different framing of the problem. I shall revisit this perspective of generative metaphor in Chapter 07: Metaphors and framing. The link between metaphor and framing, in contexts outside of design, is discussed extensively by Lakoff (2004) and Lakoff and Johnson (1980 and 1999).

A definition of framing

The different rhetoric surrounding framing should not obscure that most of these researchers are talking about the same construct – different though the language may be they are "internally consistent" (Stumpf 2001). Built from these different discussions of framing I propose the following definition of framing I return to throughout my research.

> **Framing** *is the process by which people consciously or unconsciously structure a situation by selecting relevant features: what is important and what is less important. Framing provides structure from the viewpoint of an actor both highlighting and hiding different elements. Frames often include assumptions of a desired end state and of what is good or bad.*

Because most definitions emphasize the tacit "underlying" nature of frames, studying frames and their evolution is a challenge. Here I propose four key constituents of a frame that allow them to be identified and tracked throughout the design process:

1. A desired end state or goal

2. Relative importance and relevance of features (prioritization of designers' attentions)

3. Boundaries to the design situation (problem scope, solution scope, resource constraints)

4. Criteria for evaluation (of new information, features, and possible solution concepts)

Using their own definitions, I'll now review how others have studied framing as it takes place in the design process.

Studying framing in the design process

Schön (1984) used a form of narrative analysis to analyze the contrasting frames a student designer and his mentor brought to a design review and how they interacted to produce the final design. The review highlighted the evolution of the design as the student designer named elements in the situation and gave names to their design strategy. In particular, this study emphasized the importance of shifting frames when a problem became unworkable in one framing.

In an empirical study of design student teams, Christiaans (1992) found that the longer a subject spent defining and framing the problem the "better able he/she was to achieve a creative result." Despite this conclusion it is not clear exactly what designers should be doing when they spend more time defining and framing.

Later, Valkenburg employed Schön's paradigm of *reflective practice*, developing a coding notation based on the stages of naming, framing, moving and reflecting. In a study, Valkenburg and Dorst (1998) coded the activities of two design teams in competition using the notation to identify how and when a team's framing of the situation changed. The study analyzed video footage of the two teams working over a period of two days and was able to identify changes in frame of the design team. While demonstrating the ability to identify

changes of frames was a step forward it is difficult to draw from the study precisely what teams should do differently.

Gasson (1998) adopted an ethnographic approach in which she observed the course of a product development project in the telecommunications industry. In the analysis of the project she discusses design framing at the individual and group level noting that the team experienced a "framing problem" due to the decompositional design approach the team adopted – an analytic approach of breaking a problem down into sub-problems and separate design stages. The team's design approach struggled with the "intertwining" of problem and solution, a situation common to wicked problems.

An alternative, practice-based approach at the Stanford d.School advocates that teams adopt a Point Of View (POV). A Point Of View concisely states the relationship between a user and a need[7]. For example, "Campbell's Soup is Tom's quick-and-always-on-hand meal." Examples of these POV are close to what we would identify as a frame.

These prior studies show that framing applies at multiple levels: at the level of the individual (how a particular designer views her task), at the team level (how a team collectively views its task), and at the organizational level (a company's perspective on its business and the value it provides for its customers). My interest here is primarily on the framing that occurs at the team level. As I shall show, framing at the team level rather than the individual level provides an additional level of complexity that cannot be ignored when attempting to understand framing throughout the user-centered design process.

Team framing

While understanding framing at the team level may not immediately seem to present particular challenges for design teams it turns out the situation becomes substantially more

---

[7] See for example handouts from "Experiences in Innovation and Design Thinking - ME377," Stanford University, Stanford, California, United States, Winter 2006.

complex. Bucciarelli provides as an example to consider the page (or screen) in front of you (Bucciarelli 1988 163):

> "It is an object. A naïve empiricist would sense its weight and measure its size. Another reader might note its colour or its texture. A chemist on the design team would describe its resistance to discoloration and its acidity. A mechanical engineer would be concerned with its stiffness and its thermal properties; an electrical engineer with its electrical properties, its ability to conduct or to hold a static charge. All of these attributes of the object are understood within different frames of reference and they all might contend in a design process, e.g. in the design of the machinery for the manufacture of the paper, or in the design of the paper itself."

Much of the complexity in team framing then is a direct result of the diversity of cross-functional design teams. When individuals enter a group setting they do so with different perspectives, viewpoints, and interpretations of the issues involved. These differences "interfere with the ability of the group to view issues in similar ways" (Mohammed 2001 408) and decide on a common action. As a result, a substantial part of the collective effort of a team is dedicated to resolving differences in how members interpret issues, and, indeed, in which issues are important. Mohammed further argues that "the process by which individual interpretations translate into collective interpretations has not yet received systematic attention." Divergence between member's frames may be greatest on highly inter-disciplinary teams meaning that issues of team framing are particularly relevant for user-centered design projects. As Boos (2007 26) explains, "Each participant is an expert in their specialized field. Based on individual experience, professional training and acquired knowledge, each participant will most likely view the task differently." In this thesis I hope to have provided some of the attention that was lacking.

Frames are cognitive and often implicitly held by individuals; that is they exist, often unconsciously in the minds of individuals. This hidden aspect of frames makes them particularly challenging to study in the team context where an understanding of different members' perceptions is not easily accessible (in contrast to, for example, think-aloud studies of individual designers). While there are studies of framing in design at the individual level (e.g., Schön 1984), studies of design team framing at the group-level and how that negotiation is achieved are rarer. Yet team framing activity has received much attention from researchers in decision-making, organizational behavior, management and psychology. Klimoski and Mohammed (1994) provide a bewildering array of related terms used across different studies including: group cognition, collective causal maps, collective interpretation, intersubjectivity, organizational consensus, strategic consensus, cognitive consensuality, coincident meaning, group belief structure, collective cognition, shared frames, shared meaning, shared understanding, negotiated belief structure, shared (mutual) models, collectively produced frames of reference, social cognition, group culture, shared mental models and collective mind. Once again, the language is intuitively coherent, yet precision is often hard to come by, and where precision is found it is rare to find it combined with a holistic perspective. The outcome of this research is, at the least, an emphasis that the negotiation of a shared team frame, or, more colloquially, 'getting on the same page', is an important part of successful group processes. Another outcome is the insight that there is a lack of clarity regarding its definition, with different researchers proposing that what is shared between group members may include beliefs, attitudes, assumptions, values, understanding, frames of reference, concepts, relationships, metaphors, commitment, interpretation, perception, content and framing. Mohammed (2001) folds the different strands of related research into the term *cognitive consensus*, the degree of similarity among group members regarding how key issues are defined and conceptualized.

The majority of studies on team framing (or related concepts) allow us to learn about group activities in general but fewer studies are specific to design and new product development. In particular, many studies are of control situations such as air traffic controllers, yet how design team framing affects tasks in uncertain, complex and non-routine situations such as design is still only poorly understood (Badke-Schaub et al. 2007). Mohammed (2001) provides 9 propositions based on prior research on team framing for the expected implications for team practice. These propositions include the expected implications of: different backgrounds; commitment to positions; group size; unanimous decisions; decentralized leadership; failed attempts; discussing underlying reasons; implementation; and repeated engagement. While in the abstract these propositions make intuitive sense for the actions of teams, the generalized implications remain difficult to translate to the specific context of user-centered design. I shall therefore briefly review some studies where researchers have explicitly attempted to understand design team framing.

In the literature on product design teams, the negotiation of shared frames has sometimes been interpreted as the formation of shared understanding. Shared understanding is necessarily a group-level phenomenon. Song et al. (2003) building on techniques developed in Hill et al. (2002) used the measure of semantic coherence calculated using the linguistic technique Latent Semantic Analysis (LSA) (Landauer et al. 1998) as a proxy for shared understanding measured from design documents (for a justification of this approach see Dong 2005). They found that high performing teams enjoyed high semantic coherence just before stage gates, but cycled between low and high semantic coherence in between, generally ending with high semantic coherence at the end of the process. This pattern was also seen to be true from measures derived from sketches and surveys of design team members (Agogino et al. 2005 and 2007). In management, Kilduff, Angelmar and Mehra (2000) found that top performing teams exhibit high cognitive diversity, in terms of their interpretations of a project, early in the project, but later converge on a common

understanding. Whelton (2004) also outlined how the negotiation of a shared frame is vital to the outcomes of team design processes during the management of construction projects.

In another study of the conceptual stages of design, Stumpf and McDonnell (2002) used argumentation as a basis for a coding scheme to analyze design team transcripts. They were interested in the negotiation that takes place within design teams as to how the team settles upon a shared frame. The authors identified frame shifts during the design activity and highlighted the difficulty of representing different 'levels of frames', or levels of abstraction, in order to discover frame conflict between members – that is, team members viewing the situation from different and conflicting frames. The focus of this study was not solely the framing activity but also on designing tools to support the experiential learning cycle (Kolb 1984) of design teams in line with a view of the innovation process as a learning model (Beckman and Barry 2007).

More recently, Kleinsmann (2006) used the 'learning history' research method to analyze two industry design projects, a retrospective pilot study, and an explorative observational study. Her study provided insight into the barriers and enablers for the creation of shared understanding at the actor, project and organizational level. Like Kleinsmann, several other researchers have investigated team mental models in field studies (see Lim and Klein 2006; Mathieu et al. 2006; Smith-Jentsch et al. 2005; Waller et al. 2004). However, these studies are not specific to design teams.

As some of these studies have shown, high shared understanding throughout the length of a project is rarely optimal. To illustrate this, Mohammed conceptualizes cognitive consensus as a continuum of sharing shown in Figure 2.3:

> "At one end of the continuum, many incongruent interpretations coexist and frames are entirely idiosyncratic. In the middle of the continuum, frames are widely held. At the other end of the continuum, there is perfect convergence

and every group member has an identical frame of reference. In general, the

extremes of this continuum are considered dysfunctional," (Mohammed 2001

411)

Boos (2007), who discusses optimal sharedness for effective group performance, suggests that effectiveness and sharedness vary according to a bell-shaped curve. Other metaphors, beyond *convergence*, used to understand team framing include assessing the *alignment* or *overlap* of individual frames. It is often argued that differences in opinion help a team find more creative solutions, the accepted wisdom being that a team with similar opinions and experiences will explore less of the solution space.

Sharing of group members' frames

Idiosyncratic   Widely   Perfect
shared   convergence

Dysfunctional   Dysfunctional
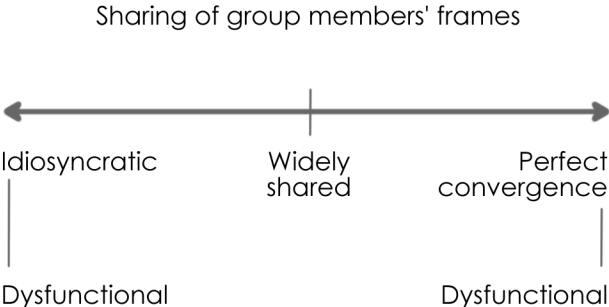
Figure 2.3   A continuum of cognitive consensus

My research studies framing at the team and individual level in the context of the user-centered design process. As I explain in the next chapter on Methodology, I build off the specific definitions provided above while combining this with a holistic perspective on the project drawn from personal experience and the story of the design path as told by the design teams. Below I will reiterate some of the major unknowns that still remain after this review of prior research on framing.

Research questions revisited

With a better understanding of the historical context of framing, approaches to the design process, the user-centered design processes investigated in these studies and prior studies of team level framing we are now in a position to revisit the research questions that guided this thesis.

1. What role does framing play in successful new product development?

Few prior studies were able to provide guidance on what role framing plays in successful design as opposed to average design. In this context by successful design I mean the development of new products that are well received and have strong potential to be adopted by users. Through my study of many design teams' activities I am able to discuss the role framing played in the final form of the design and its evolution in both successful and less successful projects.

2. How do design teams settle upon a suitable frame for their design situation?

Systematic attention is lacking for the study of how individual team members' frames converge or align. Through an understanding of the twists and turns of a design team's path from the perspectives of each of its team members I am able to bring structure to the otherwise confusing and amorphous process of teams negotiating a shared frame.

3. What tools could help support design teams to better understand and apply the framing process towards successful design?

With an improved understanding of the framing process I am able to address a lack of concrete directions for design teams for effective framing. My studies allow more actionable guidelines by providing a theoretical foundation for design teams to understand the framing process and potential pitfalls as well as specific themes and principles for effective framing.

Onwards

Although framing has been investigated across multiple fields the implications for user-centered design teams remain confused. What exactly are the implications for the early stage research and sharing activities that teams perform? How should design teams share their research with their team? What does research on framing suggest that teams do when making decisions on which needs to address or when they're deciding between concepts? What activities give teams the greatest difficulties and divergence in frames? It is understanding and recommendations at this level that are still lacking for really learning from research on framing. Rather than generalized abstract advice design teams require concrete guidance derived from solid theoretical and empirical foundations in order to change their practice.

Having covered the background regarding framing and the context of my research, in the next chapter I will discuss what is required of a suitable approach to studying design team framing and explain my choice of research approach and data collection methods.

03 Methodology

Studying design team framing

Summary

In this chapter I present my research approach to understand framing. I compare prior methods of studying framing including case-studies and lab research with the three criteria of realism, access to data and quantity. I chose a hybrid approach to understand framing that combines many small scale, in-depth cases studies with graduate student design teams together with interviews with professional designers and an industry case study. This approach provides excellent access to data, close to realistic design situations supplemented by insight into real design cases, and the benefit of comparing many cases with each other from over 60 design projects.

I also detail the primary research test bed, of graduate design projects at both Berkeley and the Massachusetts Institute of Technology (MIT), data collection methods and methodological issues that I needed to overcome and should be accounted for when assessing how widely findings can be applied.

Introduction

Studying design team framing in the user-centered design process presents a unique set of challenges. And it is critical to select a research approach matched to the phenomena being investigated. To explain my approach to studying design team framing I begin by discussing the criteria for evaluating a suitable research approach. After comparing typical approaches against these criteria I present my approach: a hybrid of studying many student design team projects together with interviews with professional designers and an industry case study.

Criteria for a research approach

Two primary goals for choosing a research method are to ensure we give ourselves the opportunity to observe and study important events in the design process, and also to have confidence that our findings will be applicable beyond the immediate study setting. In my case I am interested in informing both design practice and design education. If a researcher both sees the important events and is confident they can generalize at least to a larger subset of real design practice then they are in a good position to provide recommendations. To achieve this goal I believe design research methods must meet three criteria before they can provide solid recommendations for designers.

Realism

To provide recommendations for real design situations researchers should strive for realism in their research settings. Realism in design can be further broken down into three key aspects: timescale; constraints; and team composition.

Timescale refers to studying a project that is of typical length for an industry design project. Depending on the product or service being designed this can range from several months to several years and longer. Studying projects of only a few hours or days will be less realistic than studying longer projects.

Constraints refer to whether the context of the project is similar to how it would be in industry. This includes, among others, meeting the needs of a client, negotiations with management and stakeholders, working within a budget, managing schedules, competing interests, project briefs, realistic risk of failure and rewards for success.

Team composition includes having a realistic mix of experienced and inexperienced members. It also includes having members with different disciplines and skills, values and perspectives. In other words, team diversity should match the kinds of diversity that occurs in industry.

Access to data

Data is at the heart of research. Therefore the second criterion is sufficient access to data. Yet access to data varies widely. As I discussed, frames are cognitive and difficult to observe. Access to designers' thoughts and rationale for decisions is critical to study design team framing.

Quantity

Quantity increases the confidence in research findings. If a behavior has been observed in many similar situations the researcher can be more confident that the behavior is common and is likely to generalize beyond the study participants. If an event is seen only once it is difficult to generalize findings and be confident that this wasn't a unique instance.

Second, studying more design situations provides more chances to see interesting and important events. If the one project you study happens to be very routine or, alternatively, highly idiosyncratic, then a researcher may not witness key events needed to build theory or may build theory based on atypical situations. The more projects studied, the greater the chance of seeing many different situations and the greater the chances of seeing interesting events.

Comparing research approaches

Dunbar and Fugelsang (2004 59) provides a useful taxonomy of research approaches. Among the common methods and their implications in a design context[8] are:

- *In vivo* – studying design activity as it happens

- *In vitro* – controlled experiments with designers in carefully chosen tasks

- *In historico* – reconstructing an understanding from historical data

- *Ex vivo* – protocol studies, interviews or diary studies as designers go about a real design task

Each of these approaches has its own advantages and disadvantages in terms of the types of knowledge that can be learned. In vivo approaches provide limited access to the thoughts of design team members and no ability to control the parameters, but have a high validity. The in vitro approach, in contrast, can provide high access to a participant's thought processes, and a high degree of control at the expense of external validity. In historico methods provide high validity but provide no control or access to participants' thoughts at the time. Ex vivo methods are a somewhat middle-ground between the other approaches. Ex vivo studies provide relatively high validity, relatively high access to participant's thought processes and a varying amount of control over the situation. As these approaches play out in design research they commonly translate to case-studies of an ethnographic, in vivo nature, or controlled, in vitro, lab experiments with artificial design tasks.

For realism there is no doubt that an in vivo approach studying real design teams and projects in industry is best – it is real. A case study (see Yin (2003) for an excellent discussion of case study research), or action research (e.g. Dickens and Watkins 1999), provides 'real' data for design researchers to understand. In contrast, the in vitro approach of lab studies

---

[8] Dunbar and Fugelsang also include In magnetico and In silico in their taxonomy of methodologies.

sacrifices a great deal of realism for the ability to make quantitative comparisons and for control over the study. While industry design projects may take several months, lab studies are rarely more than several hours and occasionally over the course of a day or a week. The collapsed timescale makes for a less realistic design situation without, for example, time for designers to engage in key activities such as primary research, data gathering, time to resolve disagreements and longer term activities such as incubation (Wallas 1922).

Lab studies also have very different constraints to industry projects. Typically, they are performed by either many novice designers or a select few experienced designers. Often they study individuals rather than a full design team because team dynamics take time to evolve and studying teams is more challenging to arrange. Lab studies also suffer from different engagement of designers; performing well in the design task will not earn them a promotion, and performing poorly won't lead to a pink slip. The absence of clients and management moves lab studies further from realistic settings.

Short timescale studies in a laboratory also rarely allow recruiting teams with a past history together or give them time to develop ways of working together and communicating. In the same vein the composition of the team lacks the mix of industry experience often present in industry. In the short time-scale of lab studies participants are generally peers and often meet each other during the study.

Despite these drawbacks, lab studies provide researchers with an unprecedented amount of control over the parameters of the study. Only in a lab study is it possible to maintain control over relevant task parameters. Lab studies therefore provide an accessible means of evaluating causality between an intervention and its effect.

Where the industry case-study approach is undoubtedly realistic it can suffer in both access to data and quantity. Access to data can be limited and hard to come by in industry. Findings or events that may be seen as negative for the company may be restricted or distorted when

presented to the researcher. In other cases a company may deny the opportunity to publish the results if the outcome could be seen as negative publicity resulting in an unusually high proportion of positive case studies. It may prove impossible for the researcher to attend all relevant project meetings or have access to the physical artifacts of designing including documents and prototypes. This is particularly the case when studying design teams as the time to launch a new product can be significant and a new product is often a source of substantial competitive advantage and thus closely guarded. Researchers may also face political and social challenges to gain access to data based on trust, seniority and must avoid compromising participants' job security. In retrospective studies it can prove difficult to contact all past design team members. In addition, events may be remembered inaccurately, or be subject to the halo effect of remembering events in a more positive light, and team documents may not have been archived.

Industry case-studies also often require a great deal of time and effort from the researcher. Studies typically require six months or more of a researcher's dedicated time to build rapport with the design team members and key company stakeholders, and witness the full evolution of a project. In practice this means, in the relatively short time-scale of a PhD, a design researcher is restricted to studying a maximum of about four projects from start to finish.

Student design settings

Data in this thesis is primarily built from a middle ground between the industry case-study approach and the traditional lab experiment. I chose to collect data from multidisciplinary NPD teams in a graduate student NPD class. This is effectively a modified ex vivo approach where we can learn about real design behavior though in a somewhat contrived, though not easily controllable, setting.

Advantages

Although student design teams do not operate in an authentic design setting it is significantly more realistic than a lab setting. For example, student design projects used in this study spanned three months from conception to working prototype; three month projects are not uncommon in industry, particularly in the design consulting business. While the members of student design teams are by necessity learning to do design they nevertheless possess a range of experience. Each team typically has members with at least three years of industry experience together with members setting out on their first multidisciplinary design project. In this way, more experienced members help to mentor and lead the less experienced.

While a University setting will always be different from industry, the faculty work hard to create projects that closely match a common industry setting through enforcing similar stage-gates, deliverables and activities. Alumni of the class have confirmed its similarity to projects in industry, for example, one alumnus commented: "Working on a cross-functional team is so important. I know that today more than ever – the vast majority of my work is on a cross-functional team. In all my classes [during my studies] that class was the closest to reality."

Student design teams in this study are also multidisciplinary with graduate students from business, industrial design, engineering, software development and information management. The mix of disciplines closely mirrors the skills required in real industry projects. Teams are also guided by experienced product development coaches from local design practices reflecting guidance from senior members of design firms.

Student design projects provide a distinct advantage for both access to data and quantity of projects available to study. The open classroom setting allows a design researcher to closely watch the evolution of the project, witness team meetings, successes and difficulties and provides access not only to final deliverables but to intermediate project documents. We have

45

further supplemented our data collection through the use of surveys and team interviews to provide a comprehensive picture of each project.

Finally, studying student design projects enabled me to closely watch the development of over sixty different projects in the course of four years. Studying this many projects has allowed me to observe both unique and repeated situations and to witness many interesting events. The range of projects allows us to compare the experiences of similar teams and teams working on similar projects. With over four hundred graduate students involved we are also able to support our qualitative observations with quantitative analysis from surveys and class outcomes. These benefits of studying student design teams has led them to become a mainstay of data for design researchers across the globe.

Limitations

Despite these advantages I recognize it is easy to dismiss theory built from student design settings. Without the organizational constraints typical of industry projects, the class context and lack of experienced designers it is important to interpret findings with care, judging what is more broadly applicable and what is an artifact of the research context.

In particular, motivation to succeed varies widely in design student settings. Some students take the class for the desire to develop a product for market, others because they intend to be leaders in NPD. Yet, some students inevitably take design classes purely for the experience, because it fits into their schedule or purely for a grade. While this is true, it cannot be said that all participants in industry design teams are highly motivated. Motivation and commitment to a project inevitably varies.

We have attempted to address these limitations in several ways. Research findings and qualitative interpretations were discussed and checked among research collaborators such that only findings we were most confident of are reported. Findings are only included when we were able to verify them through repeated observations. To assess the transferability of

findings to industry we conducted interviews with professional designers in industry and a detailed case study of an industry NPD project. When framing issues for design teams surfaced both in the student teams and the industry situation our confidence in the research findings and applicability is increased. Later in this chapter I also carefully review how widely I feel findings from this thesis can be generalized.

Building on prior research

As I alluded to in the previous chapter, I have tried to build upon existing framing research. In particular, I have attempted to address gaps in research methodology in prior studies by studying:

- *Multidisciplinary rather than Unidisciplinary teams:* Many studies used data from uni-disciplinary design teams in experimental settings. Real-world design is performed with designers from multiple disciplines with varying backgrounds and skill-sets. I therefore studied multidisciplinary teams.

- *Teams rather than individual designers:* Many studies, particularly protocol analysis studies, focused on individual designers only. Though designers often design as individuals, a complete product development project in industry is performed by teams. Many critical phenomena present in team design are absent from the practice of individual designers.

- *An order of magnitude more cases:* Though one study analyzed data from nine individual designers, team-based studies typically used only two to three student design teams. Research presented in this thesis is built from analyses of over 60 design teams.

- *Realistic design schedules:* For the purposes of recording the design sessions most studies took place in a highly compressed situation over several hours or several days. I collected data from projects lasting 2-3 months.

- *Prescriptive rather than descriptive:* By studying a wide range of projects it is possible to observe not just what design teams do but what practices are beneficial and what practices are detrimental. While previous studies have identified framing as an important activity this research goes further to provide recommendations for effective framing and pitfalls to avoid.

The research test bed

In this section I describe the research test bed where the majority of team data was collected.

New product development at UC Berkeley and MIT

Data for this thesis were gathered at two graduate product development classes, one at the University of California at Berkeley, and the other at MIT. At Berkeley, the class focuses on teaching students the innovation process through the lens of user centered design. Material covered in the class broadly follows the textbook *Product Design and Development* (Ulrich and Eppinger 1995 and 2005) supplemented by readings and lectures on user-centered design and ethnographic research methods. The students also 'learn by doing' through a team project – with project areas ranging over: easier exercise; a sexier soccer bag; more blood donors; local transporter; reducing obesity in the young; and healthy meals for schools[9] (see Appendix for the complete list) – that spans the length of the fifteen week semester.

Each team is interdisciplinary with some mix of business, engineering (mechanical, electrical, chemical, industrial, civil and environmental), information management and industrial design (California College of the Arts and one year from San Jose State University) students. Each team is coached by the three course faculty as well as by a local design professional and evaluated at the end of the semester on how well it has undertaken the process as well as on its final prototype. Faculty and judges from well-known product development and design firms (such as frog design, IDEO, Jump Associates, Apple and

---

[9] Project names throughout this thesis have been altered to provide anonymity for the teams. However, the general content of the project is reflected in the adjusted names.

Cheskin) evaluate the team's performance based on a project presentation and a prototype display stand and demonstration.

Over the course of this thesis I collaborated closely in data collection with Caneel Joyce, of the Department of Organizational Behavior in the Haas Business School, and five undergraduate research assistants. Three faculty members, with a combined experience of teaching the class of over 30 years, validated interpretations regarding team performance and provided additional insights.

Data in this thesis was also gathered from one semester at MIT.[10] The MIT NPD class follows a very similar format to the UC Berkeley class. The primary textbook for the class is the same, so the teams follow largely the same design process. The team composition is similar – it is a graduate class comprising engineering and business students at MIT with industrial design students from the Rhode Island School of Design (RISD). The class is also team taught by engineering and design faculty. Differences between the classes include having no external design coaches for the teams and an increased emphasis on a working final prototype. A greater part of the design grade is based on the final prototype and consequently less class activity is devoted to user research activities and more to prototyping and testing.

Data collection

The primary goal with the research approach was to be able to tell the story of a project. To do this well I first needed to understand the activities and actions that were performed. To explain why these activities were performed I also needed to understand the basis for the decisions the team took with regard to, for example, who they chose to observe, which concepts they chose to develop, and the results of their testing. Just as designers listen to the stories of their participants in order to learn about them, as a researcher of designers I listened to the stories the designers told about the design process in order to understand and

---

[10] I am very grateful to Jessica Dolak for her role in helping collecting data at MIT during the semester.

design for them. In some senses I was performing design ethnography of design ethnography. Reflecting on the framing carried out by the design teams, I followed Rein and Schön's (1991) suggestion that this frame reflection should be on the stories that identify frames and the values, norms, metaphors, appreciations and directions for solutions they contain (Stumpf 2001 70). In particular, framing becomes visible when teams become stuck or realize a failure with an existing approach, for example, when a team cannot agree on a way to move forward or when an end user rejects an early prototype causing the team to rethink what is important.

The following is a list of the data collected in order to be able to confidently tell the story of each project.[11]

Initial project proposals: I captured both the written project proposals from each student in each class as well as observing their presentation of the proposal to the class. This provided the first description of each project, and thus a base from which to measure its adaptation over time.

Short free response survey: For two semesters, several weeks into the semester we asked in a voluntary free-response survey for students to tell us the goals of their projects, the strongest points of consensus on their team about its mission, the most significant issues about which team members were not in agreement, and how they thought their team's mission statement had changed in the past week.

Observations of in-class team meetings: I observed in-class sessions in which teams were working on their projects alone as well as with faculty coaches.

---

[11] Due to scheduling difficulties it was not possible to interview a number of the projects in the design classes over the four years. The projects where I was not confident of accurately telling the story from the team's perspective were not included in the study.

Interviews and observation of meetings outside class: one researcher met with each design team to observe and audiotape a meeting for between 30 – 150 minutes. Near the end of the meeting we conducted a short structured interview of approximately 25 minutes to hear the story of the project as they saw it including the customer research performed, mission statement development, challenges they faced or imagined facing on the project, the number of times they had met to date, and the amount of work they had been able to contribute to the project. For each observation there are field notes and transcriptions of the interviews.

Discussion with class instructors: Research insights and observations about a team's process and dynamics were supplemented by thoughts from the class instructors both during and at the end of the projects.

Mid-semester and final team evaluations: Halfway through and at the end of each project students were asked to complete a comprehensive survey about their team's performance and the performance of each of the individuals on the team. Free response questions on the surveys provided an opportunity for team members who were less likely to speak out during the collective team interviews to provide their opinions. An example of one such survey is included in the Appendix.

Design documents produced and exchanged by the teams: We accessed the design documents produced and shared within the teams as well as the class deliverables. These documents, together with observations of two project presentations to their peers during the semester provided a public viewpoint of the teams' understanding of their projects.

Project journals: Each student was required to maintain a design journal throughout the semester. The design journal contained a mixture of meeting notes, design sketches, individual work, class notes, information from external sources including photographs and print-outs from the Internet, and reflection on team process and dynamics. The quality and depth of journals varied widely. Each journal was studied at the end of the projects and the

information was used to inform the understanding of the project. In certain cases, quotes were extracted directly from the journals. To learn more about the typical content of the design journals see Song and Agogino (2004).

The same data were collected at both MIT and UC Berkeley save project journals which were not available from the MIT class and several design meeting observations that were performed by a research assistant rather than directly by the researchers.

Industry case study

To help understand the transferability of results to industry I supported the data collected from the graduate design teams with an industry case study and interviews with new product developers in industry. In Chapter 06 I present a case study of the company Powder Net through the early formative years of the company. As discussed in Chapter 06 I used a criterion sampling method (Patton 2002), constructing interviews with the founders of the company asking them to tell the story of the project as they saw it. The interviews were semi-structured with a core list of questions to understand the original framing of the design situation and the insights and decisions that led to their final framing. When possible the interviews were recorded and transcribed. If the interviews were not recorded then notes were taken during the interviews and written up directly afterwards attempting to preserve as much as possible the original wording of the interviewees.

In the course of studies for this thesis, presented in Chapter 04, I, and my colleagues, also performed interviews with 12 design coaches of the UC Berkeley NPD class, all professional designers, and 18 alumni from the NPD class who are performing NPD in industry to different degrees. Though I do not ultimately present them in this thesis, interviews were also conducted with two other early stage NPD firms as potential case-studies.

Finally, I also drew on my own two years of NPD experience at two design consulting firms I Europe and the US. My own experience was an additional cross-check for findings

throughout this thesis, although all conclusions and guidelines are first and foremost developed from the data collected specifically for this research project.

Data analysis and research protocols

Data collected for this thesis was analyzed in multiple ways for different purposes and with different colleagues. Table 3.1 details the chapter, data set, data type, analysis colleagues and research publications resulting from each study.

As the analysis of each data set varied for each study, rather than include each protocol and analysis method here they are included in each chapter or referred to in the Appendix.

Methodological issues

In collecting and interpreting this data four methodological issues were foremost: the researcher effect; group interviews; anonymity; and generalizability. I will briefly present each of these issues in turn and how I sought to deal with them.

The researcher effect

Whenever a researcher is in direct contact with study participants, the presence of the researcher and knowledge about the research being performed can affect the behavior under study. In other words, in observing and interviewing the design teams I also affected their process. In my case this was also compounded by my role as a teaching assistant throughout the years of the new product development course at Berkeley. A teaching assistant has a role of authority and an obligation to the students to avoid letting the research activities strongly influence outcomes for students in the course. Indeed a primary concern was to ensure students that their thoughts provided for research would not play a role in their class grades.

Table 3.1 Research studies, data sets, data analysis colleagues and research publications presented in this thesis

	Chapter	Data set	Data type	Research publications
04	Lessons Learned in NPD	Berkeley NPD class years 2000-2005; Berkeley NPD design coaches; Berkeley NPD alumni 1996-2005	Lessons learned; design coach interviews; alumni survey and alumni phone interviews	Hey et al. 2006; Hey, Van Pelt et al. 2007; Cobb et al. 2008
		Analysis performed with: Alan Van Pelt, Corie Cobb and Melissa Lock		
05	Finding Framing	22 Berkeley NPD teams 2005; 10 MIT NPD teams 2006	Team interviews; observations; team evaluations surveys; design documents; project journals	Hey, Joyce, and Beckman 2007
		Analysis performed with: Caneel Joyce		
06	Design Paths	57 NPD teams 2004-2007; industry designer interviews	Team interviews; observations; team evaluation surveys; design documents; project journals	Hey, Yu, and Agogino 2008
		Analysis performed with: Jonathan Yu		
07	Metaphor and Framing	Design textbooks; Berkeley NPD teams 2006; experiment with senior engineering undergraduates	Team interviews; design documents; controlled experiment	Hey, Linsey, et al. 2007; Hey, Linsey, et al. 2008; Kolb et al. 2008
		Analysis performed with: Julie Linsey, Alan Shih, Jonathan Yu		
08	Principles	57 NPD teams 2004-	Team interviews;	Hey, Yu, and

and Tools for	2007; industry	observations; team	Agogino 2008
Effective	designer interviews	evaluation surveys; design	
Framing		documents; project journals	

Analysis performed with: Jonathan Yu

To reduce the researcher effect I made sure to clearly explain to all students that any data provided to me was confidential and would not affect their position in the class. The first two years of being a teaching assistant this was helped by my officially not being allowed to provide grades. The study was approved by the University of California, Berkeley Office for the Protection of Human Subjects (OPHS) and the Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects (COUHES).[12] I also tried to reduce the effect of research by conducting interviews towards the end or after the class was completed. As teams are graded largely on their process much of their grade is already decided at this point. When conducting interviews I forced myself to listen without providing advice other than what is normally called for in the role of a teaching assistant. Also, in the consent forms for participation and the description of the research provided to the students discussion of the research aims and themes was kept deliberately vague so as to not artificially produce the effects I was trying to study.

Being a teaching assistant also provided me with several valuable benefits. It was expected that I would be present during lectures, in-class lab sessions, presentations and tradeshows. Design teams were therefore quickly comfortable with my presence. Indeed, in most situations it was apparent that students did not consider me a researcher. As a teaching assistant I was also in the unique situation of being both a peer to the graduate students of the class, and therefore more approachable for them to air their concerns and team issues, while also having the benefit of learning from faculty interpretations and discussions

---

[12] Human subjects approval is included in the Appendix.

regarding team progress. This position was reflected in the students' typical openness to participate in the research.

Group interviews

The majority of interviews with design teams were performed as group interviews. In most cases all, or most, of the team was present for the full length of the interview. Group interviews were performed partly for scheduling reasons. Rather than perform nearly 400 one-on-one interviews, which would have been impossible, group interviews made it possible to reduce that number to less than a quarter. But group interviews were also chosen because of the unique context of design teams. Group interviews allowed me to observe a microcosm of the overall project team dynamics during the course of the interview. It is possible to see who is outspoken, who is quieter, who is a leader and who contributes. By observing social cues such as interruptions I could infer whether the dynamics of the team were adversarial or respectful and cooperative. When asking for the story of the project a group interview provided an excellent opportunity to observe first-hand the differing accounts often produced by group members. As one team member would relate the motivation for a decision, another would jump in to say he had seen it very differently. In this way, bringing the differences of opinion into the open with the team allowed me to learn a rich history of the project as team members built upon and constructed the story. The teams often, though not always, found the interviews both educational and enjoyable.

Group interviews are subject to the dynamics and presentation of the project in a public way. Where there were strong differences of opinion or personal conflicts team members may have been unwilling to bring these up in the public setting. Group interviews also do not create the ideal environment for more reserved team members to speak their mind. In most cases, however, the combination of data collection methods helped me gain a second or third perspective on team members' experiences. They were able to provide their thoughts in the online team evaluations and through reflection in their journals. On several occasions,

individual team members contacted me for a private interview after the group interview. While I can be certain that I did not learn the full story from all team members over the four years of study, I am certain that I learned enough to understand the bulk of key decisions that affected each team's path through the design process.

Anonymity

Throughout this thesis I shall refer to design projects and student comments as specific examples to support my observations. It was made clear to participants that their contributions to the research would remain anonymous. This is made more difficult when discussing details of a project to illustrate a point. A project in the abstract is far from a project in the specific. As a result, team projects in this thesis are discussed with the original names of the projects changed. Individual contributions remain anonymous.

Generalizability

It is important to consider how far findings generated by this research approach can reasonably be generalized. In other words, how much do the experiences and phenomena that I have observed in the graduate NPD teams and the interviews and industry case-study have in common with those experienced by other design teams. My research approach has sought to inform both design education and design practice. If findings are comparable between industry and the graduate design teams then confidence is increased that insights from the NPD teams are transferable outside of the design education context.

Certainly the Berkeley and MIT NPD courses are broadly representative of an increasing number of interdisciplinary design programs (the Corporate Design Foundation (2008) maintains a list). The two courses are also similar but different, therefore if I encounter similar situations in both courses we can be more confident of generalizability to other NPD courses.

With regards transferring learnings to professional NPD teams in industry an important consideration is expertise. A key difference between professional NPD teams and student design teams is that student designers are by necessity learning the process. Many, though not all, industry NPD teams are comprised of members with significant expertise. Lawson and Dorst's (2005) model of design expertise is instructive. They divide design expertise into 7 levels: naïve; novice; advanced beginner; competent designer; expert; master; and the visionary (The model builds on Dreyfus' model (2002)). The graduate students in the NPD classes studied range in expertise from naïve, those with the most simplistic understanding of design, to the rare competent designer who is able to become the creator of the design situation improvising with process as necessary. Most professional NPD teams could be expected to comprise slightly elevated levels of expertise, from novice to expert (often responding to situations with intuition from many years of experience) with the occasional master. While professional design teams then are likely to operate slightly differently due to increased experience there is also significant overlap in the range of skills present between both industry and graduate NPD teams. The Berkeley design teams also benefit from the guidance of professional design coaches and the design faculty who effectively help raise the experience level of the team. We can thus expect many of the results to transfer to regular NPD teams in industry although there may be less relevance to truly expert NPD teams such as those found at the leading design consultancies. It is important to recognize that it is also only reasonable to generalize results within the context of user-centered design projects, with sufficiently open-ended design situations, most likely in Western design cultures.

Onwards

In this chapter I outlined the reasons behind my choice of research methodology. I also explained the data collected to understand the stories of the student design projects. Lastly, I discussed specific methodological issues I ran into including, minimizing the researcher effect, group interviews, anonymity and how far I believe results of this study can be

generalized. In the next chapter I present a study on what issues NPD teams find to be of both most value and most challenging during design projects.

04 Lessons Learned in NPD

What do NPD students need?

Summary

In this chapter I discuss a study on the self-reported lessons learned of new product development students. The study serves to support the value of new product development education, multidisciplinary project experiences and highlight what remains difficult for students of design. Students consistently highlighted working in multidisciplinary teams as the greatest learning experience followed by learning to elicit, deal with, prioritize and manage user needs. A more detailed look at these needs points to a need for guidance when framing design situations in a multidisciplinary team.

What do students learn in new product development classes?

A key first step of designing is to identify needs that are not being met. My study begins then by trying to identify the needs of design teams. The study I present in this chapter investigates the needs of design teams through analysis of reported 'lessons learned' at the end of a design project. These 'lessons learned' are an important window into what the teams a) found valuable in the design process, b) found difficult in the design process, and c) found

memorable or surprising about the design process. Together with Alan Van Pelt[13], I collected over 2,300 individual statements of lessons learned from student design teams and sorted them to understand the issues that are difficult when doing design. The results of this study form the basis for later studies investigating the challenging activities on a multidisciplinary team of getting to agreement about a common framing of the design situation – getting to agreement about what people want.

The chapter begins by presenting the research setting and outlining the challenges in assessing what students actually learn from New Product Development (NPD) classes. I discuss the forms of data collection including triangulation through interviews with professional design coaches, before detailing the analysis and results. I follow with a discussion of the most important takeaways from the study revolving around teamwork and dealing with understanding customer and user needs. Finally, I recognize that a study on student design teams has its limits for generalizability so I briefly present the results of a survey of alumni of the Berkeley NPD class where I aimed to determine if the value still holds.

Research setting

Data for this study were collected from six years of the UC Berkeley graduate NPD class described in Chapter 03. The class employs a project-based learning pedagogy (Dym and Little 2003; Dym et al. 2005) that builds on the Kolb model of experiential learning, Figure 4.1.

---

[13] This work was performed with Alan Van Pelt resulting in the publication of two papers (Hey et al. 2006 and Hey, Van Pelt et al. 2007). The analysis presented here was strongly enriched by my coauthors Alan, Dr Sara Beckman, and Professor Alice Agogino.
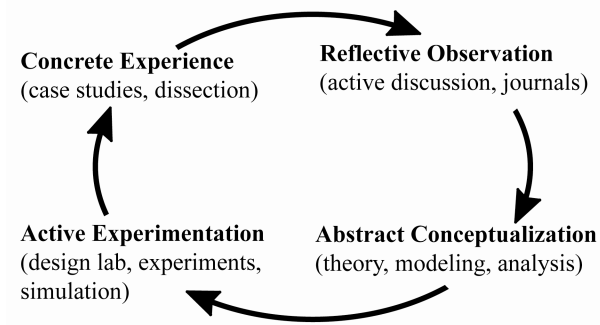
Figure 4.1   The Kolb model of experiential learning

The Kolb model is particularly appropriate for teaching NPD as it cycles the learning experience through concrete, hands-on activities, and experimentation sequenced between activities of abstract conceptualization and self-reflection. Reflective observation, or self-reflection was recognized by Schön (1983) to be a key skill for a design practitioner. Schön refers to the 'learned intuition' of professional practice as 'professional artistry' or 'knowing-in-action'. He suggests that it is the ability to reflect both during and after an activity that distinguishes the effective practitioner. Reflection on the design process and the students' team experience is therefore required at multiple points throughout the design projects. The students were asked to reflect on their experiences after each assignment (e.g., their first customer interview), and to share their team reflections at each of three presentations to their peers. By the time they get to the final class assignment, generating the lessons learned that are the subject of this paper, they are well-experienced in reflection.

Lessons learned as self-reflection

'Lessons learned' exercises as a form of self-reflection in design classes provide insight into what students themselves experienced as the most salient parts of a course. Whereas a written assessment tests knowledge that the instructor thinks is most pertinent, asking for lessons learned focuses on the students' experience. It reveals not what students were supposed to learn, but what they thought they actually learned and what they felt was most

important about what they learned. A disconnect between the two – what students were supposed to learn and what they say they did learn – provides useful feedback for the instructor. Assuming that what was not considered worthy of selection as a lesson learned is felt to be sufficiently mastered, lessons learned also provide an understanding of what remains challenging, unique or particularly valuable to NPD.

As a pedagogical tool, articulating lessons learned encourages reflection and reinforces key learning and meaningful experiences. It encourages students to reflect on their experiences and develop transferable lessons to be applied in other situations in the future. When conducted in a group, reflection helps students learn from the experiences and stories of others, as discussion of each lesson elicits anecdotes of actual project experiences. In turn, sharing also solidifies the individual's lessons learned. Hearing about others' experiences and analyses of similar processes or situations encourages critical thinking and discussion, as experiences and interpretation often differ.

Sharing lessons learned in groups other than the original project teams allows students to socially construct knowledge about their own team experience without worrying about their teammates' differing opinions or about hurting their teammates' feelings. Furthermore, since names are not attached to the lessons learned, and since the exercise is not graded, students are more likely to provide an honest assessment of their experience, positive and negative, without fear of consequences.

The data analyzed in this paper are elicited when, in preparation for the final class of the semester, the students are asked to:

> *"Reflect on the experience you have had working with your team in developing your product this semester. Capture 8 – 10 key lessons you have learned from the experience on Post-It™ notes (one per Post-It™). Bring those notes to class with you to share."*

The wording of the assignment usually results in consistent interpretations by the students as to what to bring. Students are placed in groups with students from teams other than the one on which they participated during the semester to discuss the individual lessons they brought with them and to cluster similar lessons together on pieces of flipchart paper. At the end of the class, students share the most significant lessons from their conversations in a broader class discussion that concludes the class for the semester. The teaching team collects each of the flipcharts with the clustered Post-It notes, or what I refer to here as 'lessons learned', from the student groups at the end of each year's discussion. This paper analyzes over 2,300 direct student quotes as transcribed from the Post-Its collected over six years of NPD classes – 2000-2005. The numbers of students and lessons learned by year is shown in Table 4.1.

Table 4.1   Numbers of lessons learned collected

Year	Number of students	Total number of lessons collected
2005	68	448
2004	76	427
2003	63	473
2002	52	448
2001	48	244
2000	49	308
Total	356	2,348

After the collection and analysis of student lessons learned my collaborators and I listened to the experiences and perspectives of the industry design coaches to compare to the students' experiences. The coaches were not shown the results of the analysis of student lessons before providing their thoughts.

Design coach reflection

Design coaches – experienced designers from industry who are asked to coach and mentor the NPD teams – are used successfully by an increasing number of product design programs (e.g., Eriz and Leifer 2003; Ochs 2007; Cardozo et al. 2002). The design coaches guide the students as they navigate the NPD process, helping them to explore and articulate what the problem space is and what the solutions might look like. Design coaches provide the benefit of an outside perspective on the process and help the team resolve issues with team dynamics. Interaction with industry professionals encourages learning by helping students connect class experiences with real-world constraints, priorities, and quality expectations. Design teams in the NPD class at UC Berkeley are encouraged to meet with their coaches to seek their advice and share their experiences, at least three times during the semester. Student reflections show their appreciation of the coaches:

> *"Design coaches were invaluable. I wished we'd seen more of ours."*

> *"Design coach was an excellent resource and was open and helpful. He was a great contact to the professional world."*

> *"I have a new respect for people who do this professionally."*

> *"Mentorship or outside consulting helps tremendously."*

> *"Talk to the experienced professionals. They know what we have to improve!"*

Over 60 design coaches have been associated with the NPD class in the last six years with over twenty of them coaching for more than one year. The design coaches have unique first-hand knowledge of the students' design experiences as they meet with the students and observe where the teams struggle and where coaching is most needed. Often they can elicit information from the teams that the faculty are not able to, as the faculty are seen as controlling course grades, while the coaches are seen as knowledgeable professionals who are

offering their expertise. In addition to what the coaches learn and observe about how the student teams work, they have their own body of knowledge about the skills NPD professionals need to know to be successful. They are thus well positioned, with an outside perspective, to determine if the class does indeed develop these skills.

To make responding as easy as possible, three options were provided for the coaches: an email survey, a phone interview or a face-to-face interview. A seven question survey asked coaches to rank the clusters of lessons most commonly identified by the students in terms of both what they see the students learning, and what would serve them best in industry. While some coaches returned the survey form, other coaches preferred to share their thoughts and experiences in a short phone interview covering similar questions. Although the survey questions were used to guide the conversation, the design coaches were encouraged to share the stories and experiences that seemed most relevant to them.

Data analysis and results

In this section I first describe how the lessons learned from the six different years were merged, then present the summary data, and identify important results. I then dig into the lessons learned that focus on the NPD process itself, and analyze the "Customer and User Needs" category in some depth. Both the customer and user needs lessons and those lessons relating to teamwork bear the greatest impact on design team framing. Finally, I describe how the data provided by the design coaches was analyzed, and how it compares to what the students provided.

Merging 6 years of lessons learned

During the class exercise, the students clustered the lessons learned into categories of their own choosing and named those categories using a process commonly referred to as affinity diagramming (or the K-J method, see for example, Brassard and Ritter 1994). The resulting categories reflected the particular mix of student experiences represented in each group.

Each year, after collecting all the lessons learned, these categories were used as starting points for a high-level clustering exercise to integrate and re-sort all of the lessons from the class. In this step, Post-Its from similar categories, such as 'milestones' and 'deadlines' for example, were grouped together into one category to make the list more digestible. The new clusters of lessons learned were transcribed to create a summary document which was returned to the students. Utilizing the students' category names as much as possible ensured that their perspectives and means of organizing their own experiences were retained.

The high-level clustering performed each year varied in both the naming and granularity of the categories, so to make the data comparable across years yet another high-level clustering exercise was performed. In this case, similar categories were amalgamated and larger categories broken down to form a uniform set of categories that spanned the six years. Each of the individual lessons learned within each category were carefully checked to ensure consistent application of definitions. Each year there were several categories – such as "Effective Workspaces," or "Archiving Documents" – that did not show up in any other years; these were eventually folded into an "Other" category. Categories that consistently showed up across all six years remain distinct in all of the analyses that follow, and all of the final categories I present here were suggested by at least several groups of students throughout the six years. Table 4.2 shows the results of this organizing activity. Because the total number of lessons varied from year to year, the data are normalized to show the percentage of lessons each category represented in each year. (Also in Table 4.2 is the percentage of formal class or lecture time that was spent covering topics in each category.)

Table 4.2   Proportion of lessons learned categories per year

Process Team Other	% of lecture time	Lesson category	% of Total Lessons							
			Total	2005	2004	2003	2002	2001	2000	σ**
P	15	Customer and user needs	14	14	11	16	12	14	17	3
O	0	Meetings and scheduling	8	10	9	7	11	3	2	4
T	*	Roles, responsibilities and skills	8	9	8	6	9	7	4	2
T	*	Team diversity	7	9	4	9	8	7	4	2
P	26	General process learning	7	5	7	5	9	7	8	2
T	*	Communication	7	9	8	7	7	4	3	2
O	15	Other	7	5	6	15	2	5	5	4
P	5	Concept generation	6	6	6	6	8	5	6	1
O	4	Project management	6	3	7	4	8	7	8	2
P	16	Prototyping and testing	5	5	4	4	3	10	9	3
P	3	Concept selection	5	7	4	3	6	9	6	2
T	*	General team learning	5	3	9	2	5	7	8	3
T	*	Team building	4	2	4	5	4	6	2	2
P	2	Mission statement	4	5	4	3	3	3	4	1
O	0	Design coaches	3	4	2	3	3	2	4	1
T	*	Conflict management	3	1	4	3	1	2	5	2
T	*	Leadership	2	2	3	3	2	3	3	1
P	5	Financial, economic and business	2	3	2	1	2	0	2	1

* the total lecture time spent on team issues was 8%, or 1.5 lectures

** standard deviation

Three broad clusters of lessons learned categories emerged. Team-related categories (indicated by a T in Table 4.2) comprise 35% of the lessons learned, process-related categories (indicated by a P in Table 4.2) comprise 42% of the lessons learned, and other categories (indicated by an O in Table 4.2) comprise 23% of the lessons learned. 'Other' includes topics that were general and not specific to NPD, such as managing time. I'll now examine the team-related and process-related lessons learned in more detail.

The categories of team-related lessons learned, ordered by decreasing frequency of mention, include: Roles, Responsibilities and Skills, Team Diversity, Communication, General Team Learning, Team Building, Conflict Management and Leadership.

Three categories stand out by their frequency of mention (Table 4.3): Roles, Responsibilities and Skills, Team Diversity and Communication. The General Team Learning category includes a number of smaller categories that did not appear consistently across years, including Trust, Humor, Team Values, Team Flexibility and Decision-making, along with a large number of quotes commenting generally on the team experience (e.g., "Having fun together is key to acting as a team rather than a group," and "Everyone is valuable.") To provide a clearer idea of what is included in each team-related category Table 4.3 provides sample quotes from the students.

Table 4.3   Team related categories with examples

Category	% of team related lessons	Example lessons
Roles, responsibilities and skills	22	"Don't pigeonhole someone into a role based upon their background" "Utilize others' strengths. If they can do it better than you, let them"
Team diversity	20	"Each member of a team learns differently and approaches problems from different angles based on experience, personality type etc." "Involving others in your project is opening up to vulnerability, however having another expert take up the slack makes projects race where they would have crawled if you worked alone"
Communication	19	"Have regular meetings and communicate as much as possible" "Face-to-face meetings are best; don't always rely on emails"
General team learning	15	"Agree on process to get buy-in" "Allow for time to gather necessary information so that decisions are fact-based"
Team building	11	"Spending time outside of regular meetings can help build team chemistry and enable you to work more effectively" "An ideal balance between humor/play and serious work can be achieved"

Conflict management	7	"Be honest about problems early"
		"Just because someone says 'yes' does not mean they really agree"
Leadership	7	"Clear leadership is helpful to allocate jobs more efficiently"
		"A team leader is not really needed as long as the group can reach a decision. Otherwise, a team leader is needed to reach a decision"

The process-related lessons learned categories identified by the students, not surprisingly, parallel the NPD model the class follows (Ulrich and Eppinger 1995), including: generating the goals and mission statement of the team, customer and user needs research and analysis, concept generation, concept selection, prototyping and testing, and financial analysis. The largest category of process-related lessons mentioned by students, see Table 4.4, related to identifying and dealing with customer and user needs; the phases of concept generation, concept selection, prototyping and testing, and financial, economic and business were less significant to the students. As Customer and User Needs is the most significant process-related category, I more closely examine the breakdown of the 318 lessons learned in that category to understand what aspects were the most significant.

Table 4.4   Percentage of process-related lessons learned by category

NPD Phase	% of Total Lessons
Mission statement	4
Customer and user needs	14
Concept generation	6
Concept selection	5
Prototyping and Testing	5
Financial, economic and business	2

User needs lessons analysis

Over the last several years, the need-finding process and a deep understanding of customer and user needs have become increasingly important, with both industry and design classes placing greater emphasis on them (see, for example, Leonard and Rayport 1997). The need-finding activity poses the greatest amount of uncertainty to developers because customer and user needs are unknown and out of developers' control. Finding new or unknown customer and user needs has more potential to change the end result of the development process than any other activity (Zirger and Maidique 1990; Rothwell 1972). Yet, arriving at a precise list of needs to address can be a difficult and time-intensive endeavor because consumers often have trouble articulating and prioritizing their needs when they are not responding to offerings with which they are already intimately familiar (Laurel 2003). It is perhaps not surprising then that lessons related to user needs are frequently mentioned.

Two approaches were taken to understanding and analyzing the lessons relating to customer and user needs. One researcher placed each lesson on its own note card and then performed an affinity diagramming exercise (Brassard and Ritter 1994; Beyer and Holtzblatt 1998) in a

large open space. Rather than use the categories suggested by the students, which were not at the required level of granularity, the researcher independently identified natural relationships or clusters, named them, and let them evolve until all 318 lessons learned were incorporated. Separately, another researcher coded each lesson with an evolving set of codes that emerged from the data (Glesne and Peshkin 1992 127-149; MacQueen et al. 1998), first on paper and then using Nvivo (see www.qsrinternational.com), a software package supporting qualitative analysis. In both cases, individual lessons learned statements could be assigned multiple codes, to reflect the overlapping and subjective nature of the process, as well as some lessons learned statements containing multiple insights. As much as possible, the researchers let the content and wording of the lessons learned statements drive the natural development of the categories and codes. After both analyses were performed, the two sets of classified data were brought together and differences, discrepancies, patterns and similarities discussed. Table 4.5 identifies the major categories formed and provides definitions and examples in the students' own words for each.

Table 4.5   Breakdown of major lessons categories pertaining to customer and user needs

Category	Definition	Examples
Listening	The importance of listening to what people say and what they say they do.	"Ask plenty of open-ended questions of users/customers." "Listen, listen, and listen again."
Observation	The importance of observing people, as opposed to just talking to them.	"What customers say doesn't always = what they do." "During interviews, watching is just as important as listening."
Context	The importance of observing and talking to users in the context in which the product will be used.	"Direct observation is essential. Experience use in the customer environment." "Get out of the office! Viewing customers in their natural environments is key."
Perspectives	Understanding the users' perspective, resolving conflicting viewpoints, designer biases.	"Ground the conversation in on "individualization" to avoid the bias that each member envisions themselves as the end user." "Users' ideas can be very different than what you think."
Sharing within the team	Sharing user research with other group members, getting and staying on the same page, group understanding.	"Field trips are good. Going out together to get more info is better than just talking about it in a room." "The team could have done a better job compiling information."
Scope	The variety of people to talk to, different people have different needs, broad vs. narrow, size/diversity of focal group.	"There are many types of users, users are different, and you can't satisfy them all." "Make time in the planning phase to investigate the broader context for use. Don't narrow the scope too soon."

Prioritization	Competing needs, prioritizing needs, contradictory needs, trade-offs among needs, balancing needs, focusing on a need, deeper versus big picture needs.	"Locating the "base" need is very helpful; gets thinking outside the box." "Hard to get at what truly matters to users (need prioritization)."
Accuracy	Finding the "right," "real," "true," or "wrong" needs.	"Find the right customer needs." "Accurate identification and prioritization of user needs is critical."
Latent/ Implicit needs	Latent needs, those that many customers recognize as important in a final product, but cannot articulate in advance.	"Observation and past stories can give hints to latent needs." "Customer stated 'wants' might be very different from their real behavior."
Ongoing/ Iterative	Continual feedback, constant communication with users, and the iterative nature of need-finding.	"Contact with the customers should happen all the time, before, after, and during." "Need to revisit customer needs repeatedly."
Quantity	The amount of need-finding that should be done.	"Meet as many people as possible." "Learn as much about needs as possible early in the process. Time spent up front saves lots of time at the end."
Need-centric	Focusing on user needs above all else.	"Stick with user needs, not solutions." "The consumer's voice should be heard above all others."

Design coach survey and interview

Data from the design coaches was in the form of both written answers to the survey questions and transcripts of the interviews. As the number of coaches was significantly smaller than the number of students, no quantitative conclusions could be drawn. Qualitatively, however, the coaches' prioritization appeared to mirror that of the students and provided an outside validation of the students' self-assessments. The coaches' comments,

however, were more nuanced and sophisticated, perhaps reflecting the form of input. Here are some representative answers to the questions concerning what they see the students learning that is of most value to industry practice:

> "Negotiating a wide range of views – different people looking at the same set of information can come to different analyses – they have to work through this as a group."

> "The initial ideation is easy when there's nothing at stake. But that second round of ideation, when people have different perspectives – that to me is the other real world learning. Working out who their team is and how to get it to work. That's huge."

> "I think the most important thing is to clearly perform market research and market segmentation before tackling any design challenge. User research is also something that is lacking from most industries that I've worked in."

> "User needs identification: Stressing use of observation - and story telling using visuals will enhance the students' work, innovation and communication skills."

> "Communication skills are at the heart of presenting ideas to team members, clients, end-users, etc., which is at the heart of the user-centered design process (getting ALL stakeholder inputs). Identifying user needs are again a heart of user-centered design. These skills will be at the heart of designer/analyst professional expertise."

Discussion

The discussion is organized around two major findings. First, while only 8% of the total lecture time is devoted to working in teams, team-related lessons learned account for fully 35% of the total lessons learned. The design coaches also highlight team-related learning as critical. Second, of the process-related lessons learned, 14% concerned Customer and User Needs, which was at least twice the frequency of mention of any other process-related category.

Team lessons

It is not surprising that the breakdown of lessons learned does not match the breakdown of lecture time in the class. Learning about working in multidisciplinary teams is best done by actually working in multidisciplinary teams. And although little lecture time was spent on teams and team dynamics the teaching team did conduct a mid-semester team review in which students were asked to evaluate their team's performance and provide individual reviews of their peers on the team. Let's examine some of the specific things that the students learned.

Of the team-related categories of lessons learned summarized in Table 4.3, the items in the top two categories – Roles, Responsibilities and Skills (22% of the lessons learned) and Team Diversity (20%) – are highly related to working on a *multidisciplinary* team. Clearly, a multidisciplinary team experience provides valuable lessons that a uni-disciplinary experience does not. A number of students cite this as a primary reason to take the class in the first place. For many, this is the first multidisciplinary project team experience they have had. While many students work on group projects in other classes, few are multidisciplinary, and even fewer require the students to conduct their work and make decisions as a team to the degree that new product development projects do.

Many of the lessons learned refer to the challenges and benefits of working with significantly different disciplines, citing the different motivations, thinking and communication styles of different disciplines as the primary challenges: *"It's great to have people who are good at different things;"* *"People with different backgrounds sometimes speak different languages;"* *"Variety of background helps with division of labor, but leads to more misperceptions and greater tensions."*

The harmony, difficulties, synergy and dysfunction that arise from working in teams impact the students' experiences throughout the entire product development process. Often, making their team work is the biggest challenge the students encounter, which may lead to the emphasis on team-related lessons learned.

Communication was strongly represented in both the student lessons (e.g., *"The way each person communicates his thoughts has to do with his background,"* and *"Don't assume everyone agrees just because they don't speak up"*) and the design coaches' comments, often as a solution to dealing with the diversity of the multidisciplinary team. Team members in this class not only have to learn to communicate across disciplinary bounds, but must deal with the challenges of not being co-located. The California College of the Arts campus is located in San Francisco, while the other students are all in Berkeley. Even the small distance between the cities creates a significant challenge for the students in scheduling time together and forbids the chance meetings that might happen were they in the same vicinity. The students also commented on the different choices for communications technology – e-mail, phone, instant messaging – that are chosen and the difficulties in choosing a common mechanism. These issues are not much different than those experienced in industry. See, for example, Allen's (2007) work describing the effects of distance on communications.

Leadership, a common focus for entrepreneurship and innovation programs, is the least represented of the team-related lessons learned categories, accounting for just 2% of the total

lessons learned. Leadership tends to show up more in comments about roles and responsibilities, as the students allow the leadership role on their teams to rotate (e.g., *"In the absence of an assigned/imposed leader, every team member has in one way or other assumed a leadership role,"* and *"Successful teams don't always have a clear leader or hierarchy."*), though this is by no means always the case (e.g. *"Assign roles and project leader. No rotation of roles!"*).

The design teams often split the leadership role into a product champion role and a project management role, acknowledging that the roles might best be played by different people. The project champion is often, although not always, the person who proposed the project. The project management role is focused on keeping the team on schedule, making sure that deliverables are complete, etc. There is some fear among the students of taking on explicit leadership roles that might be perceived as hierarchical in some way, as they are working with their peers. Thus, they tend to use conversation, influence and consensus-building to reach decisions rather than allow one individual to drive them. Not all teams are successful with this approach; some receive facilitative leadership from their coaches at crucial points in the process. Our design coaches told us that this is reflective of a more general trend in industry in which product development, design or innovation teams operate more on the basis of interpersonal influence than on the basis of strict hierarchical control. Leadership roles are often shared among team members.

Customer and user needs lessons

Tables 4.2 and 4.4 show that the greatest proportion of NPD process-related lessons learned was in the area of Customer and User Needs. Several factors may contribute to this result. Perhaps the user needs category is a broader "bucket" than others, thereby encompassing a wider range of experiences and thus lessons learned. Perhaps students were biased to include those lessons, as the overriding philosophy of the course was customer-driven as opposed to technology-driven design, and the class placed significant emphasis on the

product definition phases of the process. On the other hand, 15% of lecture time was spent on Customer and User Needs, which tracks with the lessons learned in this category representing 14% of all lessons learned. Examination of the data, however, suggests that this was a category of lessons that were learned by making mistakes (e.g., *"Analysis of customer responses and inference of potential product from these needs is time consuming and should be done by the entire team!"* and *"Spend more time developing your user survey/questions. You might have only ONE chance."*) or lessons that stood out as particularly positive or useful (e.g., *"Watching people is fun as well as informative; you find out some things you overlooked."*). In other words, the lessons learned were experience-based – positive and negative, and not something they could have learned from the lectures.

While no causal connections can be made from the post-hoc data analysis, there are sound reasons to suggest that the high number of lessons learned relating to user needs reflects both the importance of that phase within the NPD process and its impact on students' experiences. First, as I discuss further below, effective need-finding requires skills not traditionally associated with the disciplines of engineering, business, and information systems management. Effective need-finding requires designers to empathize with their users (Leonard and Rayport 1997), drawing on their listening, observation and understanding skills as well as their intuition. Need-finding is a "fuzzy," non-linear, and inexact process, unlike the more analytical, linear processes often taught within these disciplines. Other phases of the NPD process that draw on more traditional skills may provide students with fewer salient learning experiences.

Second, requiring students to test their products with real users reveals to them the importance of effectively performing the need-finding stage. When a technically proficient design does not please users in the prototyping and testing phases, students may relate this failure to a gap in their understanding of user needs. It is possible, as a result of these experiences, that students associated lessons learned through the prototyping and testing

phase with identifying customer and user needs, thus in some ways falsely inflating that category relative to the prototyping and testing category. This may help explain why Prototyping and Testing, while 16% of lecture time, only accounted for 5% of lessons learned. The emphasis on customer and user needs is reflected in the feedback from the design coaches as well.

I also analyzed the interrelationships between the subcategories within Customer and User Needs. The interrelationships suggest three interesting aspects of understanding customer and user needs for these student teams: the adoption of new skills, the need for framing and reframing based on user needs and the difficult task of managing and analyzing needs once collected. I discuss each topic below.

New skills

There were many interrelated lessons learned relating to the skills required to do need-finding, particularly in the subcategories of Listening, Observation and Context (Table 4.5). Some students learned about the importance of effective observation skills (e.g., *"Observation is key for identifying user needs."*), others about the need for listening skills (*"Listen intently to consumers. Their needs should drive every step regardless of the developer's original intent."*), and yet others about the need to observe in the context of a product's use (e.g *"Direct observation is essential. Experience use in the customer environment."*) As the examples show, many of these lessons overlapped. Current design researchers and practitioners also emphasize the importance of these skills in uncovering users' latent needs: *"Today, the message is to observe customers working in context to find out what those customers need, not just what they say they need"* (Patnaik 2004). The inter-relatedness of these subcategories indicates both their importance to an effective product development experience and how new these skills are to many students taking the course.

Frames, perspectives and sharing

Together with the subcategories relating to new skills, the subcategories of Perspectives and Sharing raised issues of framing the situation and negotiating frames within the teams. As discussed in Chapter 02, framing is how designers and users structure their experience, deciding what are and are not the important elements of a situation, the boundaries of a situation and the criteria for success. Many lessons learned related to the importance of relinquishing the frames and viewpoints that students originally held and replacing them with the user's perspective (e.g., *"Customer needs can surprise you and change everything; Understanding issues, step into the shoes of your customer."*). Related lessons pertained to biases that product developers themselves bring to user research, often obscuring the user's perspective (e.g., *"Customer research may be biased by [the researcher's] hidden agenda."*). In this and similar cases, the frames that the developers themselves bring to the situation, may consciously or sub-consciously lead to hidden agendas or biased data collection.

Students identified the resulting importance of developing shared frames as a team. They learned the importance of conversation to create shared understanding (e.g., *"Before surveying customers the team should survey itself to ensure a consistent understanding of responses; Analysis of customer responses and inference of potential product[s] from these needs is time consuming and should be done by the entire team!"*). And, they learned of techniques such as personas and grounding insights in real user data to assist in the negotiation of different frames within the design team (Hey, Joyce, and Beckman 2007) (e.g., *"Being in touch with the end user helps keep things in perspective - Make sure words are always attached to a face."*).

Identifying and managing needs

Finally, students recognized that figuring out what to do with the customer and user needs once they have been captured is non-trivial. These lessons learned show up in the highly interrelated subcategories of Accuracy, Scope, Latent Needs and Prioritization (Table 4.5),

with many lessons fitting into two of the subcategories. Students emphasized the importance of finding the 'right' user needs, or those that resonated most with the users (e.g., *"It's important to get true customer needs and do a good job early on so that you pick the right direction in the end."*). However, there was also a tension between finding and prioritizing the 'right' user needs to address and limiting the scope of users from which to draw insights. Several lessons learned emphasized the notion that *"Initial customer needs assessment has to be broad with input of several sources,"* while others favored a narrower scope: *"There are many types of users, users are different and you can't satisfy them all,"* or *"You can't please everyone."* Though students found it valuable to study a diverse range of users, interactions and scenarios, there was also a feeling of being 'bogged down' in the amount and variety of data that resulted, often revealing conflicting needs. In short, they found that managing divergence and convergence is a difficult task.

Understanding, managing and prioritizing needs once they were identified also seemed problematic. There was an emphasis on the importance of identifying latent, hidden or implicit needs (e.g., *"Locating the 'base' need is very helpful; gets thinking outside the box;" "Ask why – find out what's behind customers certain behavior;" "We are not only designing a new physical product, but a part of people's life;" "Users' latent needs are hard to define but it's extremely useful."*) However, deciding where to focus appeared difficult partly due to the different 'levels' of user needs (e.g., *"Many times customer needs are all over the map, making it difficult to judge which needs to focus on;" "User needs/wants are often contradictory;" "Hard to get at what truly matters to users (need prioritization)."*).

Together, the lessons learned in these four subcategories typify what is hard about framing the design situation around user needs and what is so important about doing it well. It is not easy to identify hidden needs that a customer cannot articulate themselves; designers must learn effective observation, listening, and empathy skills. Once needs are identified, it is then difficult to manage and prioritize these needs for the range of users studied. Perhaps the

most important underlying lesson the students learned is the highly iterative nature of the need-finding and product development processes. To effectively identify, analyze and prioritize needs, the students had to revisit conversations and other forms of customer needs multiple times. The design coaches also highlight the importance of iteration in getting at core customer and user needs.

Limitations

While I find these conclusions compelling, I also recognize the study relies upon self-reported data from the students. In contrast to other research methodologies, such as a written assessment of learning or direct observational data, our use of self-reported data introduces some uncertainty in our conclusions. Students may be biased towards recalling only certain types of lessons learned. When asked, they may be more likely to recall those things that stood out as unusual or unexpected, or had an associated emotional charge, thereby excluding more mundane, but equally important learning. They may not appreciate the importance of some lessons until they have had experience working on a professional NPD team. Or, according to the recency effect (e.g. Deese and Kaufman 1957), they may place disproportional weight on recent events when making their evaluations.

Academic or peer pressure may also introduce bias in student responses. Students may, for example, identify what they perceived they should be learning, or what they thought would make a suitable or interesting lesson to share with others. There could be a tendency for students to focus on what they thought the instructors wished to hear, and not on what was actually most salient to them. This bias was minimized by making the lessons learned exercise both anonymous and ungraded and by encouraging sharing among peers rather than with the instructors.

Takeaways

I presented an analysis of over 2,300 lessons learned from over 350 students collected from six years of a multidisciplinary new product development class and comments from the design coaches that support that class. It was found that team-related lessons learned are nearly as significant for the students as the lessons learned associated with the NPD process. Clearly, team and process development complement each other, yet many of the textbooks on new product development, such as the one used in this class, focus almost exclusively on the NPD process with little discussion on what makes an effective team. In fact, it is not unusual for design textbooks and design classes to have virtually no formal content on teamwork. Yet, team issues are hard to learn, as our data from both the students and design coaches suggest, and are clearly critical to NPD success.

These results also suggest, perhaps not surprisingly, that some things are best taught through experience rather than through formal lectures. Team dynamics is one of those topics. Only two lectures, or 8% of the total lecture time in the course, were spent on team-related topics, yet 35% of the lessons the students learned were on these topics. Of course, I might argue that more lecture time be devoted to team-related topics given that they are so important to the students. There is no doubt that there are other tools and techniques that might be formally taught to help the students in their teamwork. As for many schools, we are left with the question of how and where team-related topics should be taught. To what extent should a class focused on the new product development process teach teamwork? To what extent can students learn teamwork in a unidisciplinary class (e.g., within the business or the engineering school) or in a lecture-based class? Given the importance of teamwork in industry, and the fact that the students emphasize learning about team skills, this is a question with which many institutions must grapple.

A general theme emerging from the process-related lessons learned is that need-finding is neither formulaic nor entirely methodological. Instead, need-finding is better represented by Schön's metaphor of a reflective conversation (Schön 1983) and Horst Rittel's view of design as an argumentative process (Rittel 1984). Direct, spontaneous interactions with users, within design teams and around prototypes make these early stages of design appear as a form of improvisation (see for example, Weick 1993). The 'back and forth' between developers and users, and within the teams themselves, was clearly evident as the teams negotiated need-finding and iterated toward final prototypes. In addition, there was also the realization that the designer's own viewpoint and expertise remain valuable within the user-centered design process, as eloquently voiced in this lesson from a student:

> "While asking the customer what they want sounds so simple and logical, someone still needs to interpret. Even following the best process around, if there is not insight/empathy/ intuition – it's all for naught."

Deeper analysis of these lessons learned identified the importance of new skills for product developers in empathizing with users, including observation, listening and the importance of context. I suggest that greater emphasis be given to the teaching and practice of such skills, traditionally associated with the social sciences and qualitative research. Further, the lessons pointed to the importance of practicing and applying these skills within the context of the design process, for although the instructors of the class cover the basics during class lectures, application still provided many learning experiences. Tools like interviews, observations, and real-world interactions rarely follow predictable scripts; there are simply too many variables and possible outcomes to sufficiently prepare students in the classroom alone. It may be that if part of the benefit of working in multidisciplinary teams is learning from teammates, then incorporating team members with these skills, such as anthropologists and other social scientists, may prove beneficial to teamwork and overall team performance.

Finally, analysis of the lessons learned indicates a need for guidance while understanding, analyzing and prioritizing customer and user needs. While it is clear that teams must engage in a messy and iterative process of gathering and interpreting needs, teams would also benefit from assistance with the framing and re-framing of customer needs. As the class employed both a well respected NPD textbook and current readings this need it is evident that effective coverage is lacking.

The "lessons learned" exercise allowed a better understanding of what the students are learning, and how the class might be fine-tuned in future years. I believe the students also gain from being required to reflect on what they have learned and by sharing their lessons with one another, particularly in cross-team groups. I thus advocate this pedagogical tool for multidisciplinary NPD classes. The reflection and sharing of lessons among class members appears to be a useful learning experience, as well as a valuable window for instructors into students' real design experience.

New Product Development lessons in industry: a longitudinal study

While this analysis was performed from lessons collected at the end of a recent NPD project how can we be sure if different issues are not relevant once the same students are performing NPD in industry? Are these issues specific to an educational setting or do these issues also apply to NPD in industry?

To address questions like these, a longitudinal study was performed by following up with alumni of the UC Berkeley NPD class (Cobb et al. 2008 – working paper). [14] I will briefly describe the approach to this study and some selected results to inform our understanding of the applicability of the original lessons learned study more broadly.

---

[14] The study and analysis was performed with collaborators Corie Cobb and Melissa Lock, building from an initial set of NPD alumni interviews (Cobb et al. 2007)

Approach

In the study we reached out to all the alumni we could contact who had taken the class since 1996. Collecting from department alumni databases and faculty records we estimated 282 working email addresses for NPD alumni. These alumni were contacted with a survey. We received 132 responses to the survey, a response rate of 46.8%. As our interest was NPD in an industry setting 10 participants were ineligible to complete the survey as they were still in full-time education. Full numbers of study participants are in Table 4.6.

As it turns out, the most complete records of alumni contact addresses were held by the business school.[15] As a result, of the 282 alumni contacted 186 were business, 88 were from engineering disciplines and only 8 were from industrial design or information management (SIMS) (the industrial design numbers are particularly low partly as a number of these students had taken part in a previous study).

Table 4.6   Alumni study participants

	Number in class	Number contacted	Number responded	Number interviewed
MBA	412	186	82	86
Engineering	319	88	43	80
SIMS	63	6	6	72
Industrial design	90	2	1	64
Total	884	282	132	19

---

[15] It appears business schools may do a better job at keeping in contact with their alumni than do engineering or design schools. Perhaps there is a lesson to be learned there.

The survey questions covered the following topics: satisfaction with the NPD course; ranking of importance of NPD topics in their current job; how user research, concept generation, concept selection and team formation is performed in their current company; tangible takeaways and specific lessons from the class; suggestions for improving the class; the value of the project experience in the class; whether they attempted to continue their project after the class was complete and why; how the class' value compares to others they took in graduate school; contextual information about the current role, industry and job responsibilities. The full survey is included in the Appendix.

The survey also asked alumni if they were willing to participate in a follow-up interview. 30 alumni agreed to be interviewed and 19 phone interviews were conducted by the three researchers. The interviews were conducted after the initial survey analysis and therefore questions were asked that both helped further understand the aggregate survey responses and that probed further into the individual responses each alumnus gave.

I will discuss results from specific sections of the survey most relevant to the discussion of NPD learning and importance of topics in industry.

Results

The survey analysis was performed by three researchers. We performed simple compilations of numerical results but also broke down the responses to questions by industry, current job type and discipline (Engineering related, MBA or industrial design) when they took the class. Similar to the analysis of lessons learned, responses to open-ended questions were first analyzed by a single researcher and coded with an evolving set of codes. This initial sorting was then reviewed by the other two researchers and categories and codes were updated. Discrepancies and difficulties in applying codes were discussed and resolved among the research team.

Figure 4.2 shows the number of respondents contacted and responded by year the students took the class. The response rate was an average of 46% by year (σ = 12%, Max = 75% in 2005, Min = 29% in 1996).
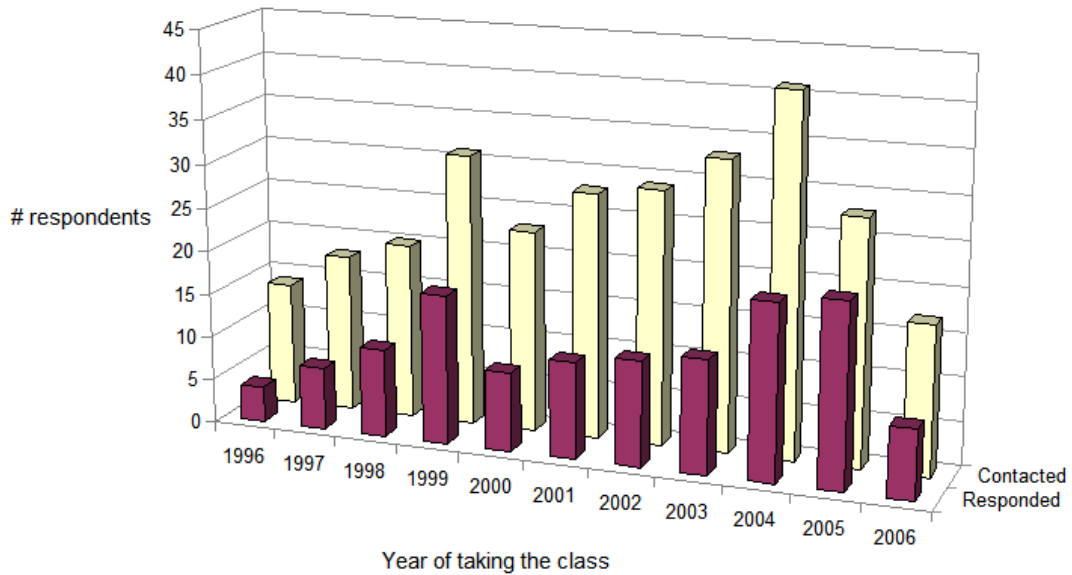
Figure 4.2   Alumni survey respondents by year

Tables 4.7 and 4.8 show the distribution of industry sectors and functional areas of alumni classified broadly by discipline (38 respondents skipped these questions). The discipline classification reflects the discipline of the alumni when they took the class i.e. MBA (business), Engineering disciplines, Information management (SIMS) or Industrial Design. The greatest number of students now work in the Computer software and IT services and in management roles. This distribution perhaps reflects a bias towards the IT sector based on the location of University of California at Berkeley near to Silicon Valley. Approximately 50% of engineering students work in an engineering or research and development role.

Table 4.7 Alumni responses by industry sector

Industry	MBA	Engineering	SIMS and industrial design	Total
Computer Software & IT Services	20	7	2	29
Biotech/Pharmaceuticals	5	3	0	8
Financial Services	6	1	0	7
Health Products and Services	5	1	0	6
Consumer Products	4	0	1	5
Electronics/Computer Hardware	2	3	0	5
Media	5	0	0	5
Automotives/Transportation/Manufacturing	2	2	0	4
Diversified Services	2	1	1	4
Real Estate	4	0	0	4
Energy	1	2	0	3
Materials and Construction	0	3	0	3
Non-Profit and Social Services	2	0	0	2
Retail and Wholesale Trade	1	0	1	2
Aerospace/Defense	1	0	0	1
Chemicals	1	0	0	1
Education/Higher Education	0	1	0	1
Government	1	0	0	1
Hospital/Healthcare	0	1	0	1
Marketing	1	0	0	1
Telecommunications	1	0	0	1
Total	64	25	5	94

In particular, it is worth considering the responses to the question:

Please rate the importance of each of the following in your current job (5 Very important – Very unimportant 1): Setting Project Goals (e.g., using a Mission Statement or Project Charter); Working in Multidisciplinary Teams; Meetings and Scheduling; Project Management; User Needs Identification; Concept Generation; Concept Selection; Prototyping and Testing; Design for Assembly/Manufacture/Environment; Costing and Financial Analysis

Table 4.8   Functional areas of NPD alumni

Functional Area	MBA	Engineering	SIMS and industrial design	Total
Management	40	7	2	49
Engineering	1	8	0	9
Consulting/Business Strategy	7	1	0	8
Marketing	6	1	0	7
Finance/Accounting/Investment	4	1	0	5
Product Design	2	1	2	5
Research and Development	0	5	0	5
Sales	3	0	0	3
Information Technology	0	0	1	1
Manufacturing	0	1	0	1
Other	1	0	0	1
Total	64	25	6	94

The topics in this question were chosen to allow comparison to the lessons learned study that evaluated directly at the end of the project experience. With the lessons learned study I

evaluated the importance of each topic inferred from the frequency of mention of lessons from each category. However, in the alumni survey we asked a more direct evaluation of importance. Because of the bias towards responses from business school alumni it is most instructive to view the importance of topics as rated by each discipline – Engineering, Business (MBA) and Information management and industrial design (SIMS). This data is shown in Figure 4.3 with the topics ordered according to importance from the lessons learned study.
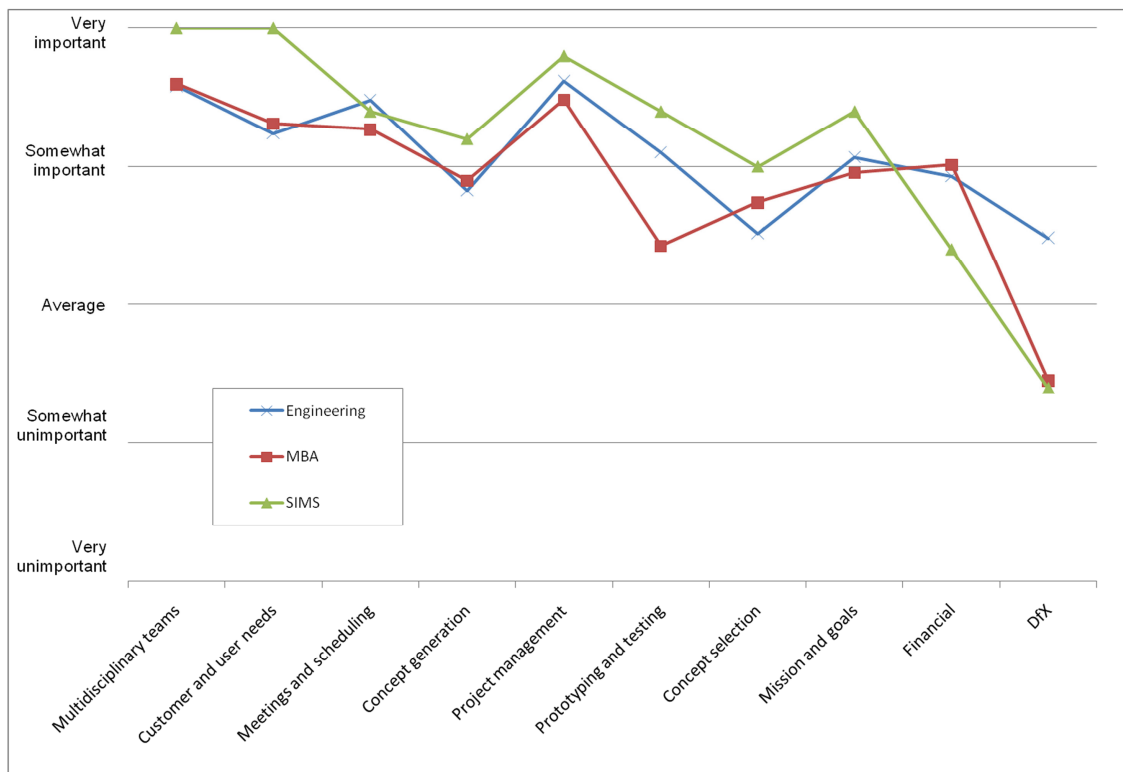
Figure 4.3   Importance of NPD topics[16] by discipline

An overall slope of the lines can be seen from top-left to bottom-right implying that the general structure of importance is similar to the original study. In particular, working in multidisciplinary teams, customer and user needs and meetings and scheduling remain important, while, at the other end, design for X (e.g. design for the environment, universal

---

[16] Topic names have been abbreviated for clarity of reading

design, manufacture and such) remains the least important in current alumni work. The peak at project management for all three disciplines suggests that this becomes more important in industry than in the class setting.

The standard deviation of the responses informs us which topics are viewed commonly across disciplines and which are more discipline specific. The discipline specific topics ($\sigma \geq 0.5$) are design for X and prototyping and testing. In particular these topics were valued less by business alumni. The most discipline independent topics, somewhat unsurprisingly, are meetings and scheduling and project management ($\sigma < 0.2$). The differences across disciplines I believe largely reflects the emphasis engineers place on design and manufacturing with higher importance given to prototyping and testing and design for X than business alumni. However, the highest rating for prototyping and testing is given by information graduates and industrial designers perhaps reflecting the importance of agile development methods in the software industry.

In general though, the alumni data suggest that working in a multidisciplinary team and dealing with customer and user needs remains important in industry although other topics, particularly management related, gain in importance.

Interviews

Interviews with the alumni provided extra richness on how their experiences in industry compared with their experience in the product development class. In particular, recurrent themes included the continued importance of working on multidisciplinary or cross-functional teams, recognizing the importance of a user-centered process but difficulty in applying it in context (in particular between large and small firms), and learning general rather than specific skills. I'll discuss each of these briefly in turn.

The majority of interviewees emphasized the continued importance of working on multidisciplinary teams. For example:

"The multidisciplinary aspect of it is absolutely critical."

"[A lot of what I do now is] thinking beyond the discrete steps – looking more holistically – really it's getting people in front of one another – recognizing we're not just a bunch of individuals."

"Working on a cross-functional team is so important. I know that today more than ever – the vast majority of my work is on a cross-functional team. In all my classes at Haas that class was the closest to reality."

"Specifically about product development, I've done many product or service development projects – I see them as very similar, it may be a web developer instead of an engineer or a graphic designer or the brand developer, and that's where you, as leader of the team, can come up and shine. You already know how the different functional people speak and think. So to me one of the key learnings was that, coming from a particular discipline I have a very skewed view of the project. But the important thing here is to learn to listen to other disciplines and learn how to incorporate everything together."

"The course was one of the first places you realize – 'Holy cow! Not everyone's like me.'"

In these excerpts we are able to appreciate the continued appreciation of an early multidisciplinary experience and its relevance in the workplace. In particular, there is an emphasis on gaining an appreciation that not everyone on your team is like or thinks like you and how a successful team can turn this into an advantage rather than a barrier.

Another theme was appreciating the value of the process, particularly with respect to performing user research. But, across the diverse areas alumni are working they often met with some resistance to the structured process from the class and the 'novelty' of direct

contact with users. As a result there were calls for learning not just how to go through the product development process but how to persuade the 'C-suite' managers of the value of its value.

> "I suppose it prepared me very well within a structured environment because it's…very distinct, very defined. Within the chaos of a startup…a lot of that structure loses some of its meaning and value."

> "At least in my case, everyone came with their own experience and background. I was trying to introduce a user-centered process. It actually seems pretty novel for when most people hear about it. They think, "Oh, you're going to talk with customers and follow them around in their house for a day. Hmm, I don't quite get that."

> "One of the key differences is when we were going through the process. Because we were all in the class we all kind of learned about different pieces of the process and we were all really invested in learning and applying the methodology. I've found that in industry it's a very 'new' process that companies/some people may not be use to using, to that effect they may latch on less to the notion of how you're going to go about the work. "

> "I think the biggest difference is that in the artifice of the course everybody's being directed to understand its value artificially because you're in a classroom environment. No one has that mandate because you don't have forced mandate. You may understand the process and value and need to go through it however those above you or your peers may not have that perception or understanding."

Another theme concerned the learning of more general rather than specific design skills. This was reflected in survey responses where more people said the class has been useful to them since leaving school yet they do not use specific lessons from the class in their day to day jobs. This may also reflect the Design for X specific skills being rated as the least important in their current work. Comments included:

> "I think it's an overarching picture that allows you to shape your mindset, but not necessarily direct skills."

> "I mean the best classes aren't classes that give you a specific tool, rather classes that tell you that OK, the world is so heterogeneous so that we're going to teach you how to think so you can apply the knowledge over multiple scenarios."

One alumnus memorably summed up the situation in this way:

> "It's like I may know this is my favorite restaurant but I can't think of anything that's on the menu"

Taken together the longitudinal NPD alumni study shows that, on the whole, similar issues remain relevant in an industry NPD setting. Dealing with customer and user needs research in a multidisciplinary team is both challenging and important. The results of the survey were also an encouraging indication that the class provides a learning experience valuable to real world NPD.

Onwards

In this chapter I set out to identify what design teams need through a study of their most salient lessons from performing New Product Development. I learned of two important challenges. First, as supported by prior design researchers, framing the project with respect

to the needs of your users – figuring out what people want – is a key challenge. Second, working in a multidisciplinary team where team members bring different interests, attitudes, values, perspectives, and ways of thinking and talking is also a challenge – coming to a shared understanding about the framing of the problem is the second challenge. I shall develop these further in Chapter 06, Design Paths. In these studies the value of developing effective multidisciplinary teamwork practices and the continuing importance of user research was validated as a concern in an industry NPD context through a longitudinal study of alumni of the NPD class.

With the need now established, in the next chapter I examine how we can identify which design activities are framing activities and the process of framing within a team during the New Product Development process – the framing cycle.

05 Finding Framing

Negotiating shared frames during early design phases

Summary

How do teams arrive at a common vision for their project? How can we identify framing in action by a design team? In this chapter I present the results of an analysis of 32 New Product Development teams. I identify the core early stage framing activities of design teams and discuss key implications for performing these activities well. The analysis led to the development of a model to understand design team framing: The Framing Cycle. I finish by explaining how the cycle plays out in design teams' activities.

Introduction

So far I have established that the twin issues of figuring out what users want and getting a team on the same page are a challenge. This has been illustrated both in past research attempting to address these issues and through the analysis of lessons learned, design coach feedback and the New Product Development (NPD) alumni survey presented in Chapter 04. Using the operational definition of framing presented in Chapter 02, we now turn to identifying where and when framing occurs in design teams and understanding the process

through which individual frames are translated into team-level understanding. [17] I first review the definition of framing and outline the details of the study before presenting the results.

Finding framing

To understand how we were able to identify and track framing activities throughout the design process it is worth reviewing the definition of framing given in Chapter 02.

> **Framing** *is the process by which people consciously or unconsciously structure a situation by selecting relevant features: what is important and what is less important. Framing provides structure from the viewpoint of an actor both highlighting and hiding different elements. Frames often include assumptions of a desired end state and of what is good or bad.*

Together with this definition I identified four key constituents of a frame:

1. A desired end state or goal

2. Relative importance and relevance of features (prioritization of designers' attentions)

3. Boundaries to the design situation (problem scope, solution scope, resource constraints)

4. Criteria for evaluation (of new information, features, and possible solution concepts)

Delineating these constituents allowed us to observe elements of a frame as they changed and understand the motivation for any changes. Differences in these four elements among team members allowed us to identify divergence between members' frames on a team.

---

[17] Research in this chapter was conducted closely with Caneel Joyce and Sara Beckman, both of the UC Berkeley, Haas School of Business. The work was originally presented in the paper Framing innovation: negotiating shared frames during early design phases, published in the Journal of Design Research (Hey, Joyce and Beckman 2007)

Data collection

Data for this study was gathered from a study of 22 NPD projects from the University of California, Berkeley graduate NPD class, and 10 projects from the MIT graduate NPD class as they executed the design process, framing and reframing over time. Projects were divided over two sections of the Berkeley NPD class and they lasted one semester.[18]

Data collection at MIT was primarily performed by a research assistant locally following a prepared data collection protocol (see Appendix for more details). In addition, myself and Caneel Joyce were present at the end of the class to perform team interviews and videotape the final presentations.

Even with this multitude of data, finding framing is challenging. Frames are cognitive, often implicit, and reside in the minds of individuals. For teams to negotiate a shared frame, an individual's frame must be shared explicitly or otherwise suggested through interactions and behaviors. Furthermore, it is possible for a team to ignore the frame of an individual member and continue its activities without that member's buy in to the project direction.

Thus, in our observations we looked for activities and interactions that (1) revealed an individual's implicit frame to others, (2) made discrepancies between individuals' frames visible or salient, or (3) engaged the team in explicitly negotiating among individual frames and constructing a shared frame. Each of these activities concerned a change in one or more of the key frame constituents: overall goals, selection of important or unimportant features, setting boundaries to the situation and selecting, though often unconsciously, evaluation criteria.

---

[18] The complete list of projects for this study can be found in the Appendix.

The multi-method perspective provides rich data for theory-development, enabling the observation of team-level framing processes while understanding fine-grained differences between individuals' frames.

To find framing activities we took a flexible approach to our data analysis. Each researcher made a careful note of key events witnessed in team observations either in meetings or class labs. We shared key quotes and stories from these observations and extracted telling phrases from the survey responses. [19] At each stage the shared team documents were used to supplement our understanding, yet the public face was closely compared to the interview responses that provided a more nuanced and detailed view of their development. Often a statement from a team interview gave the opposite impression to that given by a document. For example, the unified team face given by a team's presentation often belied the uncertainty of the late night contentious meeting that resulted in it.

Key framing activities

Our combined observations allowed us to identify five common key frame-setting activities. A frame-setting activity is one that either helped a team establish one or more of the core elements of a frame, or one which helped a team negotiate towards a shared frame. These activities are listed below with examples:

1. Writing a project proposal or problem statement

   ▪ Decomposing the situation by, for example, time, phases, location, modes, mindsets, or types of users

2. Developing a mission statement

   ▪ Product description

---

[19] More details of the data analysis themes are included in the Appendix

- Goals

- Stakeholders and selection of primary and secondary markets

- Assumptions/constraints

- Defining relevant terms and concepts within a team

3. Selection of research areas

- Which types of users to interview

- Choice of interview content – what questions to ask

- Choice of competitive products or services

- Criteria for evaluation of competitive products or services

4. Digestion and analysis of user data

- Presenting and sharing research with teammates

- Selecting categories or clusters for user needs and interview data

- Developing 2 x 2 matrices

- Developing consistent naming for needs

- What is dismissed or selected for attention

- Identifying metaphors that describe the goal or situation

5. Setting categories in ideation and brainstorming

- Clustering concepts

- Choice of prompts and problem statements to guide ideation sessions

Each of these activities and decisions were framing activities in themselves. Each has an effect on either the goals of the project, the boundaries of the project, making explicit choices

about what is relevant and what isn't, or criteria that allow the project to be evaluated. For example, a team intending to help parents enjoy meals at restaurants with their children makes a decision on the scope of the project when they identify the restaurant owners as key stakeholders. Alternatively, when a team developing better protection for bikes identifies weight as a key concern for users they are simultaneously making the implicit assumption of a product that will be carried (like a bike lock) and establishing weight as a criteria for which they can evaluate potential concepts.

Discussion of framing activities

In this section I discuss the major insights regarding how each of these activities are performed by teams. I take each activity in turn providing specific examples of design project activities. Although the themes were developed from the original study of 32 NPD teams, they have been validated through observation of an additional 47 design projects. In some cases, I have provided additional examples taken from more recent projects that better illustrate the point.

1. Project proposals: scope for flexibility

Teams starting with solution-focused proposals and strong project champions often engaged in reframing with difficulty. A team working on 'Child Floating Clothing' – a suit that would protect children in the event of falling into a pool – smoothly morphed into 'Child Swimming Pool Safety' as the team explored other solutions, such as fencing around a pool, to fulfill the need set forth in the initial proposal. However, while it was able to broaden its initial perspective, the team returned to a wearable device after exploring the wider set of options.

On the other hand, the 'Web site for Connecting Grads' project launched with a proposal to create a website to connect graduate students across the campus. With instructor pressure, team members grudgingly stepped back and broadened their scope, but only briefly:

"Is it ok to go back and say we're not doing a site? – it's what we started with."

Stepping back, particularly for the team member who proposes the project, requires students to be open to changing their initial project frame. While other members of the team may not enter the project with strong ideas about a particular solution, the person proposing the project often does. These project champions engage in reframing as a result of discussion with other team members, collection of research data or intervention by faculty or design coaches.

This finding supports Mohammed's assertion that: "Groups composed of individuals with a high commitment to their constituency position will achieve less cognitive consensus than will groups composed of individuals with a low commitment to their constituency position," (Mohammed 2001). The project champion, having often invested personal time and mental energy into the project, has a higher commitment to the initial project proposal. She brings with her a different individual frame than other group members. Teams that start with a broader initial mission based off common values, such as an environmentally conscious proposal, typically find the transition easier from a group of individuals with different perspectives to a team with a common vision. For example, one team began with the broad goal to develop a product to help reduce childhood obesity. Without any specific commitment to an initial approach early on, the team was able to learn about and frame the situation together. Higher commitment to an initial approach may lead to greater emphasis on a team developing what the designers think is important rather than what users value. Another team began with the strongly solution-focused goal of creating a treadmill that was also possible to work at – you could lose weight while you worked. The high commitment of the team member who proposed this project meant she had high resistance to change. Only in the face of data presented by the whole team and with intervention from faculty, did she become open to framing the project towards the needs of its possible users.

Starting with a need based on a product also leads teams to do 'product-focused' research rather than listening to the people and trying to understand what really matters to them, for example, asking questions about the use of a particular product rather than learning what's important to the participants. This approach closes down the range of opportunities at the outset. Product-focused research also surfaces a deeper ethical issue of choosing which target market to address. If many types of people use a device for different reasons how can a team decide who has the more pressing needs to address?

2. Mission statements: process rather than artifact

The process of creating and iterating the mission statement, rather than the artifact itself, provides greatest value to design teams. As two team members suggest, the iteration process was more beneficial than the artifact itself:

> *"To resolve a discussion we never said 'let's check the mission statement'. It was something that, after the discussion, we just kind of kept the core project goals in mind. The core concept kept us on track."*

> *"I feel I viscerally know what our mission is and don't need to refer to it, and that we all agree. But we do need to revise it."*

Discussion of the goals of the project elicits team member opinions about those goals thus helping reveal their frames. When team members take the time to discuss and select a shared goal they become open to adapting their frames, creating a common reference for both discussion and evaluation of possible project directions.

Even with a semi-formal agreement within the team, however, it was not always clear to all members what decision had been made and whether all team members fully bought in to the new frame:

"Did we agree that we're going to focus on [x]"

"Yeah"

"We're on the same page."

"What page?"

And:

"We had a really hard time deciding on an area to focus on. We had a lot of discussion and as a group we thought we had reached a decision and then one member decided that we should change the focus the next day. The rest of the group basically went along with the idea since we needed to move on."

And:

"Concept idea convergence is difficult, especially when the overall mission & goals are not well defined or fully accepted by all the team members."

"One member of the team doesn't seem to 'get it', meaning the purpose and emerging design of our product."

In these examples, some members of the teams reframed their project goals, while others had yet to do so. The differences in individual frames clearly caused confusion as to how to proceed. In some cases it was possible for teams to agree to disagree and come to a shared frame by seeing one another's perspective:

"In at least one case we had all but one person of the team agreeing on something. Although the last person did not agree, he understood where other people were coming from and we tried to understand his viewpoint. Eventually we had to settle on the majority, but he was very graceful about working with the team even though he obviously felt strongly about his idea."

107

Strong and open communication facilitated this result. In one group, for example, three members of a team were enthusiastic about the direction their project had taken, a more appropriate means for business professionals to take their own lunch to work. Yet, the proposer of the project said after the project was complete that:

> *"Although my team like the idea I will scrap it after the project is over and make it how I think it should be done."*

While you may expect this attitude to cause a dysfunctional team, in fact, the team member was very open with his opinion. This led the team to be able to move forward despite the differences in opinion. In other groups, lack of a shared frame without open communication resulted in tensions and conflicting ideas without effort to *'see where they were coming from'.*

The situations above support another of Mohammed's (2001) propositions that: "Groups whose members inquire concerning the reasons underlying others' decisions preferences, accept others' viewpoints as legitimate, and incorporate others' perspectives into their own interpretation of the issues will develop greater cognitive consensus than will groups whose members do not engage in these activities."

Mission statements that were written at the level of agreed upon user needs or shared values served as guiding visions for the teams, and required less iteration throughout the project. The 'Healthy Meals for Schools' team, for example, started with each member writing his or her own statement and found that they were remarkably similar and forged a joint statement that remained the same throughout the project. The team attributed this coherence to the mission acting as a reflection of the team's values of providing a socially responsible solution, rather than tying them to a particular solution direction or even need to address.

When the overall project vision was clear, as in this case, conflict regarding the direction of the project shifted to a lower level of abstraction (e.g., choosing categories of solutions, selecting means of achieving the team's goal). Having a strongly shared higher-level goal that coincides with team members' core values provides clear criteria to evaluate decisions and suggestions. Shared 'higher level' mission statements also resulted in, as an instructor put it, "less mission statement churn." There were fewer iterations seen in the mission statements than in past years when initial mission statements were narrower. This exemplifies the difficulty, highlighted by Stumpf and McDonnell (2002), of identifying "levels of frames." In this case the team shared the same high level frame as defined by the members' shared values, yet differed on more pragmatic aspects of the project.

Discussion of the subtle meanings and nuances of individual words or phrases in the mission statement surfaced information about individual frames. Through discussion of key words and goals, team members express their opinions and share their values revealing individual differences in understanding and interpretation. These 'defining' activities were revealed when even apparently simple terms were put up for definition:

> *"Can you define 'to be interested'?"*

> *"We have to be careful what we mean."*

> *"Our terms were so vague and so broad that we kind of forgot what they meant."*

> *"That term 'appeal' is bothering me. Is it bothering anyone else?"*

> *"Let's make sure we're all on board with the last one."*

> *"Are we focusing on protection or prevention?"*

Teams that do not take the time to ensure similar interpretations for words risk a false sense of shared frame. On the surface, they appear to have buy-in from all members, but deeper probing reveals differences in interpretation from member to member. In these cases unstated assumptions and ideas influence team member decisions and actions throughout the early stages of the project, but the reasoning behind their actions is unclear to other team members.

> *"The project focus came out of 'language learning' and it became clear that we*
> *all had different conceptions of 'language learning'."*

Discussions of the mission statement sometimes reveal members' implicit assumptions about the possible directions of their project:

> *"Usability and eco-friendliness are not necessarily in line with each other"*

In this example, one team member saw the two factors as somewhat conflicting. Statements like these both reveal the frame of the speaker and also subtly influence the frames of team members. While the statement may provoke open discussion of differing opinions, it may also lead others to adopt the speaker's frame without questioning it.

Iteration of the mission statement occurs naturally in the early phases of NPD. To some students:

> *"Sometimes it seems like the product development's driving the mission*
> *statement, rather than the other way around."*

> *"So maybe we need to revise our mission statement based on what we want to*
> *do? We need version 3.0."*

> *"We were having trouble refocusing our mission statement since some of us*
> *felt we did not have a perfect understanding of the problem. We interviewed*

more people and as we got more data, we were able to find trends and

patterns that allowed us to focus."

A student on the 'Child Swimming Pool Safety' team highlighted the conceptual difficulty of the paradox of a mission statement driving product development, in turn driving your mission statement:

"There are already a lot of good products on the market (fences, pool covers…)

that prevent children from drowning. We could choose a product that the

child has to wear but [then] it is not prevention anymore."

A student on the broadly scoped 'Improving the supermarket experience' team explained how they viewed the concurrent evolution of their mission statement with their evolving understanding of their project:

"We have been cycling through broad missions to more refined missions and

then back out again."

The cycling of broad to refined mission statements illustrates the co-evolution of problem and solution (Dorst and Cross 2001), and the nature of NPD as a wicked problem (Rittel and Webber 1973)

3. Research areas: frames drive research
The initial frames that members hold for their project strongly influence the research directions they choose. Discussion of what types of primary and secondary market research to do provides a critical forum for members to share project frames. Several teams chose research directions that coincided with their initial views and assumptions about the likely direction of the project. A member of the 'More blood donors' team – a team formed to increase the numbers of initial and returning blood donors -- explained:

"We all had in mind some kind of solution based around a needle or a chair."

111

Similarly a member of the 'Childhood Poisoning' team – addressing the issue of reducing the number of kids poisoned by ingesting toxic household substances – told us:

> *"Research moved us towards childhood poisoning risks in the home because it was a much larger issue and something that we thought we could actually improve."*

> *"We all came into the project thinking it was going to be about making locks on cupboards."*

Eventually both teams learned that their initial assumptions were incorrect – the actual process of giving blood was not what was hindering donors (it was knowing when and scheduling to come back), and physical access to cupboards was not the key issue in childhood poisoning (it was the short times that toddlers are left unattended). Another team, discussed in more depth in Chapter 06, investigated inadequate seating at airports. Yet their original focus on the travelers and the possibilities of designing bags to be the missing seats, led them to ignore until too late speaking to other key stakeholders such as flight announcers and airport managers.

Teams also made early assumptions and judgments about feasibility, even in the face of uncertain information. Seeking *"a problem we could readily address"* or *"something…we could actually improve"* reveals assumptions about what is possible and likely.

Conducting and learning from initial research is difficult when the initial frame is too broad.
A member of the 'Safer Stove' team – which sought to improve safety of household ovens for the blind, the elderly and the disabled – commented:

> *'I have realized that we have to be much more specific in defining the problem and demographic. I shied away from this at first, not wanting to miss some issue that might present itself during an ethnography that covered*

a broad scope, but I have come to understand that due to time constraints we

need to be more focused."

As team members argued about the breadth and depth of the research they should conduct, their individual frames were revealed. Some members wanted to stay open to needs from a wide range of target markets, while others were anxious to converge on a single target market. The team struggled for some time before focusing on a single user group, but was then able to make headway as they had developed different ideas of what was important from speaking to different user groups. Other teams did not engage in as much research, and thus did not learn about one another's frames:

"I think that we haven't explored things enough to really have large

disagreements."

4. Dealing with user research: keep it real

The presentation of user research itself provides clues to team members' frames as individuals distill and prioritize what they share. Team members select what they believe to be important to the rest of the team and exclude what they feel is unimportant. Team members may genuinely see only "what they were prepared to see," but information is lost in the distillation process. Other team members observing the raw data might well glean different information. Team members' individual frames may shift as they learn more about their users. They may focus on different user needs or may become sensitive to different details and nuances of behavior previously unnoticed. As they modify their frames they need to share this information with other team members.

Sometimes distillation of needs is done too fast without careful consideration of the assumptions underlying their choice. These teams, for example, immediately filtered user needs based on assumptions about the feasibility of meeting those needs:

113

> *"apart from marrying [our users], I don't know how to address that 'they don't feel settled down' [issue]"*

> *"I don't think we can expand on that in a product." "No, that's something we can't do. But we could…"*

Here team members' implicit assumptions regarding team capabilities and the possible direction of the project limited the potential solutions the team could produce. The most common implicit criteria that we observed were around feasibility. In these two examples, filtering was made explicit through brief discussion. However, more subtle and damaging errors are made by neglecting those needs that never leave the researcher's mind having been pre-filtered by their assumptions.

Sharing research information, often visually, played a key role in the satisfaction and progress of the design teams. Sharing information from user interviews, secondary research and observations can become a bottleneck. This has also been observed by Liston et al. (2000) who noted that design teams spend more time describing, sharing and evaluating the information they have collected rather than using it for rational decision-making. In the short meeting times available, it seemed nearly impossible to sufficiently share the learning of each team member with the others:

> *"We sometimes spent so much time collecting data that we had a hard time to synthesize and share the data as a team."*

> *"I feel like we have so much information, let's just put it all out there."*

Yet it is difficult, if not impossible, to convey the richness of an observation experience or a user interview with an important stakeholder to those who were not there. Greater richness in sharing by standard methods, such as discussion and sharing of notes, comes only with significant time investment. Teams that took the time to discuss their research experiences

in depth allowing room for interpretations and clarifications benefited. When research information is not adequately shared, team members' frames diverge as they incorporate the needs of different users making group decision-making more difficult. A group exploring the possibilities of mobile handheld education experienced this problem when using email to share information:

> *"We used to email stuff to each other and then tried to converge. Converging was fine for the most part but sometimes we thought we agreed but didn't…Things became apparent when we sat down together in person."*

Examples of effective information sharing included discussions based around photos of observations, visits and interviewees. Personas and user scenarios (see for example, Constantine and Lockwood 1999; Beyer and Holtzblatt 1998 102-105; Cooper 2004), when built around real people, proved a highly effective facilitator of rich sharing. Real people, supported by their actual words in quotes and photographs, bring to life what can otherwise become dry and abstract. These techniques helped several teams towards a shared perspective based upon real users.

Information sharing was enhanced by effective use of tools and space such as plenty of whitespace on whiteboards or paper to share findings visibly to the whole team. Laptop displays facilitated sharing visual information such as photos of people, places and behavior. The role of sketching in making visible conflicting frames and assumptions is well documented (Akin 1978), which our observations supported. One team member commented:

> *"I think being able to visualize what the other person is talking about is a problem we need to overcome. Talking a lot and sometimes drawing out ideas help tremendously in communication."*

Sharing user research using the exact words and behavior of interviewees helps in the development of a shared team frame. Keeping exact quotes of users and recounting research experiences as stories resulted in team members 'imposing' less of their own frames on the data. Instead, they let the users speak for themselves. Some teams explicitly chose to use quotes from their users to identify needs and others adopted the user perspective sharing and answering questions as if they were the user:

> *"They said it – that's not my opinion."*

> *"It seemed, when I talked to women, that they…"*

> *"Because she didn't want to…"*

> *"It makes Rachel feel…" "She feels…" "She doesn't like…"*

> *"He's on the extreme of independence and not letting anything stop him."*

Telling user stories also provides a compact and time-saving way of sharing needs, perceptions and experiences in a memorable way. Making user data explicit helped team members adapt their frames around shared information. Teams that had spent less time performing user research did more information sharing based on personal experience. Their sentences would often start with 'I':

> *"I think the average user's not going to want…"*

Indeed Sleeswijk et al. (2007) conducted an experiment for a new tool to share research data and evaluated its effectiveness partly through counting explicit references by designers to either their users or to their own experience. Relating information based on personal experience alone is significantly less likely to lead to the team successfully addressing the issues of real users, except in cases where the designers themselves are potential users. Relying on personal experience and information also leaves more assumptions, goals and

116

criteria left implicit and unsaid in the minds of the team members which can lead to conflict later in the process.

Teams that actively sought out real user data – in the form of interviews, observations and market research – negotiated a shared frame among team members more easily than those who relied upon their own frames and viewpoints. Some design teams allowed user research to inform and shape their projects while others used it to confirm their own frames. User data helped teams in two ways. First, it provided a concrete reference to an external source of information, forcing individuals to test their own assumptions. Second, it illuminated conflicts among individual members' frames that were otherwise hidden. By grounding the team's conversations in concrete data from an external source, ideas could be evaluated with a common frame of reference while minimizing hurt feelings. The following examples show teams relying on user data over and above their own assumptions:

> *"None of our interviews have led us to that conclusion – so we might just have to strike it."*

> *"Did that appear in our interviews anywhere?"*

> *"I want to go to more schools." "Now it's just conjecture."*

> *"It's tough to not jump to thinking of solutions and we keep reminding each other to keep it problem-based and not limit ourselves or constrain our thinking too narrowly."*

One team experienced conflict when one member, with a strong explicit direction for the project, related that her user research supported her direction. The rest of the team however, did not hear the same confirmation of needs. Without providing clear, concrete data of the user interviews performed the conflict arose as the team did not believe or trust the user research provided by this one member. As that member related to me in private, "My team is

essentially calling me a liar." This conflict required intervention and encouragement to focus on sharing real user data to overcome.

Organizing user needs is a framing activity. The teams followed several prescribed methods of understanding, categorizing and prioritizing user needs. Categorization of needs was often performed individually and then as a team; the frames of individual team members invariably resulted in different categorizations of the same needs:

> *"We already categorized our own." "Doesn't mean they're the right ones – I mean they're individual ones."*

> *"I separated mine into four groups. How should we do this as a team?"*

The categorization of the needs themselves was seen as an ambiguous and uncertain process with multiple, if not infinite, possibilities. Many teams lacked a coherent story around which to select categories. Often a process of enlightened trial and error based on personal experience and intuition resulted in the final categorization.

Naming of needs is also performed from the personal frame of each designer. Teams struggled to collect and aggregate user needs, as team members often did not understand the categorization of a need or what the abbreviated version of the need (e.g., as represented on a Post-It note) meant. Clarifying questions together with patient explanations helped develop shared understanding. In some cases a precise definition could not be found, however, discussion itself resulted in a shared understanding of the concept:

> *"Put 'mental structure'. It's a word that's familiar to our group even though we struggle to define it."*

Those in charge of the 'meeting tools' for needs collection – spreadsheet, whiteboard, flipchart – wielded power as an executive filter over others. The 'pen carrier' who wrote down the

118

needs and categories of the team often exercised liberty in naming the needs that sometimes lost the richness of the initial meaning. The process of aggregating the needs risked losing specificity – losing the core of some of the needs – that might have led to a greater depth of understanding.

5. Ideation: ideating reveals frames

At the concept generation stage team members often still held strongly different frames of how they understood the project.

> "Ideas are still coming in which greatly disrupt the consensus formed in the team."

> "…even though [the idea] might not fall under any of these [focus areas] that we decided upon…"

One team we observed conducted an entire meeting carefully discussing the user needs and user research before one member pulled out three completed concept sketches unrelated to what they had been talking about. The team member participated in the discussion, but was not open to change due to his excitement over the concepts he had developed. Allegiance to his initial frame influenced the way he interpreted new information in the meeting.

Other teams struggled to balance solutions and needs from the outset. The initial frames held by the team members contained strong enough goals, criteria and bounds that several types of solutions presented themselves automatically. These teams found themselves working backward from solutions to customer needs

> "I think it would be more useful to come up with solutions and then classify solutions [rather than needs]."

> *"In the beginning we started with solutions rather than actual customer needs and we are beginning to refine our work in terms of customer needs statements."*

> *"We kind of worked backwards from our concepts, to which needs they addressed."*

When done with attention to understanding real user needs, this reverse design process, can prove an effective way of moving the team forward.

Ideating possible solutions, and a purge of solution ideas at the outset of a project, can be a very effective way of revealing the different aspects team members see as important. In this sense, generating concepts can be a very useful activity with the explicit assumption that they do not need to be adopted but have value in making hidden frames explicit. These observations around ideation support Whelton and Ballard's assertion (Whelton and Ballard 2002), that project definition is an adaptive process that incorporates project change through the co-evolution of problem formulation and solution generation.

The framing cycle

In the previous section I presented findings about the role of framing activities throughout the early stages of the product development process including development of the initial proposal, creating and refining the mission statement, conducting user research, digesting the data collected, and creating categories of ideas for concept generation. How do these observations shed light on the process of negotiating shared frames within design teams? The collective observations and understanding of the additional roles of these common design activities allowed us to develop a model for how individual frames are shared and a common team frame is negotiated.

This model is a Framing Cycle with four phases illustrated in Figure 5.1. Let's look at each phase in turn.
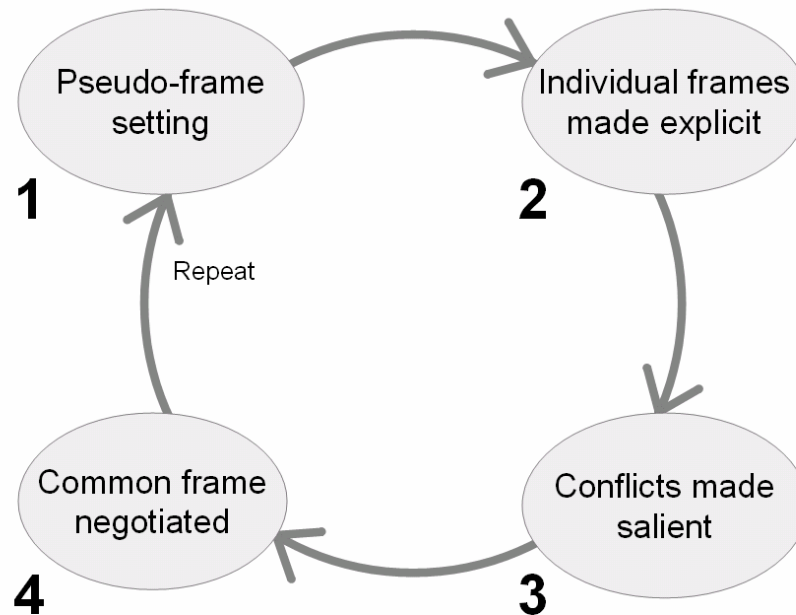
Figure 5.1   The four phases of the framing cycle

1. Pseudo-frame setting

Pseudo-frame setting is an initial understanding of the design situation, the goals, important features, boundaries and evaluation criteria. In the context of this study, pseudo-frame setting was performed based upon the initial presentation of the project proposal to the class. In industry it would be based around initial expectations of a project. The proposal sets boundaries around the problem and solution domains and, in some cases, implies strong solution directions.   Potential team members listening to the proposals bring ideas for possible directions based on their repertoire of past experience, personal opinions and assumptions. As Schön explains (Schön 1983 138),

"When a practitioner makes sense of a situation he perceives to be unique, he sees it as something already present in his repertoire. To see this [case] as that one is not to subsume the first under a familiar category or rule. It is, rather, to see the unfamiliar, unique situation as both similar to and different from the previous one, without at first being able to say similar or different with respect to what."

These pseudo-frames are often very broad, although some may assume specific needs and features relevant to real users. The presentation of an explicitly agreed-upon artifact, like a team name, proposal, or mission statement, appears to be frame setting. The use of broad, abstract language leads members to believe they are on the same page. However, the vague nature of these initial agreements can mask deep-level disagreements in goals, assumptions, values, and understandings. Individual frames are still hidden.

2. Individual frames made explicit

The process of interacting with and collecting data from users breaks down designers' preconceptions by informing their point of view and challenging their assumptions. While this notion is the primary driver of the user-centered design movement, we demonstrate that user data serves additional valuable functions.

During a team project, designers interact and make decisions about research directions, ideation emphases, and so on. In the process of making these decisions, members often discover their own implicit ideas regarding the project. The consequent sharing of expectations through team interaction makes each member's implicit frame more explicit, and thus tractable material for discussion and debate.

3. Conflicts among individual frames made salient

Multiple team activities make individual frames explicit to other team members, and thus conflicts among different frames salient, for example, building a group vocabulary through

defining terms, writing mission statements and other textual artifacts, labeling user needs and other concepts, prioritizing user needs, categorizing ideas, and dimensioning users. It is only once conflicts between individuals' frames have been made salient that the members of a team recognize their differences of opinion and common frames can begin to be negotiated. When large conflicts arise too late, such as in concept selection, a team may not have enough time to successfully negotiate a common frame leading to conflict about the eventual decision.

4. Common frame negotiated

Teams that made individual frame conflict salient used a combination of user data, discussion and listening to negotiate a shared frame. Dedication of the team to user-centered design gives the team a common anchor against which to tether constantly evolving individual frames, thus enabling the eventual arrival at a shared frame. Team members on the 'Healthy Meals for Schools' project, for example, did not hold strong frames at the onset of the project and were able to build a shared frame directly from user data without significant conflict.

Other teams did not gather sufficient user data or care enough about success in the project to find and address conflicts between individual frames. In the case of the 'In Touch in the Developing World' team, the team struggled to find potential users to interview and so never reached the stage of frame conflict. Another team disagreed about the values of the team members, which led to difficulties in negotiating a shared frame despite frame conflicts becoming apparent.

It was useful for teams to perform a full iteration of the framing cycle early in the project. The sooner the team was able to "get on the same page," as many students described it, the sooner it was able to focus on addressing the needs of its users without differences in understanding and assumptions getting in the way.

Onwards

In this chapter I highlighted the important and pervasive influence of both individual and shared frames throughout the early stages of NPD. I also identified the activities that support the negotiation of shared frames and provided real examples of effective and less-effective means of carrying out these activities. In particular, I emphasized the role that concrete user data, effectively shared, plays in the formation of a shared frame.

The paradoxical nature of user research is that teams seek out information they predict to be important before knowing what is important, and yet the information they gather in part determines what ends up becoming important. That user research serves to illuminate hidden frames helps to explain why teams experience such difficulties in narrowing their focus towards user needs. In other words performing and sharing user research plays an important role beyond its most obvious. Like brainstorming (Sutton and Hargadon 1996), user research serves not only to guide the team towards effectively addressing user needs, but also the latent function of assisting the effective negotiation of shared frames.

While the contributions of this chapter – the framing cycle, and a deeper understanding of the functions and impact of early design team activities – help more clearly understand some of the difficulties teams encounter we still lack a clear picture of a design team's journey, or path, through the design process. Through assessing their current situation and teams' most common patterns we may be better equipped to provide solid recommendations to these teams. In the next chapter, then, I introduce the notion of design paths and a framework to help understand the interplay of effective framing and the negotiation of frames within a team.

06 Design Paths

The Design Path framework

Summary

In this chapter I discuss the notion of design paths – the path a new product development team takes through the design process. In particular, I relate these design paths to the dual dimensions of whether a team is on the same page, in agreement about the framing of the situation, and whether that framing is matched to its target market's needs. Understanding a design team's path along these dimensions helps better understand successful design teams and the pitfalls teams can experience. By telling the story of three very different projects I illustrate the three most common design paths I observed and named: Back Roads; Backtrack and Direct. Finally, I present a case study with the firm Powder Net to illustrate how this framework remains applicable and relevant outside of student design settings.

Introduction

This far we have seen how important effective framing can be on a design team's experience and eventual outcome. We have further seen how, to achieve a shared goal teams follow a cycle of negotiating a shared frame throughout the early stages of the design process. Yet, as

design teams continue their research activities cycling in this way, they are also building empathy for their eventual users, framing the situation around their most important needs.

While I began this thesis seeking to understand the framing process, it is clear this process is not complete without an understanding of how the different frames of members on a design team interact. For example, a team may have strong agreement about a framing that is not based around their users. Or team members may each have strong ideas about what is important for different user groups – they may each have built empathy for users, but have little shared understanding about what the team's action should be. This situation is exacerbated by the different perspectives and ways of thinking brought by members in a cross-functional team. As design teams begin the early stages of product development each design team member brings with him or her a different understanding of the situation; they may each see different needs as important, have a different scope for the problem or varied expectations about what is possible. For example, one member of a design team beginning to develop a product to encourage recycling may see it as a question of creating a bin that helps in the process of disposal, or as developing a service to encourage more efficient collection and another member may see it as a problem of raising awareness of local recycling programs. Each of these perspectives leads the members to frame the problem differently. What ultimately matters however is to frame the problem in a way that leads to a solution users want – a framing that is based on core customer needs.

In this chapter, I introduce the notion of design paths and introduce the Design Path framework to help track a team's progress along the two dimensions of shared understanding and framing according to the needs of its target market. The chapter begins by presenting the research approach for this second study, followed by introducing the Design Path framework used as an analysis tool. From a large study of student design teams I present the three most common design paths observed together with an illustrative case for each. The final part of this chapter seeks to assess the validity of the model in an industry design

setting. To do this I present a detailed case study of a technology startup during its first six years and consider its mapping to the Design Path framework.

Research approach

This second framing study took as its base a substantially greater range of teams than led to the identification of the framing cycle. In total 57 teams were tracked in detail and interviews performed with 36 teams. The goal in each case was to understand the story of the team as the team members saw it and understand the decisions that defined its path.

Our research approach was designed to complement and build on prior work. Prior studies are based on a relatively small, though, rigorously analyzed, number of design projects. Other than several industry design team case studies, the teams typically studied in the past are uni-disciplinary rather than multidisciplinary. That is, participants were typically teams of engineers. The scenarios studied were also highly compressed design scenarios taking place over the course of a few days or a few hours. Finally, while the prior work has illuminated much about team framing and shared understanding, there is little in the way of concrete advice offered for design teams.

To support these studies then, our research approach has been based on a number of important factors. We studied a large number of design teams – over 50 projects were tracked in detail. To do this we studied graduate NPD teams that also enabled us sufficient access to data. Multidisciplinary teams were composed of engineering, business, industrial design and information systems backgrounds. Rather than a few days, projects were carried out over the course of 13 weeks. This enabled us to learn from the full context of design team activities including user research, incubation, iteration and extended team dynamics.

As discussed in Chapter 03, the design class context introduces some peculiarities relative to design projects in industry. Teams work in a more flexible, ad-hoc environment without

existing organizational infrastructure and are free to select their own team leaders or agree to have no official leader. Students also have the opportunity to select their initial project focus and the latitude to reframe their project away from the initial focus as user research dictates. Oftentimes such modification goes beyond what would be possible under industry, and brand, constraints; of flexibility in industry projects a senior human factors specialist at IDEO once related to me her frustration at having , "experience working on an uninteresting problem right next to an interesting problem and not having the power to turn the tanker..." In the design class we allow our teams to turn the tanker. Teams also benefit from the advice and guidance of a design coach and faculty. These differences are highlighted to better understand the context in which the projects operate. However, as the class and design teams are modeled after industry practice, I believe that these results also apply to industry design teams, a belief partially validated by recent longitudinal studies of graduates who have gone on to work in industry (Cobb et al. 2007). This is also addressed in the case study at the end of this chapter.

Prior approaches to measuring team framing have included survey-based approaches where individual team members respond to a series of questions developed about their task or context including the relatedness of relevant concepts. Shared understanding is inferred based on the degree of overlap of their responses (see Mohammed et al. 2000). A related technique is Concept mapping, where participants are asked to map concepts to different aspects of their task domain (e.g., Marks et al. 2002). These techniques have the advantage of providing a quantitative measure of overlap between individual mental models. However, most prior studies have involved command and control tasks in simulations where the relevant concepts and content of frames can be specified in advance (for example, by experts in the domain) and used to create the measurement instruments. We followed the advice of Badke-Schaub et al. (2007), "Given the uncertainty and dynamic nature of the creative process, it is unlikely that the content of mental models could be easily specified a priori and

supplied to participants as has been done in performance-focused team samples. Therefore, it seems more useful to elicit the content of mental models from expert designers using qualitative techniques at appropriate times during the process." In other words, as researchers, we cannot know in advance what will prove to be an effective framing of the design situation. The content and context of the frames are continually changing throughout the process as the team makes important decisions based on the results of their user research.

Consequently, to overcome the limited ability of highly structured experimental approaches (Marshall 2007) a more integrative approach was adopted tying together observations, interviews – framing in their own words – with design artifacts – the content of frames as presented. We were investigating a combination of both task and context framing – framing regarding the needs, constraints, opportunities, boundaries and target market being addressed. The qualitative observational approach allowed us to better follow the socially negotiated character of design team framing that is not a "straightforward aggregate of the individual cognitions of its members" (Marshall 2007).

This approach provides an important additional view into design team framing activities due to the research context – many, multidisciplinary, 13 week design projects – and the integrative approach to data collection (in contrast to, for example, the controlled setting and quantitative measurement approach by Bierhals et al. (2007)). This approach therefore has the potential to understand design team framing in a more holistic way than prior studies and provide insight into the effects of longer term activities such as gathering and digesting user research.

The intention through data collection was to grasp the ebb and flow of the team's shifting framing to better understand the forces behind the decisions. I sought to know what teams were doing and what thoughts motivated them to make those decisions. For example, if a set

of key needs was selected, how was this selection done? What was the process? How was consensus reached? On what data or arguments were the decisions based? Was everyone in agreement?

Traditional analysis of design team documents including design journals, presentation decks, concept selection documents and concept sketches provide only a partial understanding of design team activities. These information sources therefore were supplemented by team interviews. Group interviews were found to be effective at eliciting differences in opinion at different stages of the process – different team members had their own unique viewpoints within the context of the overall story and would even present different stories (McDonnell et al. 2004). Placing these stories in the open through group interviews provided additional valuable insights about team activities and understanding.

I observed that documents produced by the team represented the final decisions made and their justification as a predominantly rational process. The team members however, would often describe the process as anything but rational. Key decisions, often the result of "marathon meetings" late into the night, were frequently painful, emotional, and trying times for the team. It is not uncommon to find decisions hotly debated up until shortly before the deadlines and even then not every member of the team bought into the direction taken throughout the course of the project.

To provide the opportunity for individuals to anonymously voice their opinions about their team and team processes we also collected data from two self-assessment surveys. The surveys provided insight into individual thoughts and feelings often masked in both the documentation and the group interviews.

Data were analyzed by two researchers. Each researcher reviewed the documents a team produced including their evolution of mission statements and intermediate and final presentations. The researchers reviewed the individual survey responses in the team

evaluations. A careful analysis of interview transcripts was also performed by both researchers. Each researcher extracted relevant quotes and stories from the transcript of each team interview looking for common themes, situations and motivations for decisions. In particular the focus was on information regarding framing the situation in a way that matched their users and the shared understanding of the team. The extracts were then compared and discussed together sorting them into the following themes developed during the analysis:

- With regard to understanding the needs of the target market

  Initial framing; Surprises; Performing user research (including how it was done and how much); Different learnings; Sharing user research; choice of target market; prioritizing needs; evaluation by users.

- With regard to the team's shared understanding

  Different values; Knowledge differences; Strong agreement; Differences in perspective; Split decisions; Team conflict; Tension points; Emotion; Focusing (selecting and narrowing); Assumptions and filters; Metaphors (process and content).

- Important events

  Key decisions; Stories; Time management.

The Appendix includes an explanation of each of the above themes. During this analysis the Design Path framework, discussed in the next section, was developed as a means of understanding the different circumstances and activities of the teams.

The Design Path framework

In this section we present a framework that has helped us better understand the twists and turns of design teams. A good framework must be accurate, clarifying and actionable. This means the framework should reasonably represent the world, or selected aspects of the world, it should make things clearer, and, to be of use for a designer, it should point the way to action. We believe this framework meets these criteria through: (1) being constructed from a study of 57 design projects and interviews; (2) teasing apart the often conflated dimensions of framing and shared understanding; and, (3) by visualizing these dimensions and opening the way to interventions and awareness to help address problems.

The Design Path framework is shown in Figure 6.1.
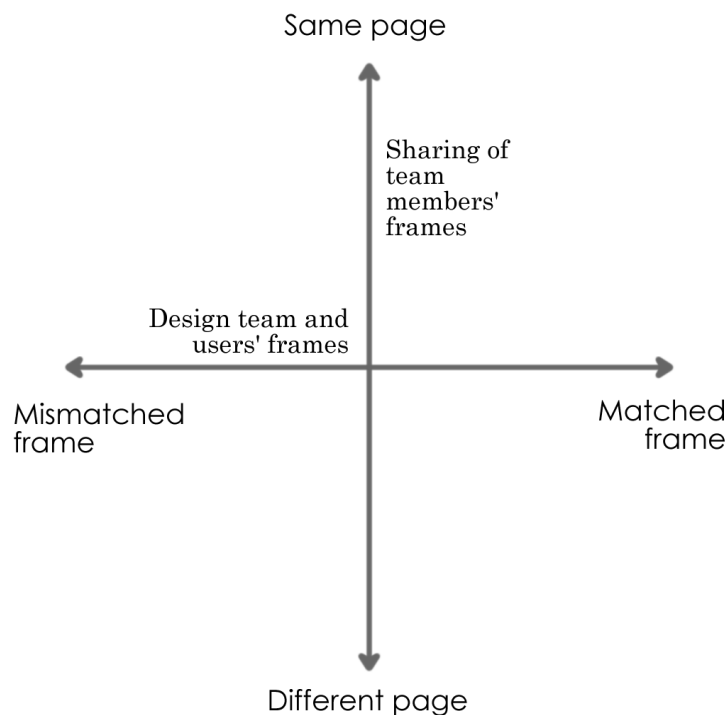
Figure 6.1   The Design Path framework

Design path dimensions

The framework is built out of two axes. The horizontal axis is the framing between the design team and its eventual users. The vertical axis is how much the team is on the same page internally, or its level of cognitive consensus. There are no strong reasons why the axes are chosen as horizontal or vertical. For clarity we will present the framework through-out in the same orientation. Let's take a look at each axis in a little more depth.

Framing between designers and users

The horizontal framing dimension is a measure of whether the designers' framing of the situation is matched with how users see the world; is the problem to be solved one that has value for users?

The selection of this horizontal axis is based on the observation that a large number of design teams alter their initial project proposal as the project progresses. This reframing may occur for several reasons: the original need is found to be impractical due to technical, business, time or expertise constraints or unimportant for the target group; or the target group itself is changed. With each reframing, a change of position along the framing axis, the team ideally moves towards a framing of the problem that better reflects what the target market really needs.

To create a successful product those needs must also be poorly met by existing products. Kim and Mauborgne (2005) give the example of Yellowtail wine's identification of an opportunity in the U.S. wine market. The U.S. wine industry had been focusing on "how to create a more sophisticated wine for special occasions." Yellowtail found an opportunity that better matched how its target customers think by reframing the challenge "to a new one: how to make a fun and easy-to-enjoy wine for every day," (Kim and Mauborgne 2005 112). The reframing allowed Yellowtail to raise its price to more than double the cost of a jug wine. In short, successful teams tend to move from the left – what the designers think is important to

make, or in the case of wine, what the established industry thought was important – to the right – what the target market actually finds valuable.

This dimension is related to the notion of the accuracy of a mental model (Badke-Schaub et al. 2007). The closer a designer's frame is matched with their target market's frame the more *accurately* it represents the users' perspectives. However, accuracy is not entirely appropriate as, in comparison to having an accurate mental model of a mechanical system, there is not one right way to conceptualize the needs of a target market. Framing depends on the target market chosen, the particular context of the project and the opportunities chosen to address. We can evaluate whether a designer has *a* matched frame with their market, but not if they have *the* matched frame. Team members may also have closely matched frames with their users, but may have different ideas as to who their ultimate target market is. Accuracy in this context also can only be evaluated through testing with users which, in the case of some projects, is sometimes only possible towards the end of the project. The design teams themselves however, often clearly revealed in interviews whether they had a matched frame with their users when they described the results of their testing activities. For example, to protect children from finding chemicals and medicines in house cabinets, one design team we studied developed a 'play station' to occupy children while their parents were busy. But when they tested it with parents they found, "The parents just didn't get it. We said it was a safety device, so they didn't understand how it could also be a toy." The team had failed to match their users' frame.

As teams move from left to right they learn more about their users building empathy for their situation (from *em* – in, and *pathos* – feeling) and an understanding of the customer need. The team begins to see the world through the eyes of the people it is designing for (e.g., Seybold 2001; Leonard and Rayport 1997). At a more fundamental level, as teams move from left to right, the designers get closer to making, as Malinowski famously put it, "the psychological transference whereby *they* becomes *we*," (Stocking 1983).

134

To better illustrate this reframing that occurs, Table 6.1 presents a number of mini-stories illustrating the initial framing of the project by the team, an insight from user research that led them to change it, and the final framing for the project.

Shared understanding

The vertical axis of the framework is a measure of a team's agreements on the framing of the situation, in words that design teams themselves use, how much they are on the same page. This axis mimics Mohammed's continuum of cognitive consensus discussed in Chapter 02 (Mohammed 2001) and sharedness as described in Badke-Schaub et al. (2007).

In practice, team members can be on a different page from each other for a number of reasons. They can be in disagreement about the target market they are designing for, about the needs they are trying to meet, and how the team should address the need. It is also common for design teams to believe they are on the same page when in fact many differences of opinion lie beneath the surface. The framing cycle implies that if these undercurrent differences are not moved into the open before the team must make critical project decisions then the resulting conflicts may seriously hinder progress.

As with the framing axis, the measure of the team's agreement can be expressed in multiple similar ways. It can be understood as a shared understanding of what the project is about, or it could be defined through a metric like that of semantic coherence (Song et al. 2003). As a team develops a shared understanding and language it also begins to develop its own team culture – an agreement on shared public meaning. Teams transition from a team of individuals pushing different perspectives to a unified, directed team. As with the framing axis, the team makes a transference whereby *I* becomes *We*, as team members and their different perspectives are acknowledged and understood. Teams themselves also use alternative metaphors to 'being on the same page' including *cohesiveness*, developing a *bond* or *gelling*, *standing together*, or *aligning*.

Table 6.1   Mini-stories of team reframing

Team name (Year)	Original framing	Research insight(s)	Final framing
Kid Net (2007)	Use the collective knowledge of parents to help create lists of web sites kids shouldn't visit.	There were many other important unmet needs not being addressed including parents feeling unsure about their kids using the Internet.	Helping parents feel confident about introducing their kids to the Internet.
Feedback (2007)	Help people lose weight by working on a treadmill by attaching a laptop to it.	The team heard little support for the original framing but did have the insight that much of the reason people don't exercise is they don't know how much they get.	Provide people with information about their daily exercise. The feedback will encourage people to exercise more. Incentivize the program through company and friend sponsorship.
Oski cycle (2007)	How can we make taking the bus less painful with less waiting, missing the bus, getting cold…	There were companies already addressing this problem with electronic systems that largely solve the problem. But lots of people traveling less than two miles took the bus who could have biked.	Encourage the mid-range commuters to bike by providing accessible bike borrowing.
SIGNALS (2007)	How can we stop motorcyclists from being hurt in road accidents? In particular, their current gear doesn't	Most of the reasons motorcyclists get hit is because cars don't see them. Raising their visibility helps them remain safe.	A system of motorcycle lights to help cars see motorcyclists more easily.

	provides little neck protection.		
Lavacleaner (2007)	The yin yang toilet: Women complain about men keeping the toilet seat up. How can we resolve this thorny problem?	The toilet seat turned out not to be much of an issue. However, people hated cleaning the toilet and it was hard to clean with the tools available.	Help people clean both the inside and outside of the toilet without having to go near the ends of the brush.
FutureBook (2006)	A device that allowed people to do their college reading on an electronic device.	eBook technology was not ready but students struggled with managing the whole system of readings and course notes, syllabi, calendars and assignments.	Provide a software package to neatly integrate all education resources in one place allowing them to be shared and built on by peers.
DriveConnect (2005)	People don't continue to give blood because they're scared of the needles.	People aren't worried so much about the needles. They often don't come back simply because they don't remember to go to the drive or know where it is.	Providing s a tangible and digital reminder to give blood that helps schedule and remind you about the next appointment.
Childhood Poisoning (2005)	How can we better protect cupboards at home from children getting into them and eating harmful substances?	Cupboard locks are effective but children are most in danger when their parents aren't supervising them during the short time after they get home.	Occupying kids in a fun and engaging way during critical unsupervised time will help keep them safe.
GiftDisc (2004)	CD packaging looks	CD packaging breaks	Create a streamlined

		because it's cheap. But current packaging doesn't satisfy when people give CDs as gifts – it's either time-consuming to make a nice CD, or quick to make an ugly one.	system to create professional, attractive gift CDs.
	ugly and always cracks, scratches and breaks		
WaterMeter (2004)	Personal water bottles get "stinky" if you use them a lot.	Though people carry water they don't have a good idea of how much they drink in a day.	Collapsible bottles make for more efficient storage and provide feedback on how much water has been drunk.

Design path cases

Design projects vary widely, from tweaking a backpack to reinventing the shopping experience. Yet teams are taught to follow the same basic process and adapt it to their situations. As a result, teams follow the same basic stages of research, needs analysis, concept generation, selection, testing and iteration but do these on very different subjects and at different times.

In determining the position and movements of the design teams, we turned primarily to the interviews, survey responses, design documents and journals. In many cases, only with retrospective knowledge of the project were we able to confidently place a team in the framework. For example, it is only after user testing that teams were able to determine if their frame was matched with their users. Following each team's story we looked for actions supported by quotes, stories and observations to determine their movements.

With blank frameworks two researchers separately plotted the path of each team as they saw it supporting each location and movement with quotes and observations. Thus each position was typically supported by two or more data points from observations, team documents, interviews, survey responses, or project journals. The paths were compared and differences in interpretations discussed. It was ensured that the data collected made the final decision. Using this method paths are not precise measurements but illustrative of the general state of the team at different stages in the design process. The transitions are the broad movements of each team.

When the different paths design teams take through the process were mapped onto the framework, three recurring situations were found which I termed: Back Roads, Backtrack and Direct. In this section, by means of a prototypical case study for each, I'll discuss these three patterns, their traits, distinctions and typical outcomes for the design teams. I highlight in each team's case a quote or observation that supports each position on the framework (The Backtrack and Direct cases each have two possible starting points shown). More details on the protocol used to assist with classifying the different paths and positioning the teams on the framework are included in the Appendix.

Case 1: Back Roads

The Back Roads design path (Figure 6.2) is usually characterized first with the team beginning on the same page but within its own frame; the team often has a strong idea of what it thinks its users want and the team members are enthusiastic behind that vision.
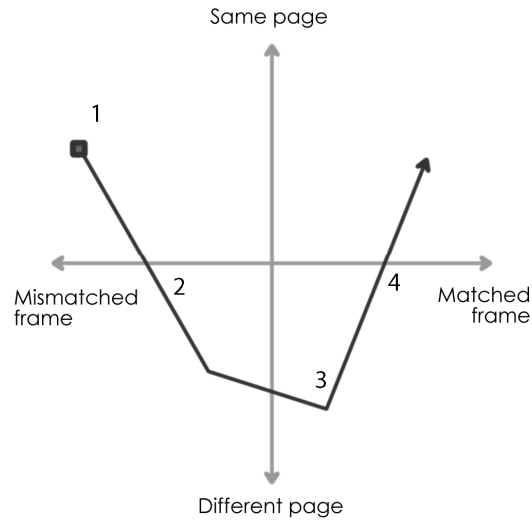
Figure 6.2   The Back Roads design path

As the teams perform user research they begin to gain a better understanding what their market wants. Yet, at the same time the team members learn different things from speaking with different potential users. The team members formulate individual opinions that differ from one another. Often, members attach themselves to the needs of the users they spoke with. The team can go through a difficult period of uncertainty as each member believes the team is confused and they struggle to integrate all they have learned. Yet, as the team takes time to share using rich methods and tools and sift through its research team members begin to understand each others' perspective and the different needs each member identified. The teams consolidate their ideas and frame the situation around one or several core needs of their users rather than the designers' original visions. They deliver, or at least attempt to deliver, a product their users really want.

Healthy Instant Noodle case

A good example of this path is the *Healthy Instant Noodle* team. The team began with a clear goal: "We were eating a lot of ramen on the road and just felt, Gosh, why isn't there a healthy instant noodle." The idea is easy to visualize and seemingly easy to implement – the team began largely on the same page: "coming into class with this very clear idea, this

140

experience that I completely related to and what I wanted in this product" (position 1– see Figure 6.2). Yet this is a product the team wants based on the team members' own experiences which they can not be sure is shared by their potential target customers. The team performed deep and effective user research to get at some of the deeper reasons and attitudes behind eating instant noodles. Team members collected a lot of data and stories causing them to relate to different needs and users reducing the initial team cohesion. The team began to feel as if it were "totally out in the middle of nowhere … so far away from instant or … so far away from noodles" (2).

After gathering and analyzing customer needs, project deadlines require the teams to present a project focus. The team first chose a framing based on a mix of what they had heard, one that highlighted the traditional and authentic noodle experience. However, their design coaches slammed them saying "you can't just bandy about the terms traditional and authentic." The team reexamined what it had heard and refocused on the common core need: "that really forced us to…reexamine, go back and do like six more prototypes and really focus, zero in on how do we get the culture, how do we get to authentic and tradition and we wanted to get at it through fresh…Food that conveys freshness and health through a traditional recipe" (3). The reframing was right for the team's users and the members could relate to it from what they had experienced and heard in their research. With this core need as a focus they developed a product, integrating fresh vegetables and a novel, transparent packaging design emphasizing freshness that their users loved (4).

Case 2: Backtrack
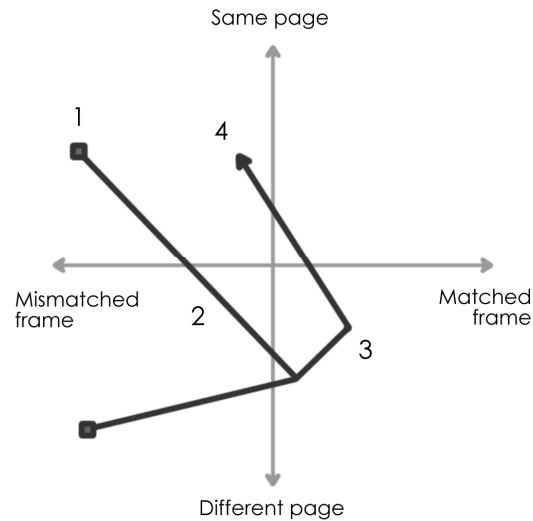
Figure 6.3   The Backtrack design path

Backtrack projects (Figure 6.3) often have a strong product vision to start and perhaps a team member who has a strong personal stake in the project. These leaders are often reluctant to let go of their initial vision, often because it is something they have envisaged for some time, or because they have already invested a great deal of their own time and energy before launching the project with the team. This situation can cause problems because, not only are the team's members unclear about what the consumer wants, they also come in with differing, and sometimes conflicting, ideas of what *they* want.

Teams in this situation often enter the project with an attitude seeking to confirm what they see as the problem, rather than learn how the users view the world. As a result, they often collect only shallow data from user research based around the initial product frame without any major insights. When seeking to confirm a need for a product you hope to build it is easier to both ask leading questions and shallower questions that do not get at users' deeper needs, for example, asking, "How would you like it if you could exercise while you work?" Rather than, "How do you feel about exercise?" When pressed by coaches or faculty to broaden their research they may take new directions and try to expand their horizons but too

142

often too late. Teams will often have learned more about their target market's real needs but not have time, or the motivation, to follow up a completely new path. Pressed by a decision point the team is trapped by its research. To make a decision the team *backtracks* to its original framing of what the consumer wants. Depending on how the team did its research this decision to backtrack can often cause conflict.

Airport seating case

The *Airport Seating* team began with the central experience of one member, a frequent flier, struggling to find a comfortable seat while waiting for a plane. He had an insight that if you could also comfortably sit on your luggage then seating would never be at a premium at airports. While the project was pitched more generally as seating at airports, this idea lay beneath the suggestion: "we were already thinking of luggage you can sit on" (1).

The team's initial research accordingly revolved around chairs and seating. Team members observed people of all ages sitting on the floors at airports, families, business people, students and more. The team was urged to dig deeper and try to understand the broader needs people have at airports and the team did this, reframing at a higher level: "[Our] mission statement changed to problems associated with waiting while you are traveling in an airport" (2).

The team used these broader needs to develop concepts ranging from renting chairs to using a pager system that radically changed how people board flights. With its broad user research across all market groups and very diverse ideas, the team struggled to select a concept or even a focus. The team struggled with the level of abstraction of the solution – a focused product such as the design of a chair, or an attempt to define a new airport experience based around the travelers rather than the airlines. Individuals sided with the users they had spoken with leading the team to lose its cohesion internally (3). As time pressure drew on they had a "marathon" meeting to make the decision as to which framing to adopt. The team was divided as each member had spoken with different people and seen different things. Yet,

143

the bulk of their research was based around seating; at this late stage it was difficult to switch focus towards needs and solutions they had less research to support. The team backtracked to the original proposal idea, the luggage chair (4). The team was largely able to unify behind this decision – in some senses it was the easy way out, sticking with something they knew – but ultimately the process was not based as much on a deep understanding of their market as the original intuition of the design team itself.

Case 3: Direct

These situations (Figure 6.4) are characterized by steady strong team cohesion throughout the process. The teams travel through the uncertainty of the design process together, learning from each other and sharing their doubts; when the team members are confused, they are confused together. Teams may begin either with a strong initial vision or with a more general need and differing expectations for the project. As the teams perform their research and learn about users they make steady progress towards a better understanding of what users need and they frame, or reframe, their situation accordingly.

Characteristics of these teams include doing their research together. When the teams perform their user research together team members share experiences with users. As they learn about their real needs more than one team member can appreciate and stand behind the needs they observed. However, doing research together can lead to missing some educational *side trips* or *back roads*. If they do not perform research together, these teams will often share their research richly with the rest of the team. They will use photos, video, stories, quotes and transcripts to communicate what they experienced in the field. This rich sharing helps the entire team to relate with the user and the perspectives of the team members. Often, these projects are explicitly designing for a target market more difficult to access or very different from the design team; for example, in these cases, the design teams are students and working professionals, but their target markets may include the elderly,

144

doctors, children and so on. The effect of the different target market is to require the team to step out and learn from its users as it begins with little prior knowledge.
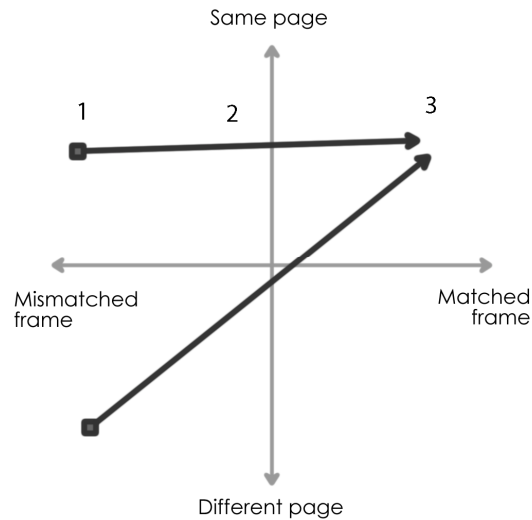
Figure 6.4   The Direct design path

CAD (Computer-Aided Design) Estimation Case

The *CAD Estimation* team came together with a strong original focus based on academic research, a tool to give designers information about manufacturing problems during the creation of CAD models. The original mission statement clearly stated the technical problem they had to solve (1). The focus also became the team's name.

The team needed access to professional practicing engineers and designers to understand what it needed. It took time to arrange meetings as access was limited. For each interview, the team took full advantage and all team members were present. The team took detailed transcripts of the interviews and took time to discuss each interview in depth including their own opinions and surprises. The team found that customers were cold to their original product idea and found itself pushing harder to find a need that was not there. One member explained: "We even tried to steer some of the initial interviews to get that result … because that was the whole reason we were doing this: To almost legitimize the initial idea." As

145

another member later put it: "[In] research you try to find a hard problem, not something that people want maybe… Cost is something [our users] can relate to a lot easier than how easy a product is to manufacture. Once we found that we stepped back and found another goal." Learning from their research the team reframed from ease of manufacture to early cost estimation.

Yet, the Direct path does not imply an easy transition. As one group member recounted about the reframing, "we all kinda' had the wind knocked out of us as a group – when we had to just change gears" (2). But it was the *team* that was knocked out rather than individuals on the team. Though they found out that their initial product was a mismatch with their target market's frame, they at least were all working from the same information. They struggled together. When the transition was complete and the team accepted they had found a frame matched with their users, the technical aspects were readily overcome because the team had a clear shared understanding of what was needed (3).

Frequency

We observed all the three design paths occurring frequently over all the design teams studied. Table 6.2 shows the frequency of each path, the average per year and the standard deviation of the frequencies over the four years of data collection. The high standard deviation of Back Roads and Direct reveals that different years of the class had slightly different patterns. I believe this may be due to factors such as whether projects have a target market different from the students and one year where projects were given a focus of social responsibility. However, I have been unable to find significant correlations for possible causes suggesting an area ripe for future research. The paths of seven teams are not included as the teams treated the project almost as a technical problem-solving challenge. These teams did not move significantly on the axes as they did not learn anything significant from their research to change their original vision.

146

Table 6.2   Frequency of design paths

	Back Roads	Backtrack	Direct
Total over 4 years	19	16	15
Average per year	4.8	4.0	3.8
Standard Deviation	2.2	0.8	2.8

Discussion

Having presented the design paths in this section I present some observations about the framework itself, including the implications of different quadrants, the different activities that move teams around the quadrants and some observations underlying the framework.

Quadrants and movements

As we see from the three design paths most design teams begin their projects on the left two quadrants – they have some idea of what they think their target market needs, but they are not sure if they are correct; it is the designer's view of what is important. What is more, members on the team may either be in agreement with the initial project mission, or they may have different ideas, and expectations of the needs of their market. This initial forming of the teams places them in either the top left or bottom left quadrants.

In the bottom right quadrant team members have learned about the needs of their target customers. Yet the experiences they have had, and the needs they see as important, differ from each other. Individually, each member has a better idea of what is needed than before, but the team as a whole may be in more confusion than at first as each member expresses, and often vigorously defends, his or her different perspective. Team members may argue for hours and never come to a shared understanding if adherents have trouble understanding

the source of members' frames. In this quadrant, as in the bottom-left, teams experience conflict about the direction of the project.

In the top-right quadrant the team has identified some true customer needs and each member has agreed upon them. The team members have a problem worth solving and all the members are committed to solving it.

It should be noted that not all quadrants are equally likely. For example, more design teams pass through the top-left quadrant than do the bottom-right.

Transitions between quadrants are prompted by specific design activities and events especially memorable for the design team. Debate and the sharing of opinions about the initial direction of the project can move teams upwards from the bottom-left to the top-left as it develops both a common language and perspective on the situation. Later in the process effective discussion and sharing of user data, and finding frameworks that provide new opportunities will help a team move upwards from the bottom-right to the top-right. Similarly, discussions over a mission statement, who should be research participants and what research questions are important will tend to move a team upwards.

In general, performing good user research will move teams to the right along the framework as they better understand the needs of their users. Performing user research as individuals however, will tend to move teams down and right as, although they learn about the users, team members learn different things, attach themselves to different needs and their individual frames diverge. In contrast, performing user research in pairs or as a team will tend to move teams up and to the right, though in gathering data there is also the possibility for added confusion.

It is also possible for teams to move from right to left on the framework as we saw in the Backtrack case. Typically, this occurs when a team disregards what they have learned from

users, becomes overwhelmed with complexity or overlooks research findings that conflict with their original vision. Most commonly this occurs when internal conflicts (frame differences that are not resolved) or time pressures result in teams taking the easy way out and returning to their original view of the situation.

Observations

There are several observations to be made regarding the framework. Prior research suggests the most successful teams will be largely on the same page at the end of the project in order for them to make a single product (e.g., Kilduff, Angelmar and Mehra 2000; Song et al. 2003; Boos 2007; Badke-Schaub et al. 2007). For example, research has shown that implementation is problematic when group members still hold different frames regarding an innovation, and more so, when they are unaware of how they differ (Sproull and Hofmeister 1986).

Prior studies have also shown that projects will be more successful when they have successfully framed the situation around real user needs (e.g. Zirger and Maidique 1990; Rothwell 1972). This observation does not hold in all contexts as many breakthrough products originally meet with strong resistance by customers and investors. The value of the radio, for example, was lost on an investor who retorted '[it] *has no imaginable commercial value. Who would pay for a message sent to no one in particular?"* (TerraMedia 2008). Yet even then, radio took many years to be adopted and recent authors have argued that the most successful breakthrough products should be "boring" (Wai and Mortensen 2007). Therefore, within the scope of the majority of design projects we can expect successful teams to end a project on the right of the framework.

It is also entirely possible for design teams to slip up by performing poor research, not generating useful concepts or simply not putting in the work to understand their market and work as a team. These cases occur more commonly in a student design team setting, and typically lead to a team that does not move significantly through the framework. It does not learn about its target users, nor does it communicate enough as a team to either uncover

149

disagreements or to settle them. Essentially, teams that do not follow the user-centered design process are more likely to finish on the left side of the framework.

Industry case study: Powder Net

This framework was built from and applies to graduate student user-centered design projects. Does the framework apply more broadly outside of this context? To test the Design Path framework in an industry context I performed an in-depth company case study with Powder Net.

In this section I discuss the story of Powder Net and how the Design Path framework also applies to the development team as it sought to choose a direction and compelling value for the company over its first five years. I begin by presenting some context for the case including how it was chosen and how data was collected. Then I present the story of Powder Net as a narrative before discussing its design path using the Design Path framework.

Context and data collection

The decision to learn about the story of Powder Net was taken nearly two thirds of the way through my research program. Powder Net is a wireless sensor network company founded by a Professor at a large West Coast University. I learned about the company after a presentation by the founder, Alan Brownell[20] about the early years of the company and its current product.

Powder Net is a compelling case to study for several reasons. As with the student NPD teams, Powder Net was still in the early stages of the company's development where it retained flexibility in choosing the direction to be taken with the product. Like the NPD teams, the founders of the company possessed a mix of prior business, engineering and NPD experience, while they are not beginners, nor are they seasoned experts. Also, although the product development was largely based on a core engineering competency the team members

---

[20] Names of participants have been changed

each have different backgrounds and expertise. Finally, the founder's post at the West Coast University meant I was more likely to be able to access important information about the early stages of the firm.

Despite these similarities to the student design team setting there are some important differences. The project is significantly longer; decisions on direction for Powder Net were made cumulatively over a period of five years in contrast to the accelerated three months available to the students. While the students had regular guidance and direction from experienced new product development faculty and design coaches, the Powder Net team relied on its own experiences and the contacts the members already had. Finally, while the team undoubtedly brought different skill sets and backgrounds to the table the primary discipline that united it was engineering; each of the team members had at least some background in engineering. This makes the Powder Net team arguably less diverse than the majority of student design teams studied.

Data were collected through three semi-structured interviews using a Criterion sampling approach (Patton 2002 243). In this case we were interested in the experiences of those with the greatest impact on the early stages of the company. To meet this criterion I interviewed the primary founders of the company, Alan Brownell, Peter Taylor and Tim Freeman, over a period of two months. Collectively, these three founders held the greatest sway in influencing the direction of the company. Interviews were conducted at their current offices. Only the initiator, Alan Brownell, still remains at the company. The interview with Tim Freeman was recorded and transcribed. Of the other two interviews, one was conducted in an environment not conducive to recording, and in the other the participant preferred not to be recorded. Quotes other than from Tim Freeman are therefore from notes taken during the interviews. While the company still exists the interviews concerned the time from the earliest days of the

151

company. The interviews then provide a retrospective account of the Powder Net story. Analysis of the interviews was conducted by me with a second researcher.[21]

With an understanding of the context of the case study I will now tell the Powder Net story as pieced together from the information provided by the founders together with data from secondary sources such as press coverage. As far as possible I have tried to tell the story in the interviewees own words.

The Powder Net story

The beginning

The vision for powder-sized wireless sensors was conceived around the mid-90s. Sensor technology could be shrunk down as small and nearly as cheap as dust. The sensors could be spread over an area and, communicating to each other wirelessly, rapidly configure their own ad hoc robust network. The network would send back accurate information from whatever sensors it had on board.

The original vision was formed with an application in mind. Dropping powder-sized sensors out of a plane on a battlefield could provide the commanders with perfect knowledge of what's happening on the ground, where tanks were driving and troops were moving. Peter Taylor explains,

> *"At first it was all about size – the original concept was these dust-sized sensors, so small they could float in the wind."*

While it was a compelling vision, the military application was also formed not least because it would be a reliable source of early funding. The proposal was accepted generating excitement and funding that launched the project. Small, cheap, ubiquitous sensors open the door to constant monitoring and diagnostics of systems as diverse as power stations or

---

vineyards. Spreading the sensors out like dust, a network could self-configure to begin transferring real time sensor readings with minimum installation and maintenance. The number and density of sensors allows the network to be robust to failures of individual sensors.

But creating tiny sensors and keeping them powered is no small challenge. Communication is a large drain on the power. To communicate the tiny sensors must regularly send and receive signals from their peers. Optical communications seemed an early promising route as they are low power. But that would take time, and one of the most difficult parts, the communication algorithms would also need to be tested. So Alan's research lab put together a small wireless radio board that would allow the team to begin prototyping the communications piece.

The original board was created by a graduate student and it evolved through several iterations. An operating system was developed by a computer science team. The board was built in a modular fashion making it great for prototyping and relatively easy to get started with. Because of the interest (and funding available) for defense applications, other research teams began working in the area and it wasn't long before requests were coming in from other researchers to buy the little radio boards. Tim explains,

> "Alan was looking at network communications and because the optical stuff
> was so much harder he set some guys to put together a little radio board that
> he could use to start testing some communication algorithms, because he
> knew that would be a hard piece. So they built this little radio board and they
> went through a few generations of this radio board...He started selling that
> vision and got a lot of excitement in the defense community which basically
> then goes out to all of the other universities because that's where they find
> their funding, and they all come up with new ideas and so he spawned this

whole movement of Professors doing research around wireless mesh communications."

"And Alan was on the technical advisory board of another company and he wanted someone to be building these boards for all these other researchers around the world. He encouraged them to do it and they started selling these little boards at a hundred bucks a pop and they pretty quickly turned that into a million or multi-million dollar a year business selling these little boards that a grad student had designed."

Forming the team

At this stage, there was research work in the area and a business selling the radio boards but Alan was regularly encouraged to start something to help make his vision of smart dust happen. He recruited a team of people he knew well, whom he could trust, and several key graduate students to continue developing the technology.

Tim Freeman became involved when Alan asked him to help out two consultants who were being paid to write a business plan for the company. Although Tim was skeptical at first, after being "burned" in a previous technology venture, the experience of selling the benefits of the technology to help compose a business plan convinced him to join the team.

Peter Taylor found Alan through his interest in transportation when he was looking for wireless technologies for a business of his own. After talking with Alan at the University he joined Powder Net as a founder. Peter is a well rounded person with a Liberal Arts background, an MBA from Berkeley and also some experience in engineering. Alan also recruited four other current Berkeley graduates whose research had been around developing the technology.

The early days

In the early days of the company, the discussion centered on finding a direction and compelling applications for the product; a task not without conflict. Peter commented,

> "The biggest problem initially was we had a really cool technology – what are we going to do with it? We had a lot of discussions of what the value boiled down to."

> "The dynamic of the company from the very beginning was very adversarial. There was a lot of yelling at each other that this won't work and this is the way to do it. Lots of violent opposition – at least between three of us - and then we'd all go and grab a beer afterwards and it would be fine."

Alan commented,

> "You couldn't imagine three more different personalities. We fought all the time. At times we didn't know what we were doing, we didn't know who we were making it for and we had no data. No wonder there were some conflicts."

The three primary founders played three very different roles. Tim was all about getting the company laser-focused. Peter commented,

> "He would say, 'We have to focus like a laser on one application.' He was also willing to bet the company on this one thing. Alan on the other hand wanted to diversify," but "part of the trouble was no one really knew what they wanted."

This diversity of applications had initially concerned Tim,

"When I asked people about what the applications were they would say, 'the applications are anywhere; you can do anything with it. Anything you want to do with it you can do.' Which to me always meant that people had no idea, hadn't thought about it enough, or couldn't find anything where the story was defensible, and so they punt and don't make a commitment around a specific application. So all this seemed a little bit fuzzy to me... I didn't necessarily buy that that idea would turn into a business."

Peter saw his role as *"kind of the balance point in the middle,"* of Alan and Tim.

In the early stages of the company, they were trying to figure out if they should bootstrap, making enough money through operations to fund continued development, or seek venture funding. Peter and Tim explained,

Peter: "We pursued a number of small government contracts, whatever we could get. The survival of the company was foremost. So we got a few hundred k here and there that kept us going."

Tim: "And we probably could have kept going on that path and succeeded, but everybody in the company wanted it to be a big commercial success – which was inconsistent with bootstrapping and doing research – to actually deliver things that would be scalable in the real world. And we didn't have a way to do that with the research programs we were being funded on."

Early in their development Powder Net had lost one of their key engineers – the graduate student whose PhD had helped develop the original technology. The parting was difficult as the company was still getting off the ground. But the company successfully secured $7M in funding from several venture capitalists allowing them to pursue their vision.

Finding their feet

The team was still trying to find the 'defensible story' and a target market that was right for their technology.

> *Peter: "In some senses we had three different visions, defense, industrial automation and transportation. I mean there was some common wisdom – it was true that this was a brilliant technology – but no one could figure out what to do with it. We agreed on most things, but it was a big, messy process.*
>
> *At the beginning we had a number of projects we started with potential clients where they would tell us what they wanted and we'd try to figure out if we could do it, but we didn't ever really deliver on them for whatever reason. There were a number of false starts. And I think that's good for the company."*

The team grappled with the dual challenge of finding a suitable market, and figuring out what the key value proposition of their technology could be. Tim explained,

> *"I don't know if the decision ever really got made it was just a sort of evolution over time and very early days it was sort of a look at all these applications we're going to support all these applications…And then eventually it evolved … think about it like we're going to support quasi-static large scale wireless networks versus totally dynamic moving around things. We're going to focus on battery operating networks, that sort of thing. So not markets specifically but technology and then it evolved … and we would actually start talking to customers in each of the markets and try to get a sense of who was interested and trying to get people interested and we would start getting … interest in certain areas and then we would elevate those things in our plan and eventually we'd end up with three different segments*

157

and we ended up breaking those segments down quite a bit more from that

and end up focusing on specific applications...Ultimately what we settled on

was industrial automation, building automation and defense and security."

The challenge of finding a suitable target market was confounded by the difficulty of deciding the level of abstraction of the product; as Alan put it, *"where in the food chain we wanted to be."* The company could choose to sell the hardware itself leaving others to write software for it; they could sell the hardware running their own software; they could be at the data management and aggregation level; or selling a whole integrated solution. With so much uncertainty in the needs of clients, and potential target markets the decision was difficult.

At the same time, despite the stated value of having tiny, powder-sized, sensors, it became clear that potential clients' concerns were not with size. Alan: *"For real applications what people needed were systems with high-reliability and a long lifetime."* While this realization was gradual it wasn't until a 2005 survey of barriers to adoption of wireless networking technologies by a business intelligence firm that they were able to point to some data that showed this. Results from the survey are shown in Figure 6.5.
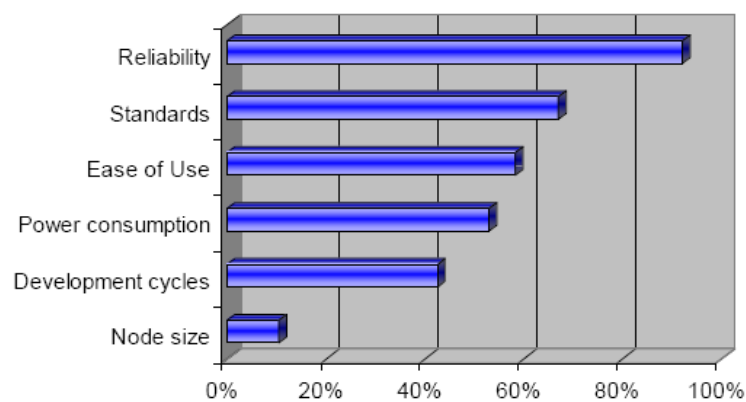
Figure 6.5 Survey of barriers to adoption for wireless networking technologies (Hatler and Chi, 2005)

158

The survey pointed to reliability, consistent standards, ease of use, low power consumption (tied to a longer lifetime), and reduced development cycles all as greater concerns than the size of the sensor nodes.

This shift from an emphasis on small took time:

> Peter: "After a while we realized that once you've got this small (sugar cube) going to this small (sugar grain) is not so important. It was gradual, we were all bought into it to different extents."

This clash was partly borne out of the differences in needs between research and real-world applications. Tim and Alan reflected,

> Tim: "I think one of the challenges is in the academic community you're in the business of getting people excited, and in the business community you're in the business of meeting expectations. And so I think there's inherently, sometimes, with revolutionary technologies like we had, it can be tough to translate one into the other."

> Alan: "people in academia can easily fool themselves into solving problems that people don't have."

The team was also developing a deep understanding of the different technological trade-offs that had to be made in a product and how that affected the value they could provide. For example, the team knew that sensor lifetime was a concern of potential clients but powering the sensors was still a bottleneck. Wireless sensors were typically powered by one of three batteries: AA; C cell; or D cell. So the lifetimes of the sensors increase in discrete sizes ~ three years, five years, or ten years. When potential clients expressed a need for the sensors to last, this also really confirmed that size wasn't a key issue. In other words, with the power

constraints of battery sizes there wasn't going to be truly powder-sized sensors as conceived in the original vision any time soon.

> Peter: "Longevity is all about size. We decided to optimize for power. Some of the early attempts tried disc batteries, but it wasn't long before people thought, if you can put a couple of AAs in there why not? It's not that much different."

But Powder Net did have a head start on long life sensors.

> Alan: "By trying to make the sensors really small we had to make them very low power. We created a number of low power firsts such as the lowest power radio. In this way, our drive to make the sensors small meant we also had an advantage in low power which affects lifetime. It was just a coincidence that what we were working on people also wanted."

Powder Net in the present

In 2004 Powder Net hired a CEO with previous networking and startup experience allowing Alan to take the CTO position. Two years later they hired a VP of Sales who, according to Tim, *"was a very strong character in the company. She got us very focused on a specific customer and that basically drove the rest of the story for the next two and a half years."*

The client, a large technology and engineering firm, believed in the technology and the team and pulled them along to the major inaugural product launch in 2008.

> Alan: "They pretty much told us what they needed, and we worked to make it happen. They didn't care about battery size and cost because they were selling a $1000 product and the battery costs just a fraction of that."

Tim saw that the value they settled on, making information about industrial and building automation available which wasn't previously accessible was a defensible story that business development could go out and sell.

> Tim: "we could talk to customers about it and it would make sense to them and we could talk about the vision, we could talk about what it means for people, we could talk about it from all different perspectives and it was a coherent thing – that was exciting. We were trying to narrow down our story to the point where it is sellable to someone and we did end up getting there."

Before the product release will happen however, both Tim and Peter left Powder Net for other ventures. Peter is working with similar technologies in the domain of transportation hoping to use Powder Net as a supplier for his application. Tim, having provided what he thought he could to the company, joined a nearby networking firm. In his words, in his current post, *"The challenge is solely to execute which is like a breath of fresh air to me because it's a heck of a lot easier to get things moving in that direction. Accelerate things along a known track than to negotiate, trying to get everybody on the same track."*

Discussion

Having learned about the story of Powder Net I now take a look at these events through the lens of the Design Path framework. With closer analysis it can be seen that Powder Net experienced many issues common to the student design teams studied. Powder Net is an instructive example of how a product development project can reframe the situation to better match a customer's needs. In this section I begin by presenting a view of how Powder Net's design path maps to the Design Path framework supported by observations from the founders. Then I focus on several of the key issues that Powder Net faced with regard to framing its offering in a way that mattered to its target market and developing a shared understanding within the design team.

The Powder Net framework

An interpretation of Powder Net's Design Path is shown in Figure 6.6.

Powder Net's path follows the Back Roads path identified in the student design teams. Its path can be understood from the comments of the three founders at the numbered positions on the diagram.
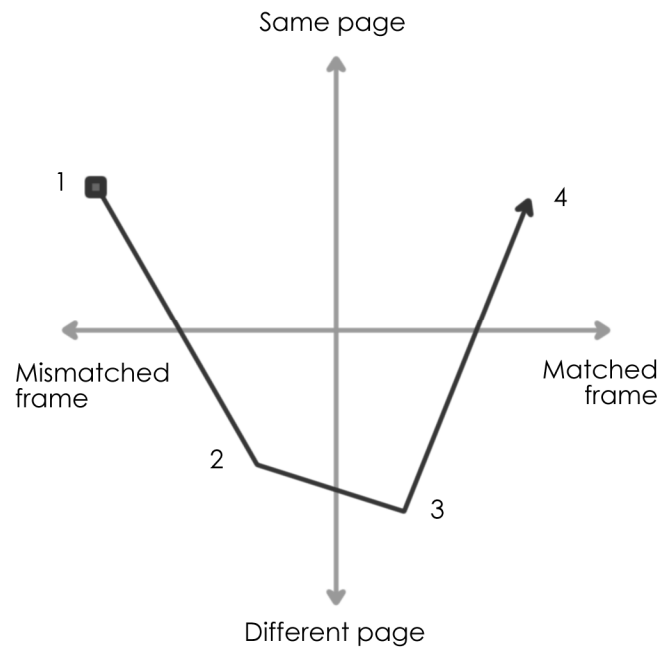
Figure 6.6   Powder Net's path mapped onto the Design Path framework

1. The company was founded based on a strong and compelling vision around a product.
   Peter: "At first it was all about size – the original concept was these dust-sized sensors, so small they could float in the wind." Tim: "These things are going to be free, and we're going to dump them out of the back of an airplane and sprinkle them across the world, and there'll be ubiquitous information. It is a really compelling vision."

2. As the team formed and discussed the value it could provide, it became clear there were different perspectives and the value wasn't so clear. Peter: *"In some senses we had three different visions, defense, industrial automation and transportation… this was a brilliant technology – but no one could figure out what to do with it."* Part of the trouble was no one really knew what they wanted."* The emphasis shifted from the original value proposition of small and cheap, Peter: *"After a while we realized that once you've got this small (sugar cube) going to this small (sugar grain) is not so important. It was gradual, we were all bought into it to different extents."*

3. The team learned more about the needs of potential markets and what was important to different clients but struggled to agree on a direction. Alan: *"You couldn't imagine three more different personalities. We fought all the time. At times we didn't know what we were doing, we didn't know who we were making it for and we had no data. No wonder there were some conflicts."*

4. The company found a client they clearly understood the needs of, leading to the product launch. Alan: *"They pretty much told us what they needed, and we worked to make it happen."* Tim: *"we could talk to customers about it and it would make sense to them and we could talk about the vision, we could talk about what it means for people, we could talk about it from all different perspectives and it was a coherent thing – that was exciting. We were trying to narrow down our story to the point where it is sellable to someone and we did end up getting there."* The new VP of Sales helped unite the company behind this customer, *"she was a very strong character in the company. She got us very focused on a specific customer and that basically drove the rest of the story."*

As the design path illustrates, Powder Net began with an initial strong vision, which faded and changed as they learned more about the needs of customers, the capabilities and benefits

of their technology. Later, with a greater understanding of the needs of their clients and possible applications the team was largely able to resolve the differences in perspective and the team got on the same page about their product.

The Powder Net story also mirrors several key framing issues experienced by the student design teams. I will discuss these in turn below.

Attachment to the initial product vision

Perhaps the defining characteristic of the Powder Net story is its birth from the original, exciting research vision of tiny, cheap, ubiquitous wireless sensors. The company's struggle to move away from this vision as the value proposition and reframe their product with their client's needs is strongly influenced by this beginning. As we learned, the shift was gradual. Tim commented,

> "What we ended up doing was driving towards really practical things where I could understand exactly how this thing was going to be used. And, in all of those cases I ended up coming to the conclusion that size wasn't the issue. But there were competing agendas in the company, naturally, in a company like that. You've got to support the vision – we wanted to get visibility, we wanted to get people excited about it, and we also wanted to develop products that meet some real world application that is going to end up being important. And, the business was basically founded around the excitement that we generated by Alan and his ideas. So it would have been impossible to just go head on and attack those ideas and expect that the only way to move forward is if we destroy those and there's shards of glass on the ground and we walk over them into the bright future. If we had done that the whole company would have been gone right. There wouldn't have been anything left".

164

In this quote Tim highlights how the commitment to the original frame was not easy to change. The team struggled to make decisions on common bases. Just as student teams who began with a committed proposer of the project struggled to move away from that original vision, the company took time to relinquish its vision and adjust to the uncertainty of learning about what its potential customers really needed.

The absence of data, in the form of observations and comments about customers, made the shift time-consuming and stressful. Data were difficult to come by and customer preferences, with the market still in flux, weren't easy to gauge. As Tim noted, *"Where should we go to make the business a bigger more successful business? And the only way to tell is, are you getting revenue or not?"* Unfortunately such a revenue stream is only available in the long term, leaving the company without a short-term yardstick to which they can measure their progress. The 2005 survey provided a useful external shared data point for the team to get behind.

Awareness of frame conflict: agree to disagree

The atmosphere at Powder Net grew from its roots in academia; team members freely expressed their opinions attempting to persuade others to their views. Tim reflected,

> *"For better or worse the culture at Powder Net that evolved was one where it was okay to continue to disagree for long periods of time. In other companies I think maybe half the people would have been fired. Stop acting that way or you're out of here. That's not the way it was at Powder. It was more respectful of opinions or ideas…If you ask people they would always say, 'Well we don't necessarily agree but we're all moving in the same direction.' But I think in reality we didn't always agree and we didn't necessarily move in the same direction."*

Although the team spent a lot of the time without high shared understanding, the open communication atmosphere meant they operated aware of their differences. Being largely aware of the different frames of the team members allowed the team to function in the state of agreeing to disagree. However, the resulting task conflict took up a lot of the startup's time. Tim: *"I'd say that there was no time when everybody was fully on the same page. I think there were always differences in the direction that people thought that we should be going. And I think that's probably true in most organizations."*

Peter also commented that *"[Alan] used to say, 'The only way to manage Tim is to yell at him.' And that was true to some extent. But it didn't change his mind."* Familiar with the concept of frames Peter also commented, *"The concept of coming to a shared frame was almost anathema to us. I mean we each had these different frames <draws four squares in the air> and there was a certain amount of overlap but getting these four frames to coalesce was nearly impossible."*

Agreeing to disagree echoes the situation discussing in Chapter 05 where strong differences of opinion, which unless made explicit often lead to a dysfunctional team, are mitigated by an atmosphere of open communication that allows the team to move forward without a shared frame.

Powerful metaphor

As we saw in the previous chapter, teams that started with a strong initial vision engaged in reframing with difficulty. For Powder Net it was the metaphor of Powder Sensors that was both their boon and bane.

On the one hand the powerful metaphor originally helped the team aggregate and comprehend all the data, vision, and ideas that were the foundation of Powder Net's product. Powder was always a great selling point, story and vision for the technology. Powder evokes small, cheap and ubiquitous.

Yet the metaphor also raised tensions that were difficult to avoid. The struggle was because of the excitement and expectation powder provided. Peter explained, *"We'd set these expectations and create the vision and then people actually see it and they're like 'Hmmm, that's pretty big. It's like a pager. That's like a dirt clod, it's not the size of a piece of powder."* The excitement and press the metaphor helped draw also made it more difficult to explain benefits other than the small size of the sensors.

Alan, like Tim, saw how the difficulty also stemmed from the different needs of academia and business, *"the easiest way to move technology from the university is to find a killer app. But if the story is different – less dramatic – it is much harder to do that."*

Tied to the company name

In another striking parallel to the difficulty experienced by student NPD teams, Powder Net struggled because of their company name. Tim commented,

> *"[It] was tough because the company was named Powder Net after all. It was very difficult to distance ourselves from the whole premise that this stuff was really small. But when it comes down to the actual product, to what customers cared about in the market it didn't have anything to do with whether or not they were small enough."*

With the company name tied to the product reframing the value is made that much more difficult.

Conclusion

In sum, the Powder Net case illustrates the greater understanding provided by the Design Path framework and a joint consideration of the framing of the design situation and shared understanding of the design team. The framework can clearly be seen to apply to this industry case.

All of these issues – a strong initial vision, a powerful metaphor, the company name – make it more difficult to adopt an open attitude of learning about the needs of your customers. Instead, the temptation is to confirm the initial product vision. While in a student design setting it may only lead to a bad grade, in industry an attitude of confirming rather than learning will lead to failure. Each of these issues were also issues that we saw student design teams grapple with: attachment to an initial product vision; different atmospheres of communication allowing productive, or unproductive conflict; a powerful metaphor as a framing tool with both benefits and disadvantages; and the seemingly innocuous tie to a team name that is made more consequential when it is a company name.

I will close with the words of Tim describing the difficulties of evaluating the design path without the benefit of hindsight and the benefit of diverse perspectives to keep challenging the NPD team,

> *To look at it realistically we never hit on a market that went through the roof which is what we were all hoping for and expecting. And so were we on the right path? Well the only way we would have said yes is if we were going through the roof. And we weren't. We're on the best path I think we found. We were always on the path that the company decided on for whatever reason. And did that path bring us into rapid growth? No. so maybe that means we're inherently not on the right path or maybe it means we're on the best path. It's hard to say but we were never sort of dumb and happy thinking we were on the right path. There was always tension and there was always disagreement. We were always trying to get onto a better path. That's the optimistic way to look at it.*

Onwards

In this chapter, I presented the notion of design paths as mapped by the dual dimensions of framing with respect to users and shared understanding of the design team. The paths of design teams in both a student and industry setting provided a greater understanding of the effect of the different early stage activities of the NPD teams and their impact on the design paths.

We also saw the power of a metaphor to frame the design situation, for good or for worse. Yet, the construct I have proposed, design paths, is also a metaphor as the teams only travel down a metaphorical rather than literal path. Through these examples we can see that metaphors cam play a role both as a framing tool and also as a means to understand the NPD process itself. In the next chapter, I shall present two studies to investigate these twin roles metaphor plays in design.

07 Metaphor and Framing

Metaphors in conceptual design, analogy and problem framing

Summary

In this chapter I consider a particular framing tool: metaphor. I consider how the metaphors we use frame our understanding of the design process itself and how that often differs from the experience of new product development teams. I found that different authors put forward different metaphors for the design process and that these metaphors affect how other core design concepts are understood. I also present an analysis of how metaphor is used in the design process compared with its sibling, analogy. The study found that metaphor use was more predominant in the early stages of the design process and analogy found greater use in the concept generation phase.

Introduction

Framing helps us make sense of a situation. In this chapter I present two studies aimed at understanding the role of an important framing tool: metaphor. Metaphor is often seen solely as the domain of artists, writers and speechmakers yet I want to illustrate in this chapter two important ways metaphor influences design and New Product Development (NPD).

Metaphor plays at least two important roles in design. First, and least appreciated of the two, metaphor plays an important role in our understanding of design itself and many of design's most important concepts. This is because metaphors excel at helping us understand unfamiliar or abstract concepts by comparing them to things with which we are more familiar, and as such are helpful in understanding and communicating about the entire process. Second, metaphor can be used as an effective design tool for framing a design situation in a new way to pave the way for novel insights and as such is valuable to a design team working on a particular solution.

In this chapter then, I will first review prior research on metaphor use in design before presenting a study of the metaphors in use in widely used design textbooks (Hey and Agogino 2007). I then discuss some of the implications of these metaphors and compare them with the actual NPD experience. I also provide a short analysis of the Design Path metaphor introduced in the previous chapter. I then present a study of metaphor use within the design process from graduate NPD projects. In particular, I compare the use of metaphor's close sister, analogy, and how they are employed differently in the design process.

Background

Metaphors have been studied and are regularly, though not always consciously, employed in several areas of design.

Software and interface design

Metaphors find their most active application in the area of user interface design because designers need to make the abstract, intangible and seemingly magical operations of computing understandable to users. Common metaphors in use, such as the Desktop Metaphor[22], file folders and windows, structure our daily experience on computers. Carroll and Kellogg (1988) provide a useful overview of metaphor use in Human Computer

---

[22] Metaphors will be referred to in this thesis in Title Case

Interaction together with examples of software applications that used metaphors to drive their interfaces. Metaphors even structure our experience on the web; for example, Maglio and Matlock (1999) showed how both novice and expert users understand the web in terms of space via the metaphor Information Space Is Physical Space. Metaphors also abound for common programming concepts: buffers; stacks; loops; and encapsulation are examples. Metaphors are common in programming precisely because of its abstract nature.

Because metaphor use is so pervasive in computing it is tempting to employ it whenever possible. However, as several authors have noted (Cooper 1995; Lawler 1999; Mohnkern 1997), while metaphors speed up our initial understanding of a new piece of software by referring to commonly understood physical actions, for example, cut and paste, they also hinder our ability to go further and use the full power of computing available to us. Cooper (1995) gives as an example, the failed suites of software that created a virtual mall to recreate the shopping experience; as one quickly finds out, traversing the distance between shops in a software program quickly becomes tedious when it is possible to head there with one click of a mouse.

Metaphors for communication

Metaphors are also commonplace within the design process as a design team works on a challenge and strives to develop a shared vision of what it is designing. Stubblefield (1998) discusses the development of a *Design for Machinability Advisor*. The software program was originally envisaged as a "spelling checker" for machinability problems. The spellchecker metaphor persisted as the design progressed, enabling both effective communication and discussion about the features of the software and between different design groups. The shared metaphor provided a common understanding of the design via a commonly understood technology – a spellchecker. As the design progressed, however, it became clear that the spellchecker metaphor was not entirely appropriate for what the team intended to do. For example, a spellchecker finds mistakes in a document, yet the team realized the

advisor was far more useful if it would also offer advice as the design was being created. The spellchecker metaphor placed a harmful emphasis on finding problems rather than preventing them. Eventually the team moved forward by employing a dual approach – using both spellchecker and advisor metaphors. Metaphors, then, also have a social context in which they operate and can both support and hinder communication and cooperation within design teams.

Metaphors are also touted as providing a strong common goal for design teams as they struggle to overcome a technical challenge or develop a new product. Nonaka (1991) illustrates how the goal of making a photo copier like a beer can – cheap to produce, lightweight and reliable – pushed the design team to develop a new type of copier with the fragile parts in the replaceable print cartridges. The Beer Can Copier metaphor provided the team with a shared goal and a common ground for communication. In 1981, Apple Computer Inc., created advertisements that employed the metaphor for a new Apple computer as a "bicycle for the mind" (Hertzfeld 1981). A bicycle multiplies the capabilities of our bodies for travel; the metaphor implies the computer would multiply the capabilities of our minds. The metaphor provides a clear goal, assists the design team in their task and communicates the benefits clearly to customers

Branding and form

Metaphors have long been recognized in industrial design and employed in the development of brands and the ultimate form of a product. For example, the new Apple iMac was designed to evoke the form of a sunflower (Quittner 2002). Lundholm (2003) provides several examples including the evocative animal qualities in the Jaguar brand, and the Black and Decker electric sander that employed the metaphor of a computer mouse, a "form that is non-threatening, fun, and a bit lovable."

Designers and marketers also evoke feeling or deeper meaning through a metaphor. For example, the Motorola Pebl phone (Motorola 2008), builds off a pebble metaphor with its

"Iconic oval-shaped design with elegant silver finish…" The pebble metaphor evokes an accessory of natural beauty with a shape, weight and texture that feels good in the hand.

Framing a problem

As I shall return to later in this chapter it has also been suggested that metaphor can play a crucial role in the framing of the design situation by a design team (Schön 1979 and 1983). Schön (1979) discusses an urban planning problem where the framing of a slum as either a 'blighted area' that needs to be cured, or as a 'natural community' that should be preserved, significantly changes the design situation itself. In another example in the same paper, Schön discusses a design team trying to improve the design of a paintbrush. At first, the team considers the paintbrush as a form of 'spreader' for the paint. A different perspective on the problem was provided by a team member who saw that the space in between the bristles of the brush held the paint and the paintbrush could also be seen as a pump for the paint. When the team reframed its problem in this way the metaphor highlighted new solution directions. Metaphor use in this way is supported by Casakin (2006) who found that architecture students found it easier to use metaphors in the early, problem framing, stages of design than later.

In another example, shown in Figure 7.1, Kimiko Ryokai, while at MIT's Media Lab, employed the World Is A Palette metaphor to reframe the digital paint bucket metaphor in a radically new direction. While a traditional artist is limited by her pallete of paints, the I/O brush created by Ryokai used electronic sensors to enable everyday physical objects in the environment to be sources of colors, textures and even movements for painting. By pointing the brush at something in the environment, the brush stores what it 'sees' ready to be the paint for a digital picture.

Figure 7.1   The I/O Brush employed the World Is A Palette metaphor (Ryokai et al. 2005)

While these are individual cases Madsen (1989 and 1994) has proposed a method for metaphorical design. He gives as example the redesign of an information system for a library. The team performed interviews with employees and users of the library and carefully dissected transcripts of the interviews. What they found was that people thought about the library in three different ways governed by three different metaphors: The Library Is A Warehouse; The Library Is A Store; and The Library Is a Meeting Place. When people spoke of the library as if it were a warehouse they emphasized the library as a repository of books and the task as simply to find the book you need. Thinking of the library as a store was similar to thinking of it as a warehouse except it emphasized the human element of having someone to assist you in finding what you need. Finally, the library was thought of purely as a place where visitors could meet each other and talk, almost like a café. With these three different ways of understanding the library the team then redesigned the information system to allow users to easily use it in each of the three modes. With this example, Madsen provides a method based on user interviews and analysis to employ metaphor in the design of information systems.

In another example of deliberate metaphor choice, McDonough and Braungart (2002) employ a number of metaphors to encourage more sustainable, or eco-effective, design. Their book, *Cradle to Cradle*, emphasizes a birth-death-birth model of products to avoid the cradle-to-grave mentality. The rebirth notion encourages elimination of waste as a recognition that

175

systems will be 'born again'. The authors also divide the world into two *metabolisms* – the biological metabolism of the cycles of nature, and the technical metabolism of the cycles of industry. Although, strictly speaking, there are no metabolisms, use of these two metabolisms as a metaphor focuses attention on both the biological components of products and how they will eventually be returned to the earth, and the technical components, and how they can be reused in future products. They also evoke a Cherry Tree metaphor for design to highlight the possibility of producing waste that nourishes. Each of these deliberately chosen metaphors helps us think of design in a new way by focusing attention on different aspects.

Metaphors for design

While, as these examples show, metaphors have been used commonly in design, few researchers have commented on the metaphors we employ for describing design itself. Design itself is an abstract topic in that we think about it in very different ways. However, to understand how metaphors can play a role in our understanding of design it is necessary to review the theory of conceptual metaphor.

Conceptual metaphor

"[The meeting originally scheduled for next Wednesday] has been put forward two days. To which day has the meeting been rescheduled?" This was the question put to participants in a study by Lera Boroditsky (2000) to determine the effects of our conceptual metaphors for time. Although not universal, much of the world holds a common metaphor for time; we conceptualize time in terms of space. This is why phrases such as, "We're getting closer to the hand-off," and "The launch date is nearly upon us," make perfect sense to us. We use a physical source domain, in this case "space", to talk about an abstract target domain, in this case "time". In Boroditsky's study, whether participants said the meeting was on Monday or Friday depended upon whether they were primed to think about moving toward an object, or pulling an object towards them. This is because we have two common perspectives on time:

an ego-moving perspective, where we are metaphorically moving through a stationary landscape of time ("We're getting closer to the hand-off"); and a time-moving perspective, where we remain stationary and events move past us ("The launch date is nearly upon us"). When primed with the ego-moving perspective participants were more likely to say the meeting was on Friday, and when primed with the time moving perspective they were more likely to reply Monday.

Metaphor use such as this is pervasive whenever we talk, or think, about abstract concepts. As Lakoff and Johnson (1980 3) argue,

> "…metaphor is pervasive in everyday life, not just in language but in thought and action. Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature."

Table 7.1 provides some examples of every day expressions (for more examples see Kövecses 2002) and the metaphors that enable us to make sense of each one. In each case the metaphor is expressed as a *Target Domain* (Time, Knowing, Importance, Difficulties…) mapped to a *Source domain* (Space, Seeing, Size, Burdens…) as in Ideas Are Objects. The mapping is shown diagrammatically in Figure 7.2.

The target domain is the domain we are trying to understand. The source domain is typically taken from our physical experience in the world, for example, we move about in space, we see, we appreciate size, we feel the weight of burdens and so on.
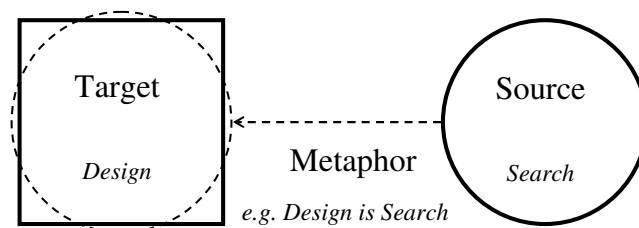
Figure 7.2   Metaphors map from a source domain to a target domain

177

Table 7.1 Everyday phrases and metaphors

Expression	Metaphor in use		
	Target domain		*Source domain*
It won't be *long* now	Time	Is	Space
I *see* what you mean	Knowing	Is	Seeing
Tomorrow is a *big* day	Important	Is	Big
She's *weighed down* by responsibilities	Difficulties	Are	Burdens
Let's give her a *lift*	Happy	Is	Up
He greeted me *warmly*	Affection	Is	Warmth
That theory has no *foundation*	Theories	Are	Buildings

A quick review of the language of design illustrates that many of design's fundamental concepts are also metaphorical, for example: we need to *narrow down on* a concept; let's *bounce* around some ideas; let's *break* the problem *down*; maybe there's another *route to* a solution; how can we *resolve* this conflict?; this is an *elegant* solution; we need to think *outside the box*; encourage *wild* ideas (Kelley and Littman 2001). Gabora (2002) also observed that many common expressions for creativity derive from expressions relating to light, for example: she had a flash of inspiration; he's a bright spark; I saw the light; we had an illuminating discussion; and of course, the ubiquitous light bulb to symbolize an idea.

Lakoff and Johnson (1999) argue that the metaphors we hold for abstract concepts provide us a richer way to understand them, allowing us to reason about them and make inferences using them. For instance, the common metaphor Time Is A Resource in effect allows us to make good use of it or even waste it. Without it time would not seem like something we could waste, and maybe we wouldn't feel guilty for that lazy morning in bed. Gentner and Gentner (1983) added weight to this hypothesis studying mental models for electricity and providing

evidence that our mental models of a domain, for example understanding electricity as flowing water or a moving crowd, affect the inferences we make in that domain. Identifying the metaphors in use to understand a domain then is the first step in understanding how we reason about that domain. As yet, this analysis has not been performed for the design process itself.

Metaphors and design paradigms

Only a small number of researchers have explicitly made the link between metaphors and our understanding of the design process. In the cases I am aware of the link is through identifying the role metaphor plays in our most broad understanding of what design is. For example, Dorst (1997) compares two dominant 'paradigms' for design. The first is driven by the metaphors Design Is Search and Design Is Problem-Solving. These metaphors originate largely from the Design Science movement championed by Herbert Simon (e.g., Simon 1969 and 1973). It is insightful to look at the example problems Simon discusses in the chapters, Thinking and Learning, and the Science of Design in *The Sciences of the Artificial* (Simon 1969): chess; word problems including the classic DONALD + GERALD = ROBERT; the magic square; the Himalayan Tea Ceremony puzzle; statics problems – for example, a ladder leaning against a wall; algebra; discovering general physics laws; given a sequence: A B M C D M E F M what comes next?; optimization problems; and the optimal location of highways. None of these problems requires designing with the explicit needs of users in mind. The second, more recent paradigm discussed by Dorst then is Schön's paradigm of reflective practice. This paradigm emphasizes the metaphors Design Is A Reflexive Conversation With The Situation, and Design Is Problem-Setting.

Before Dorst's study however, Lanzara (1983) provided a broad analysis illustrating different overall perspectives on design, giving as examples the metaphors Design Is Functional Analysis, Design Is Problem-Solving and the shift towards Design Is Problem-Setting. These metaphors were identified based on broad and holistic observations of the design process

rather than analysis. Therefore while metaphors have been actively studied for software and interface design, communication, branding and form, I believe metaphors for design itself, and its most fundamental concepts, ideas, problems and solutions, have been so far neglected. I now turn to the design of the study of metaphor use for design itself.

Study 1: metaphors in conceptual design

Approach

The most common means to learn about metaphors at work in a domain is to extract metaphors from natural language about that domain. Identifying these metaphors provides clues about our conceptual understanding of a domain. Despite this common approach I found no prior references that detailed a rigorous approach to metaphor identification from natural language. The closest is Michael Reddy's seminal paper on the Conduit Metaphor (1979) where he illustrates the process of collecting example phrases before identifying the metaphors at work. The Conduit Metaphor illustrates how the subtle, yet pervasive, metaphors Words Are Containers and Ideas Are Objects combine in our discourse about communication as when we say "It's hard to *get* that idea *across* to him," or "His words *carry* little meaning." I took a similar but more structured approach of surveying language in nine widely used English language engineering design textbooks. These textbooks were chosen based on their use by faculty in the engineering design community and to provide coverage in the United States, and Europe. The approach consisted broadly of three phases:

1. Extracting instances of metaphors from design texts

2. Categorizing metaphor instances

3. Identifying underlying metaphors

Phase 1: Extracting instances of metaphors from design texts

Table 7.2 details the textbooks that were used in this study and the number of example phrases identified in each. Note that the number of instances extracted from each are included for transparency, yet the absolute quantities do not bear significantly on the analysis as each book takes a different approach in its discussion, with some emphasizing more abstract discussion and others emphasizing more concrete examples. The linguistic nature of the domain makes quantitative analysis difficult if not misleading at times.

Design textbooks are a fruitful source of study as they hold some of the greatest potential to influence design teaching and culture. The analysis was confined to chapters that dealt primarily with conceptual design, including concept generation, for two reasons. First, these chapters generally contain the highest density of discussion of the more abstract concepts in design and are thus a richer and more concentrated source of metaphors than other chapters on the design process. Second, I am interested in how the metaphors in use affect designers' capacities for creative design including problem framing and much of the creative phase of design is generally considered in this step. While creative activity can happen just as often outside of the conceptual phase, discussion of this creative activity occurs significantly less. For example, later chapters show similar metaphors to those found in the analysis but the density of the instances within the text is much less, with more discussion of other concepts such as risk or testing. In the discussion I also draw from some widely used metaphors about design to support my conclusions.

Table 7.2   Engineering design textbooks analyzed

	Textbook title	Authors	Chapter(s)	Number of instances
1	Design Methods	Jones (1981)	Part 2: Section 3 and 4	48
2	Product Design and Development	Ulrich and Eppinger (2005)	Chapter 6: Concept generation	35
3	Total Design	Pugh (1991)	Chapter 4: Design Core: Conceptual Design	34
4	Engineering Design: A Project-based Introduction	Dym and Little (2003)	Chapter 6: Finding answers to the problem	38
5	Engineering Design Methods	Cross (2000)	Chapter 9: Generating Alternatives	14
6	The Mechanical Design Process	Ullman (1992)	Chapter 7: Concept Generation	80
7	Engineering Design: A Systematic Approach	Pahl and Beitz (1984)	Chapter 4: General Methods for Finding and Evaluating Solutions	42
8	Product Design	Otto and Wood (2001)	Chapter 10: Generating Concepts	66
9	Fundamentals of Engineering Design	Hyman (1998)	Chapter 6: Concept Generation	39
			Total:	396

To obtain a better feel for the analysis, here is an example of a metaphor instance:

"Brainstorming is meant first of all to *trigger off new* **ideas**, but it cannot be expected to *produce ready-made* **solutions** because **problems** are generally too *complex* and too *difficult* to be *solved* by *spontaneous* **ideas** alone." (Pahl and Beitz 1984 78)

In the above phrase, the design concepts of 'ideas,' 'problems' and 'solutions,' as referred to metaphorically, are in bold. The metaphorical qualifiers to each of these concepts are highlighted in italics. In the analysis, I listed all the qualifying statements for each design concept. In the example above, "Ideas" can be *triggered off*, *new*, *spontaneous* and can *solve* problems; problems can be *complex*, and *difficult*; solutions can be *produced* and *ready-made*.

Two researchers collectively identified and coded nearly four hundred unique instances of sentences or phrases concerning design or key design concepts. A protocol was developed to enable the two researchers to reliably identify the same examples over identical sources. A test coding the same chapter from a randomly selected textbook yielded 88% agreement between the instances selected. The protocol was also used successfully by other researchers in a cross-cultural metaphor study (Hey, Linsey, et al. 2007 and 2008).

Coding involved labeling each instance with the associated design concepts – the Target domain of any underlying metaphor (e.g. Ideas, Problems, Solutions). Once sufficient instances of each Target domain were identified, the researchers identified metaphors that provide coherence to each of the instances, for example, the separate instances of *"overcome the barriers between the present situation and the goal"* and *"find a way to side-step the problem"* can be made sense of through the metaphor Problems Are Obstacles.

Many design concepts are not abstract entities; they have a very real existence. So while we can refer to a Design Sketch As A Tool, the sketch itself is not abstract, it has a very real physical form. These tangible concepts, including sketches, matrices, decisions and such,

183

were not included in the analysis or coding scheme as their roles are more clearly understood than the abstract concepts of design ideas, problems, solutions and such.

Phase 2: Categorization of metaphor instances

Once the metaphor statements were collected a sorting process was begun where I first grouped instances of the same target domain, for example, collecting all the sentences that referred to 'problems'. I then listed all the qualifying statements for each Target domain in the form 'Ideas can be, refined, polished, amassed, shared, bounced around…' The tables produced as the outcome of this phase illustrate the affordances (see Gibson 1977) each design concept possesses. In this example ideas afford refining, polishing, amassing, sharing and bouncing. The affordances are what you can metaphorically do to and with the concept.

Phase 3: Identification of coherent metaphors

The next stage was to identify suitable metaphors that explained as many of the instances as possible. This phase was conducted as a series of clustering steps, in each step gathering together affordances that highlighted similar properties. For example ideas can be handed to other team members and can also be bounced off them. Both of these affordances support the metaphor Ideas Are Physical Objects.

In almost all cases each Target Domain was mapped to several different source domains depending upon the context of the statement, for example, Ideas are seen as both Food ("I need some time to *digest* what you said.") and Products ("This idea needs to be *refined*.") Several metaphors, including Ideas As Food and Ideas As Products, supported the metaphors identified previously in the literature (for example Lakoff and Johnson 1980 and Kövecses 2002). Once metaphors were identified I analyzed the implications of the use of each metaphor in design.

Results

In this section I identify the most frequent metaphorical concepts employed in the design texts and the most frequently used metaphors for each concept found.

Metaphorical concepts identified

I grouped the metaphorical concepts referred to in the design textbooks into three categories sorted by frequency of mention: Universal, Often and Occasional. Design concepts *universally* used included references to design itself and the design process, ideas, concepts, problems and solutions. Concepts seen *often* in our analysis include user needs and design tools or methods. Concepts mentioned *occasionally* include design conflicts or trade-offs, design principles, and references to creativity. All of these concepts are the Target domains for the subsequent analysis; they are the domains that we are trying to understand. The universal and often mentioned concepts, and their frequency of occurrence, are shown in Table 7.3.

Table 7.3   Common metaphorical concepts (target domains)

	Target domain	Frequency
Universal	Ideas	86
	Solutions	80
	Concepts	72
	Problems	64
	Design	57
Often	Design Tools or Methods	12
	User needs	9

Metaphor instances and mappings

I followed a process of grouping each of these affordances in the instances coded to help determine the metaphors in use for each target domain. Below I present the results of the analysis in the form of a metaphor in use, together with the affordances that led to the identification of the metaphor. I begin with the universal design concepts, Ideas, Problems and Solutions. For each affordance listed below at least one instance of it in use was extracted. In some cases such as "Ideas can be *generated*," examples were so numerous at some points they were present in almost every sentence.

Problem Metaphors

- *Problems Are Puzzles:* They can be solved and resolved.

- *Problems Are Locations:* They can be explored, be open-ended, approached, have boundaries, points of entry and we can define a problem space.

- *Problems Are Gaps:* There can be gaps in a problem space, we can require a creative leap.

- *Problems Are Objects:* They can be assembled, viewed from a different angle, divided, decomposed, be hard, big, well-structured or ill-structured, transformed, patterned, complex, broken down into sub-problems, refined, clarified, broken into parts, and stable.

- *Problems Are Formulas:* They can be formulated, underdetermined, ill-defined and require an answer.

- *Problems Are Obstacles:* They can be barriers between a present state and a goal, be side-stepped or hurdled.

Solution Metaphors

- *Solutions Are Living Entities:* They can come to you, emerge, appear and have origins.

- *Solutions Are Children:* They can be born and be embryonic.

- *Solutions Are Locations:* They can be arrived at, approached, defended, attacked, in a direction, in a space, you can find a route to them.

- *Solutions Are Objects:* They can be sought, discovered, absent, existing, overlooked, in fragments, divided into categories, integrated, found, provided by something, handed to someone, in your mind, purged from your mind, in parts, combined and manipulated.

- *Solutions Are Products:* They can be produced, ready-made, useful, generated, rough or polished.

- *Solutions Are Resources:* They can be yielded by a search space, meet a need, suggested by analogy, for a specific problem, of a problem, to a design problem, match a design problem, optimum.

Idea Metaphors

(The word 'Concepts' is used almost interchangeably with 'Ideas')

- *Ideas Are Living Entities:* They can emerge, come, cannot be forced, and they can be spontaneous.

- *Ideas Are Children:* They can be embryonic or killed.

- *Ideas Are Explosives:* They can be triggered off.

- *Ideas Are Liquid:* They can flood and flow.

- *Ideas Are Locations:* They can open new paths, lead to a solution, or be a range.

- *Ideas Are Objects:* They can hit the bull's eye, be created, judged, generated, accepted, integrated into the process, scrutinized, associated, criticized, possessed, combined, hit, bounced, sorted, found, and amassed.

- *Ideas Are Products:* They can be developed, modified, amended, changed, adapted, produced, fragile, improved, debugged, repaired, refined, useful and manifested.

- *Ideas Are Resources:* They can be a match between a problem and a solution, and exploited.

Metaphors for design

Overwhelmingly the most common metaphor identified for design derives from the Information Processing perspective of design (Simon 1969), that of Design Is Search. Consider the following example phrases taken from different textbooks:

"It will prove particularly helpful in *finding* a first solution concept as a *starting point* for further variations. It must, however, be said that this *approach* carries the danger of causing designers to stick with known solutions instead of *pursuing new paths*." (Jones 1981 74)

"Such an approach allows full *exploration* of the *design space* and reduces the chance of *oversight* in the types of solution concepts considered. It also acts as a *map* for those team members who are less experienced in design problem solving." (Ulrich and Eppinger 2005 120)

This perspective frames the process of design itself as a problem of Search. In these examples a 'design space' is laid out in which we start at some unsatisfactory location and we wish to navigate towards a satisfactory location, a solution. Several variations of the design space metaphor were identified including Design Is Exploration, Design Is Selection (among paths in the design space) and Design Progress Is Reduction of the Search Space.

Other metaphors for design were also seemingly able to coexist with the Design Is Search metaphor. These included Design Is Decomposition and Design Is Problem-Solving. The Design Is Decomposition metaphor takes a more physical view of the design situation where a problem can be decomposed into sub-problems or functions for which solutions can be found

and a final solution can be synthesized from these 'solution fragments.' The Design Is Problem-Solving metaphor, by contrast, is typically associated with a view of Problems Are Puzzles or Formulas for which a solution can be inside, be the key to unlock it, or be an answer. I also note that other authors (Koberg and Bagnall 1981), not in this study, have proposed Design Is A Journey with the Designer Is A Traveller.

Design was also universally seen As A Process. The process typically contains steps, stage-gates and iterates in a cycle.

Discussion

This discussion is organized around four themes: different views of design, a hierarchical model of design metaphor, universal metaphors and specific implications.

Different views of design

I found that different authors emphasize different approaches to framing the design process. These different views are reflected in the metaphors they use for design and the design process itself. Textbooks adopting more systematic approaches to engineering design typically employ both the Design Is Search and Design Is Decomposition metaphors with different emphases on each. I stress once again that the Design Is Search metaphor was pervasive in almost all sources analyzed.

The pervasiveness of the Search Metaphor for engineering design is an interesting contrast to the more people-centered approaches as put forward by researchers such as Bucciarelli, Rittel and Schön. Both Bucciarelli and Rittel choose metaphors that emphasize the social aspects of designing using "Design Is fundamentally A Social Process" (Bucciarelli 1988 and 1994) and Design Is An Argumentative Process (Rittel 1984) respectively. Schön employs the metaphor of Design Is A Reflective Conversation, or Design Is Problem-Setting (Schön 1983), which emphasizes the two-way and developing nature of designing. Still others have

suggested alternative metaphors such as The Design Process Is A Story to emphasize a use of narrative in interaction design (Broden et al. 2004).

I suggest that the Design Is Search and Design Is Decomposition perspectives are most suited to designing where problems are 'well-defined', where a solution space can be 'mapped out.' In contrast, the people-centered design movement in product development operates in a situation that is more difficult to map out. Here designers are encouraged to "understand the situation from the user's perspective." Companies such as IDEO expand their knowledge by repeated prototyping to learn about the situation. The Design Is Problem-Solving metaphor is less appropriate when the problem itself cannot be agreed on or is understood differently by users and designers. When Problems Are seen as Puzzles it reinforces a 'once-and-for-all' nature of a solution which is rarely the case in product development (though this can be the case in engineering design) – each solution in turn creates new problems or possibilities. The multidisciplinary nature of product development teams also reinforces the appropriateness of Bucciarelli's and Rittel's perspectives.

The Design Is Search metaphor also presupposes that a solution exists out there if you look hard enough. The more people-centered approaches encourage a more iterative approach as the team *constructs* a shared understanding of the problem and potential appropriate solutions. Indeed, some resistance to the classic Design Is Search perspective is illustrated by the now cliché imperative to 'Think outside the box,' where 'the box' is the standard design space others are searching in.

The design metaphors presented by different authors may also be an expression of different periods and design cultures. New perspectives on design are accompanied by a shift in the metaphors in use for design and some of its fundamental concepts. The shifts from Design Is Search, which emphasizes the functional aspects of a design situation, to the later

perspectives of, for example, Design Is A Social Process, which emphasizes the social nature of the designers themselves, is a good example of such a shift.

A hierarchical model of design metaphor

Different views of design are accompanied by different emphases of metaphors for the core design concepts. While most authors referred to the core concepts such as ideas and problems in multiple ways, largely as many chapters included a survey of different techniques and approaches to concept generation, each consistently referred to the concepts using some metaphors in preference to others. The choice of overall design metaphor appears to strongly affect the subsequent choice of metaphors for the core design concepts of problems, ideas and solutions.

For example, a view of Design Is Search was accompanied by greater use of the metaphors Problems, Ideas and Solutions Are Locations. Alternatively, Problems may be Obstacles or Gaps blocking the path between Need and Solution. Also common in the Design Is Search metaphor is that Problems, Ideas and Solutions Are Objects, as objects occupy a location in a space. The metaphors of Problems, Ideas and Solutions Are Objects is more often seen, however, together with a view of Design Is Decomposition. As objects they are easily decomposable and reconstructed. Examples of the two metaphor hierarchies of Design Is Search and Design is Decomposition are shown in Figure 7.3. When Design is viewed as Exploration, Design Methods Are Maps, Guides, Signposts or a Compass. When Design is viewed as Problem Solving, Problems Are more often seen as Puzzles to be solved; rather than searching in the wrong area, it becomes possible to solve the wrong problem.

In this way, our understanding of design is hierarchical and is reflected in the metaphors we use. At the highest level is our view of design itself. Beneath that, our understanding of design's core concepts changes according to the design metaphor currently in use.

As we shall see in the second study in this chapter, this use of metaphor in our understanding of design contrasts with the use of analogy in design which is used primarily as a design tool, in particular during the concept generation phase by making a connection with an existing product or system (Hey, Linsey, et al. 2007 and 2008).
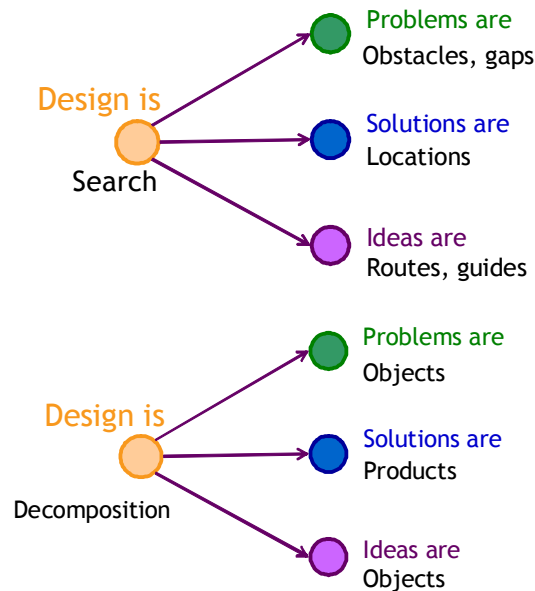
Figure 7.3   A hierarchical model of design metaphor

Universal metaphors

While I observed that many metaphors are largely specific to an author's philosophical, and even personal, approach to design, such as Design Methods Are Maps, other metaphors appear largely universal and were shared by all authors. These include metaphors such as Ideas Are Food ("I need time to digest your ideas"), and Ideas Are Plants ("I have the seeds of an idea"). These metaphors appear largely familiar as they are reflected in common language. Compared to everyday language, however, design discourse has a more diverse range of metaphors for the same concepts, for example, Problems Are Gaps In A Solution Space. I believe this reflects a more nuanced understanding of these concepts deriving from greater use and discussion.

Specific implications

Lastly I examine some of the implications from specific metaphors identified in the study, as well as limitations of the study.

Ideas Are Tangible, Physical Objects

Many metaphors for ideas refer to Ideas As Tangible, Physical Objects. Physical Objects have certain common affordances such as occupying a location, being possessions, originating somewhere, being modifiable and so on. This metaphor is reinforced by our experience of 'capturing' an idea on a Post-It or with a sketch. An interesting conflict, however, is that the nature of ideas is often very different from the nature of physical objects. I believe this mismatch is the cause of many difficulties and conflicts during the design process.

To see that ideas don't always behave as physical objects we need only consider that when you give an idea to someone else you still 'have' it. Ideas do not add up in the same way as objects. Michael Reddy's Conduit Metaphor discusses how words, in effect, act as containers for ideas. Following this metaphor when we capture an idea in writing, on a Post-It say, the idea is contained within those words; it is captured. Yet design team members can, and regularly do, interpret those words in different ways than intended. After *handing* someone an idea it can be dangerous to assume that they then also have the same idea. We construct an idea from the words; it is not transferred in the words. It can therefore be very misleading to treat Ideas As Tangible, Physical Objects, as in many ways they do not behave like them at all. The notion that Ideas Are Tangible, Physical Objects also underlies the system of Intellectual Property. If Ideas Are Objects then they can be possessed, protected, and even stolen.

Ideas Are Children

Ideas are also conceptualized As Living Entities, in some cases Children, as when we talk about an idea being born, growing, being nurtured or being your brainchild. Inventors are

often known to refer to their invention as their 'baby.' No wonder the threat of an idea being stolen is a serious one, as when a team member attacks your idea. This common metaphor may also explain the tendency for designers to fixate on a single or small number of initial designs (Jansson and Smith 1991). The Ideas are Children metaphor could also be viewed as a specialized form of Ideas are Living Entities, which can evolve, grow, be nurtured, be killed, be dangerous, etc.

Finding solutions

Within the Design Is Search paradigm, Solutions are typically seen as both Objects and Locations. It is these metaphors that enable us to *find*, *discover* and *search* for solutions. These metaphors hide the assumptions that solutions already exist and simply need to be found; with enough searching in the right place you will find them. An alternative view is "The good idea is not discovered or undiscovered; it comes, it happens," (Pahl and Beitz 1984 75). Yet, it is rarely the case that solutions are found ready-made. These metaphors lead us away from the more collaborative notions that solutions can be constructed and evolve as you build an understanding of the design situation.

Incoherent metaphors

The analysis also highlights the remarkable range of conceptualizations we hold for such a universal design concept as a Problem. When Problems can be seen as Puzzles, Formulas, Gaps, Barriers, Objects, and Locations it is not surprising there is continued debate and disagreement as to the nature of design problems. The analysis shows that our views of design problems stem not only from the circumstances of the design situation but also the overall philosophy of design held by the designer. When these philosophies diverge, debate can be difficult at a more specific level as we find ourselves literally talking about different things.

Creative design

I observed that references to creative design typically took several forms. For example, Ideas appear *involuntarily* or *spontaneously*, they are *triggered* or they *emerge uncalled for*. Our metaphorical understanding of this process sees the Ideas themselves as out of our control and moving of their own volition. Creative inspiration employs the metaphor Knowing Is Seeing with Ideas Are Light Sources (Gabora 2002). In this way, Ideas are the illumination, the creative spark or the flash that light up a portion of the design space or illuminate a solution directly. Finally, the metaphor Problems Are Gaps or Obstacles leads understandably to the common notion of the 'creative leap." In the creative leap we move locations, and therefore states, via the common metaphor States Are Locations (Lakoff and Johnson 1999).

The 'out of our control' nature of metaphors for creative ideas, together with the spontaneity implied takes the emphasis off the hard work that is needed for creative design. Consider Edison's mantra "Genius is 1% inspiration and 99% perspiration," or the advice of Bernie Roth at Stanford University that "Hard work is the best creativity method I know" (Roth 2007). The metaphors also highlight the individual contribution of creative activity perpetuating the myth of the lone inventor and downplaying the role of constructive collaboration in teams.

The Design Path metaphor

To close this study it is worth presenting a short discussion of the Design Path metaphor proposed in the previous chapter. A design path is a metaphor like any other metaphor used in design and both highlights and hides. The test of a good metaphor is whether it highlights enough to be useful and hides only the unimportant.

The schema associated with a path includes a beginning, a destination good or bad, possible junctions leading to different destinations, and a traveler or travelers. With this metaphor then we can infer the following correspondences:

- The start is the initial framing of the situation

- The end is the final framing of the situation

- Destinations are different framings of the situation

- Travelers are the design team members

- Junctions are decision points for the team

- Travelers moving down different paths are travelers adopting different frames

Paths imply that it is possible to see where you have been but not always clear to see where you are going beyond a short distance. Travelers in the same direction are teams with a shared framing of the situation.

Each of these facets so far seem to reasonably represent the NPD process as experienced by design teams studied for this thesis. Indeed, one of the founders of Powder Net in the previous chapter made heavy use of a design path as a metaphor for understanding their experience:

> *And so were we on the right path?...We're on the best path I think we found.*
> *We were on the path that the company decided on for whatever reason and*
> *did that path bring us into rapid growth? No. so maybe that means we're*
> *inherently not on the right path or maybe it means we're on the best path.*
> *It's hard to say but we were never sort of dumb and happy thinking we were*
> *on the right path. There was always tension and there was always*
> *disagreement. We were always trying to get onto a better path.*

Yet, the design path metaphor also has the power to mislead. A journey along a path is primarily linear in that you cannot simply arrive at the other end without traveling through the middle. This facet does not easily account for *creative leaps* that may immediately lead to an alternative framing. Although the design process as experienced is inherently linear –

even with iteration it remains one decision after another. The design path metaphor also hides any reference to users of a product or service including only the design team in the typical schema. Finally, the implied destination of a design path leads to the same flaws of the Design Is Search metaphor, that of an assumed ideal solution existing independently of the design team.

Design paths bear a close resemblance to a journey, a metaphor elaborated upon in depth by some design thinkers (Koberg and Bagnall 1981). The metaphor appears to resonate with a design team's experience. In addition, the metaphor points the way to the possibility of new tools and understanding including learning about possible destinations, common design paths (the beaten track), a clear acknowledgement of the possible different directions of team members, ways to locate yourselves and the possibility of means of guidance including a map to plan and chart progress.

While the metaphor holds promise it is important to reiterate that a metaphor both highlights and hides and never accurately represents reality. No metaphor is perfect and this is no exception, but a metaphor may still be useful.

Study 1: conclusion

In this study I highlighted a less known, but important, facet of metaphor use in design – that of understanding design itself. I found important differences between typical metaphors espoused in design textbooks used to frame the design process and experience in actual NPD projects. I also proposed a hierarchical model for metaphors for design whereby the dominant design metaphor influences the choice of metaphor for the core concepts of ideas, problems and solutions. Finally, I presented some specific implications as well as discussing the useful aspects of the Design Path metaphor proposed in the previous chapter.

The following study looks within the design process to compare the use of analogy and metaphor and determine how each affects the framing process.

Study 2: metaphor and analogy use in design

Introduction

Metaphor and analogy are often confused. Indeed it is not uncommon for them to be used interchangeably. However, as I shall show, there are important differences between analogy and metaphor and how they are used in design. In presenting this study I shall first provide definitions for both analogy and metaphor as they relate to design practice. I will then describe a study that brought together two sets of data to determine the role each plays in problem framing and concept generation. The study was conducted jointly with Alice Agogino at the University of California, Berkeley, and Julie Linsey and Kris Wood at Texas A&M University.

Definitions for design

Both metaphor and analogy involve comparing one situation with another. To help distinguish the two Gentner and Markman (1997) make a distinction between relational and structural, or appearance, similarity. For example, a job may have relational similarity with a prison but little similarity in appearance, whereas a zebra may have appearance similarity with prison bars, but no relational similarity. They propose that analogies typically require strong relational similarity but metaphors can span the spectrum of relational similarity to appearance similarity. The distinction is shown in a modified version of Gentner and Markman's diagram in Figure 7.4. Steve Jobs' inspiration for the iMac computer as a sunflower is drawn more from appearance similarity then relational similarity. It is therefore a metaphor rather than an analogy. In contrast James Dyson's connection between the sucking of a vacuum and cyclonic separation is a relational, causal, similarity primarily (Dyson 1997). In this case then Dyson drew an analogy between the two, rather than using one as a metaphor for the other. The emphasis on relational similarity for analogy primarily maps the causal structure between the source product or system in one domain to the target

design problem being solved. The causal structure includes a device's functional solutions, geometry or component configuration.

Both metaphors and similes can be visual as well as expressed in language. Typically metaphors are made as a direct comparison between two objects as when we say 'the flood of email'. A simile is a metaphor where the comparison has been made explicit, as in saying 'the amount of email is like a flood'.
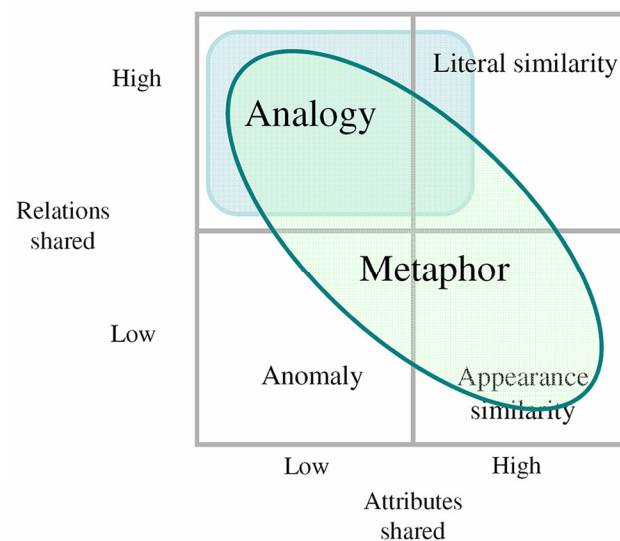
Figure 7.4   Relationship between analogy and metaphor modified from Gentner and Markman

(1997)

Metaphor use in the design process

Metaphors can be used at different stages of the process as both descriptive and prescriptive metaphors. In the early stages of design, metaphors are a tool for better understanding the design situation – descriptive metaphors. Descriptive metaphors need to closely match the current reality to make sense. Later in the process metaphors are used as a concept generation tool – prescriptive metaphors. Prescriptive metaphors do not need to match the current reality but, in using the metaphor, can point the way to a desired reality, in doing so they can help inspire designers with new ideas.

For example, seeing a cafeteria as an oasis not only helps understand the situation (as a descriptive metaphor) but may also lead to new solution directions as a prescriptive metaphor. The designer might consider how the feeling of an oasis could be better supported by the cafeteria, perhaps by providing places for rest or better closing it off from the outside world. In another example, a shower might be seen as a *reset* for the person taking the shower. They wash away the rest of the day and start renewed once they emerge. The metaphor, Shower Is A Reset, can be used to generate other solutions that could support people's feeling of starting anew even to the point of activating the shower with a button.

Metaphors are more effective than analogies at framing the early stages of a user-centered design process because they deal more effectively with the intangibles, and abstract nature of people's attitudes and needs. Metaphors are commonly used to map users' understanding, activities and reactions to a product. They help make sense of customer needs or physical attributes from the source of inspiration. Metaphors' exceptional communication ability provides meaning to a design situation; a cafeteria when seen as an oasis for its visitors becomes a different place entirely.

During concept generation, it is widely recognized that designers find it hard to ignore obvious constraints on their concepts before they have been fully developed. Various techniques such as brainstorming (Osborn 1953) encourage designers to defer judgment to allow ideas a chance to develop and be built upon before they are 'shot down.' Adams (1986) proposes the concept of conceptual blocks and various methods to negotiate them. Several metaphors have also been proposed as a means of reducing the impact of obvious constraints on designers during concept generation. Altshuller (1999) proposes the metaphor of a magic wand to encourage problem-solvers to free their imaginations and worry about the constraints afterwards. Stanford University's John Arnold proposed designing on the planet Arktur IV as a metaphor to help problem-solvers leave their earthly constraints behind. Each of these metaphors helps designers avoid early judgment by invoking the ideas of magic

and other universes. Indeed, these metaphors are sometimes not far off reality as Arthur C. Clarke observed "Any sufficiently advanced technology is indistinguishable from magic," (1962).

Analogy use in the design process

In contrast to metaphors, prior studies most commonly link analogy with the concept generation or ideation phase of design to find solutions to the design problem rather than to frame or assist in understanding it. Analogies to nature and previous designs are common. For example, a team with the design problem of creating a device to fold laundry may make direct analogies to other types of folding devices such as paper folding or metal folding. Likewise, more distant analogies may be made to dousing a sail, rolling a cigarette, or collapsing a structure. Consistent with our distinction between analogy and metaphor, these examples each map causal structure between the target concept and the sources. Analogies also support concept selection. When designers are evaluating a set of concepts, they typically reference a design they have seen before in their evaluation. Designers thus use analogies to predict the performance of the design concept.

Another type of analogy employed in design is meta-analogy. Meta-analogies are formed from sets of individual analogies. A good example is the inventive principles employed in the TRIZ methodology (Altshuller 1999). These principles are high-level abstractions derived from many examples of individual analogies taken from innovative patents. For example, the principle *Nested Doll*, storing one thing inside another like a Russian doll, is employed in many different domains wherever a thing needs to be large at one time and small at another. The sets of individual solutions such as telescopes, cables, stacking measuring cups, and extendable ladders are combined and abstracted to form the meta-analogy *Nested Doll* that can be applied more widely. A closely related phenomenon is scheme-driven analogizing, which is the application of abstract experiential knowledge to a design problem (Ball et al. 2004).

Approach

Casakin (2006) observed that architecture students found it easier to employ metaphors as a design tool in the early stages of design when framing and defining the situation than in the later stages. Here Casakin's observations are extended to compare the use of both analogy and metaphor at different stages of the design process. The research team was motivated by the hypothesis that metaphors are used more frequently during the early, problem framing, stages of the design process and analogies are used later in the concept generation phase. How does the actual use of metaphor and analogy play out in design?

12 interviews were conducted with multidisciplinary NPD teams from the graduate course at the University of California, Berkeley. Eleven interviews were performed in the final two weeks of the project and one was performed after the final tradeshow. Interviews were conducted with the full team present when possible, and the teams were asked to tell the story of their project from beginning to end explaining the key points as they saw them along the way. Interviews were recorded, transcribed and coded for discussion of relevant product metaphors and use of analogy.

For comparison to the metaphor use data, use of metaphor and analogy was coded from a prior study where design teams were asked to use a particular group idea generation technique and then spend forty minutes generating solutions to a design problem (Linsey et al., 2005). Again 12 teams were analyzed. All the group idea generation techniques evaluated for the study required teams to use only written communication. This study was a 3 X 2 factorial design. The first factor controlled the representation teams used for communication (words only, sketches only, or a combination). The second factor controlled how team members exchanged ideas, either all the ideas were posted on the wall or each team member had a sub-set of the ideas and they rotationally exchanged them. Teams consisted of five senior mechanical engineers. The experiment asked the teams to design a device to shell peanuts.

The analogy coding was based on clear references to other designs, such as "analogy to potato peeler" or "this is like a grill". This approach underestimates the actual number of analogies used by the design teams. Designers frequently use analogies without making explicit references and frequently without realizing the source of their idea (Linsey, Laux, Clauss, et al. 2007; Schunn and Dunbar 1996). In addition, the coding can not explicitly evaluate if the analogy was being used as an explanation tool or if the idea had been developed based on the analogy. A common use of analogy is to explain an idea rather than as an original source of inspiration (Casakin 2006). However, from observations of the coding process, it appeared clear that many analogies were being used for idea generation, as opposed to just explanation.

Results

The analysis shows that student design teams employ both analogies and metaphors in the design process (Figure 7.5). Table 7.4 shows that over 65% of the design teams, in the studies, used metaphors to frame their problems and about half of the design teams took advantage of analogies to generate solutions. Students who took part in the concept generation experiment were previously exposed to using analogies for idea generation in their engineering design methods class. While analogy use to generate solutions appeared spontaneous, almost no metaphors were mentioned in concept generation. Students who had been exposed to the technique of design-by-analogy spontaneously used it when asked to generate design solutions. This result replicates prior findings (Linsey, Laux, Clauss, et al. 2007), but does so within the real-world knowledge domain of engineering.

Though there was no formal teaching of metaphor use in design, 8 out of 12 design teams highlighted a metaphor in the problem framing stage as an important factor in their project. For example, one team, developing a software product for social networking, searched for a suitable comparative business and used photo-sharing: "we saw it as organizing your collection of pictures, which is very tedious to do but once you have it nice to have. So that's

what we thought we were trying to do with networking … it's kind of annoying to do networking all the time but it's nice to have a social network in the end." Extending the photo-sharing comparison the team explained "we were the Flickr of social networking - And it just helped us frame the whole process."

Table 7.4 Analysis of analogy and metaphor use in a concept generation activity

	Problem Definition Phase (Design Process Interviews, n=12)	Concept Generation Phase (Concept Generation Experiment, n=12)
% of teams using analogies	8%	50%
% of teams using metaphors	67%	8%

- "Staple remover design"
- "rotating blade shells peanut (analogy to potato peeler)"
- "Similar function to putting your hand in a bicycle chain, except your hand is replaced by peanuts"
- "maybe like two pencil sharpeners that are put opening to opening"
- "the peanuts can be collected with a device that attaches to a bike and acts like a golf ball picker-upper-thingy."
- "A rolling type of mechanism, much like a Roots-Style supercharger, with rubberized "fingers" or slots,… the peanuts are fed by gravity into the roller, hopefully the shells are crack."
- "A rolling mechanism like a ball bearing grinding machine. Two large round plates with spiral grooves cut into them that spin at a fixed distance from each other and in opposing rotational directions. "
- "Use a device with two pliers like shell crackers opposing each other."
- "Develop a large clamping platform with a bottom stationary plate and an opening/closing top plate (like a Foreman Grill ™)."

Figure 7.5 Example of analogies teams used to assist in designing a device to shell peanuts.

A team investigating electronic textbook delivery developed a restaurant metaphor to help understand their design situation and the student experience. "Educational content was like food in a meal. And so the publishers are like chefs in the kitchen preparing the content and because there's an agency problem the professors order for you and so then you get served –

so there are three aspects to the student experience – it's getting served the content, eating and digesting the content and then enjoying the content as in discussing it after the fact. It was actually quite relevant because we had to talk about how do you serve things up versus how do you facilitate some of the ability to access them and digest them on their own and then share those thoughts."

Another team, also described in Chapter 06, began with the goal of developing software that would help designers see manufacturing errors in CAD models before they went to manufacture. As one member explained: "If the user is making a model using CAD software the software will do the error detection in real time and give the feedback in real time. Something like a spelling checker in Microsoft Word. It does it in the background…"

One team, looking for opportunities to integrate computing into the kitchen developed a platform-based solution after realizing from their research that the kitchen was an organic, messy space: "I think sort of what our platform has become is tailored for picking this section of the problem. And then you know the rest can grow out from there because it's an organic space. It's a messy space. It's not supposed to be very regimented, it's the kitchen. It allows for some freedom there." The insight of the organic nature of the kitchen directed the team towards the flexible platform solution.

Further examples include a team that explored developing a NASCAR style fast food drive-through experience, and a team developing a device to remove blood clots that viewed the situation as akin to plumbing – they were creating pipes.

Comparison of metaphor and analogy use

As Table 7.4 shows, metaphors were most frequently used to frame the design situation whereas analogies were most common for generating solutions to the design problems. Although these data are not sufficient to prove this trend, the result is compelling and warrants further investigation. The data supports Casakin's results that students had an

easier time employing metaphors to assist in framing their problem as opposed to using metaphors to generate solutions (Casakin 2006). The data from the new product development interviews illustrated use of metaphor in the early problem framing stages of the design process. For example, the 'Flickr of social networking,' the education restaurant metaphor, and the manufacturing spellchecker metaphor allowed the teams to see their design situation in a different way. These results are in contrast to the results of the analogy study that showed how analogy contributed directly to the development of new solution concepts rather than providing an understanding of the design situation.

The prevalence of metaphor in the early stages of the design process may stem from the teams' search to understand a complex human design situation. A metaphor helps bring structure to the design situation and acts as a meaningful communication tool to the rest of the team. The metaphor helps the design teams figure out a story that makes their design project make sense. In contrast, the concept generation phase is often concerned with more technical aspects of design problem solving where the emphasis is on finding a technical solution that will work and is innovative rather than a story to help make sense of the situation.

Conclusions

In this chapter I presented two studies investigating different aspects of metaphor as a framing tool: for our understanding of the design process itself; and for how it finds use within design projects. The studies showed that metaphors in common use for design and its core concepts have an important effect on how we frame the design process itself, for example, whether it's a problem of search or one of argumentation. This, in turn, affects how we think about the core design concepts. We also saw that, when compared with the use of analogy in the design process, metaphor was more commonly used in the early stages of

design projects to frame the design challenge, whereas analogy was more common for concept generation.

Onwards

So far I have presented studies looking at the role framing plays in the design process including effective and ineffective framing practices (Chapter 05). I have also provided a framework that helps understand the intertwined dimensions of framing matched with users' frames and a teams shared understanding about that framing (Chapter 06). Having now looked at the important role of metaphor as a framing tool (this chapter) I will turn to recommendations for effective framing. In other words, given what we have seen, how can we provide concrete guidance to design teams for effective framing?

08 Principles and Tools for Effective Framing

From insight to action

Summary

In this chapter I take what has been learned throughout this research about design team framing and apply it to develop practical advice, guidelines, principles and tools to support design teams. I begin by pointing out the need for greater awareness, understanding and simple team practices to support design team framing rather than solely new methods or tools. I present a set of four themes and twelve principles for design teams for effective framing in design that provide increased understanding of the consequences of design team activities. I also present examples of how we can help raise awareness of framing issues and support design team activities during design meetings. I also present a method for supporting metaphor use as a framing tool.

Introduction

Almost as much as any other discipline, design teams have a remarkable array of tools and methods at their disposal. Each new research project almost invariably proposes an alternate or variant design method or set of tools that designers can adopt to improve their practice.

Examples of these include design for sustainability, manufacture, and the environment, universal design, participatory design, design probes, axiomatic design, Synectics, TRIZ, affordance based design, metaphorical design, the house of quality and more. Yet surveys of current design practices in industry found that design practices in use remained somewhat conservative. For example, despite the wealth of tools proposed to help structure the concept selection process, informal design reviews (used by 76% of companies surveyed) and intuitive concept selection (57%) are the most widely used compared with the Analytic Hierarchy Process (4%) or Pugh Controlled Convergence (2%) (Salonen and Pertulla 2005). And while two thirds of designers were aware of the House Of Quality (or Quality Function Deployment) as a tool, only 20% had used it outside school settings (Yang 2007). New design processes, methods or tools only have value if they are adopted by designers, yet designers are understandably reluctant of new approaches they may perceive as an additional burden on already stretched project schedules. Recommendations that (at least appear on the surface to) make the life of designers more complex will be resisted. New tools also need to be usable in a team setting. It is for this reason that many software-based design tools that need input from multiple team members are not adopted.

In contrast to this perspective we can also argue that although there has been increasing research activity into design team framing it is not clear how these findings should influence design practice. In other words, framing has generated a great deal of scholarly discussion but few tangible and actionable findings have resulted that design teams can incorporate and work with.

One of the important realizations of this research is that there are indeed useful tools and practices already in use by design teams, yet these activities are not always performed correctly or teams attempt to shortcut them (for example, by paraphrasing the presentation of research findings). This misuse, lack of use, or shortcutting of existing design tools is partly because teams do not always understand the full value the tools provide – in

209

particular as they relate to understanding the needs of users and the different perspectives of members of the design team. My research has led me to believe that two primary approaches are needed to support effective framing by design teams:

The first is greater *understanding* of how the different activities, tools and methods a design team employs affect the framing of the situation and the shared understanding of the team.

The second is *simple team practices* to help design teams negotiate the framing cycle and employ existing useful framing tools such as metaphor.

This chapter is structured by these two approaches.

I address better understanding of effective practices and tools available to designers through a set of design principles structured around four themes. The practices are illuminated with an increased understanding of why they are effective, and why they are often misused.

I address simple team practices by illustrating a simple and lightweight tool supporting the framing cycle that can be used within design team meetings to help elicit differences of frame and different understandings of the project. I also present a lightweight method to support metaphor use in design and work in progress on a software tool to further enhance it.

I close with a short discussion of the importance of increasing awareness of framing issues, and a consideration of the effects of making implicit practice explicit.

Understanding: Themes and design principles for design team framing

The following major themes or directives for NPD teams and twelve design principles were derived from the framing studies presented in this dissertation. The development of the framing cycle, identification of key framing activities, common design paths and the Design Path framework have all influenced their development.

More specifically, the themes and design principles are developed from the many concrete situations of design teams that I observed. In particular I paid attention to the most common pitfalls of design teams. These pitfalls were divided into those that reduced shared understanding in a detrimental way, and those that prevented teams from framing the project around their target market's needs (the two axes of the Design Path framework). The principles are the responses to these pitfalls; the most effective strategies and practices I observed that helped teams successfully negotiate the same activities or avoid the pitfalls. This selection of practices was then clustered into the four overarching themes – Learn, don't confirm; Share richly; Make decisions on a common basis; and Drive innovation through real needs. As a result, both the themes and principles have consequences for both framing the situation so that it matches users' frames and for the team building a shared understanding.

The themes can be seen as broader directives of goals for teams to achieve. While they should be achieved one way or another there may be many different ways of achieving them. The specific design principles are more concrete. They should inspire tangible actions and design ideas. I will present each of the themes and its associated principles in turn. They are also listed in Table 8.1. For each principle I have included a short description and discussion relating it to developing shared understanding and matching users' frames.

Table 8.1   Design Principles for design team framing

Theme	Design Principles
LEARN, DON'T CONFIRM	1. Choose a team name not tied to a product
	2. You are not cooking for yourself
	3. Design for people not products
SHARE RICHLY	4. Use rich media
	5. Design research is a team sport
	6. Manage the data deluge with frameworks
MAKE DECISIONS ON A COMMON BASIS	7. Manage time for iteration and learning
	8. Manage knowledge gaps
	9. Take the time to discuss
DRIVE INNOVATION THROUGH REAL NEEDS	10. Drive development from research data
	11. Look for the story behind the product
	12. Test, test, test

Theme 1: Learn, don't confirm

The most common pitfall observed in design teams is beginning the project with an attitude of confirming rather than learning. This means that a team sets out on its user research and its process as a whole with an expectation of confirming what it *thinks* is the correct framing of the problem. That initial expectation is the pseudo-frame built from a typically incomplete and early understanding of the situation and the needs of users. There is great temptation to believe that the initial framing of the situation is likely to be correct. For one it means less work; if you understand the problem already then you don't need to expend time and effort performing research. Second, team members who like action, for example, those who favor concrete experience and active experimentation (Kolb 1984), are able to begin generating solutions, solving problems and building solutions immediately. However, as Beckman and

Barry (2007) argue, this concrete approach "often fails to discover the higher level meaning-based needs that can be crucial to the success of an innovation." Third, we live in a culture that values knowing the answers – we place more emphasis on problem solving than problem finding. Adopting an attitude of learning requires humility to admit that you may not know the answer. However, beginning with an attitude of confirming leads to several important difficulties.

A confirming attitude drowns out potential consumer needs in favor of the design team's view. Confirmation can lead to biased research, as one student mentioned,

> *We were all under the impression that there was this big need for the [original product focus]. And we all thought that we'd just do these interviews, they were a formality. You know, we were going to do the interviews. It was just all going to flow into the next. One mistake we might have made was that we even tried to steer some of the initial interviews to get that result. Because I think that was the whole reason we were doing this: to almost legitimize the initial idea…We were almost trying to fit that in a box of yeah maybe there still is a need there. But there really wasn't.*

A confirming attitude can also lead to hearing what you want to hear from interviews, partly because it also provokes shallower user research. For example, the proposer of a project to do exercise while you work consistently heard a need for his product idea in his interviews while the rest of his team heard quite different needs. One of the design team coaches commented,

> *"I try to get them to go further than the obvious stuff – to get beyond obvious statements, to re-unpack their interviews so that field work isn't just a confirmation of what they thought they knew."*

An attitude of learning requires skills for listening, keen observation and building empathy with research participants (Hey, Van Pelt, et al. 2007). Teams must stay clear of their own biases and be open to compelling needs of the customer even if they conflict with gut feelings. A learning attitude also opens the door to potential reframing of the design situation. Reframing is almost a confirmation of a learning attitude. A novel insight that sparks a reframe is also the most likely to lead to a new product direction that will differentiate itself in the market. An attitude of learning can also help create a more motivated and coherent team. It forces the team to learn from, and base its decisions on its research and the stories from research participants. In this way, teams are able to come to a choice of direction together, rather than persuading others of their own viewpoints, and they can also rally behind the challenge of meeting the needs of real users.

Learning not Confirming is the first theme because it pervades all of a team's design decisions and thus has the most far-reaching nature. I will now present three design principles for how to reinforce an attitude of learning not confirming.

Choose a team name not tied to a product

A team name is typically representative of what the team is doing. However, because team names are usually set at the beginning of the project, when the team is operating within its own pseudo-frames, team names are often misleading and can be harmful. A team name is a mental bind to a direction.[23] For example, one team struggled to release itself from the 'web site' in its team name: "Is it ok to go back and say we're not doing a site? – it's what we started with."

The number of changes of a team name are a loose indicator for how well teams have reframed as they understood their users better. A new name often coincides with a reframing, for example, in his article, The Cathedral and the Bazaar, Eric Raymond

---

[23] We also saw in the case study in Chapter 06 that the concept of a team name as a bind to a direction can play an even larger role in industry as a company name.

describes how, after a reframing of the mail client he was working on, the *"design acquired an identity of its own…It was time for the name change,"* (Raymond 2001 42).

A simple guideline then is to either not select a team name until after the team has completed its user research and has a clearer idea of the eventual project's focus, or select a team name with deliberately little connection to the initial focus. In particular, related to the design principle *Design for people not products*, in the early stages of a project it is important to avoid a team name associated with a product or product idea. A stronger team name will be focused around a target market than a product group, for example, "Snowboarder aid," is preferred to "Snowboard lift comfort."

You are not cooking for yourself

While a Michelin class chef can cook his or her own version of top quality cuisine for his or her clients, a chef for an elementary school canteen has a keen sense that the school children have different tastes from him or herself. Only a few companies are like our Michelin chefs; the vast majority serves markets where it is important to remember they are not cooking for themselves.

Teams often make the mistake of assuming they already understand their market. This is particularly the case when the designers themselves could be part of the market group. In the Powder Net case, it was possible to see the values of academia initially transferred to the business world. Across all graduate design projects studied the most common target group included 20-35 year old students or young professionals (fully 40 out of 57 projects). This choice was partly driven by the convenience of access to potential users (and partly by the personal bug-listing exercise that precedes project proposals), however, with the team members part of the target market, it becomes easier to listen to your own viewpoint on the situation and harder to genuinely listen to your users'. It is also easier to dismiss research participants' views that differ from your own. When team members rely on their own viewpoints, differences in frames are less likely to surface until later in the project, and

215

designers are more likely to design for themselves than their research participants. Designers must keep an open mind about what users need.

A senior human factors specialist at IDEO commented on one of the unexpected benefits of role playing as a design exercise that *"we were all recognizing our otherness – none of us were the target market,"* (Elliott 2008). In trying to play the role of the user in the role playing exercise it quickly became clear that different team members had different ideas of what users' actions would be, and sometimes the designers realized they really had no idea how their users would react. An additional value of tools such as role-playing then is to help appreciate the importance of getting to know your users and recognizing that you are not who you are designing for – *you are not cooking for yourself.*

Design for people not products

With the decades of development dedicated to improving the automobile it can be easy to focus on the artifact as a goal in itself, forgetting that an automobile exists to serve the needs of its users, be they commuters, taxi-drivers, soccer mums or racing drivers. The same can happen on a smaller scale; it is easy to set out with a goal to make a better iron rather than to help those who do the ironing. Creating a better iron may improve the experience of those who iron, but it will rarely lead to a category changing product. Designing for the people who use it however, rather than the product, has the potential to lead to entirely new discoveries and unmet higher level needs.

The strongest teams explicitly focused on designing for people without a preconception of the product they would be making. While the Healthy Noodle team set boundaries to its innovation through the initial noodle focus, the team did extensive user research getting to know many individual users and their attitudes to ramen noodles. The development process was explicitly oriented to the people without presuming the form an eventual offering would take. Starting with strong preconceptions about the eventual form of a product makes it harder to listen, harder to value what you hear, and ask the right questions. Teams can help

purge their preconceptions through early concept brainstorms, discussion about the target market, research questions to ask and avoiding tying expectations to a product.

Theme 2: Share richly

This theme addresses the complexities of dealing with a team's shared and unshared knowledge with regards to user research. In some senses, teams operate with a transactive memory. Transactive memory is the process by which groups store and remember information (see Wegner et al. 1985 and Wegner 1987). Design teams excel at gathering information but not everyone has access to all of it. In particular, when design team members perform research with participants they learn different things. As I presented in Chapter 06, when teams learn from research participants their perceptions of the issues and the problems and needs at hand diverge from those of their team members. Team members associate best with the participants they learned from (as one team member interviewing parents put it, "you take on that parent's personality. So suddenly you're arguing for something because you heard four parents say it but you have no idea how representative those parents tare") and they also learn more than they can tell (this is similar to the notion of tacit knowledge where we know more than we can say, see Polanyi (1966)). Hence even when they present their research findings they cannot share everything they experienced that may turn out to be pertinent.

Thus this theme is about reducing the differences in what has been learned by each team member, particularly with respect to user research, but this also applies to other design activities. Sharing research data richly helps bring everyone on the same page regarding what has been learned. This both helps align team members with each other and with their users' needs.

Melican (2000) performed a study on the use of user research data by design teams where he first categorized research data formats along the two dimensions of the analytic perspective (conceptual to procedural) and the degree of abstraction (abstract to raw). For example,

217

conceptual understanding of mountain bikers' attitudes to racing might be best approached through interviews, whereas procedural understanding of the preparation process for a race may more appropriately be observed. A direct quote from a user would be on the raw end of the spectrum, whereas a summarized theme such as "mountain bikers value competition" would be more abstract. An important finding from his study was that raw research data were "clearly and overwhelmingly favored over the abstracted," – 75% of references were to raw data, with only 25% to abstract data. Raw research data was also 50% more productive (his metric) for the teams as they designed. Even more pertinent to this design principle however is the finding that,

> *"every instance in which an evocation of user research data is directly associated with a team's framing of the design problem or reflecting on the problem-solving value of an experimental move, involves the data classified on the raw end of the degree-of-abstraction spectrum." (Melican 2000 131-132)*

In particular where framing is concerned then, sharing richly, using raw data where possible, assists teams in productive framing.

I'll now discuss three design principles that support the theme of *sharing richly*.

Use rich media

Teams that shared their research data using rich media including stories, transcripts, photos and video received the dual benefits of both framing the problem in line with the needs of users and developing a shared understanding among the team. A common error NPD teams make is attempting to shortcut the data sharing phase by summarizing findings and paraphrasing the words and insights from their participants. In doing so important contextual information picked up by the researcher in the field is not transferred to the team. Sleeswijk et al. (2007) recommend that tools to communicate market information to

designers should enhance empathy, provide inspiration, and support engagement. Wright and McCarthy (2008) also provide a useful collection of design tools employed in the field of Human Computer Interaction to enhance empathy with users, in particular emphasizing the role of rich dialog and narrative.

There is an inherent conflict between the amount of information team members can convey and the length of time it takes to share it. After all, one of the benefits of working in a team is that not everyone has to learn everything. A corollary perhaps is that we can expect that an advantage of teams who have repeatedly worked together is an increased trust in the opinions team members express without having to take the time to return to the raw user data. Rich media however, goes some way to resolving that conflict. A video provides enormous amounts of detail that would be impossible to convey otherwise in a short time (see Yllirisku and Buur (2006) for a thorough treatment of the use of video in user-centered design. They employ the metaphors of Video As Designer Clay and Video As Social Glue for the design team. Also, see Gaver (2007) and Raijmakers et al. (2006)). Likewise, sharing a participant's story word for word is often a powerful encapsulation of a more general need the person experiences and thus, an efficient means of transferring information.

Design research is a team sport

There are many reasons why design research is more effectively carried out in pairs or more. Design consultancies often require that clients participate in user research in order to help with buy-in to the research findings. In other words, there is an issue of trust involved where it is easier to trust and act upon your own experience than second-hand experience. When teams perform their user research together the extra members also pick up on additional information. Debriefs are richer as members are able to support and counter each other's perceptions of what they heard and saw. When performing interviews having more than one team member allows one to engage the participant and another to take notes, photographs, video, and fill in questions if the first researcher falters.

Yet, with respect to shared understanding we see an additional benefit of performing research as a team. Doing research together, in pairs or more, means that designers pick up on the same contextual information, hear the exact words and see the same actions of their participants. The team is more likely to maintain or develop a shared understanding based upon the mutual research experience. When sharing with the rest of the team the additional perspective and detail also increases the validity of the team member's findings in the eyes of the rest of the team.

Manage the data deluge with frameworks

While collecting and sharing rich data helps teams both better understand users and develop shared understanding, this level of research data can be overwhelming. As one team member put it, *"this wave of data and context crashed on top of us."* Teams should manage the deluge using standard design tools such as personas, frameworks, metaphors, and typologies. Framing is a means to manage the complexity of the real world (Boos 2007). While rich face-to-face communication helps uncover the complexity of the design situation it then needs to be brought under control. A mentor of mine used to explain, "I don't need you to tell me it's complex. I know its complex. I'm paying you to make it simple for me."

Developing frameworks as a team is an important exercise to develop shared understanding. Frameworks like typologies, metaphors and position maps deliberately focus attention on certain aspects of the design situation. While building frameworks is commonly seen as helping identify opportunities, frameworks are also therefore an important means for teams to get on the same page. Having detailed conversations about what axes are relevant for a position map, or which metaphors are appropriate helps make frame differences explicit, and, as they refer back to raw research data, helps them negotiate a common frame.

Theme 3: Make decisions on a common basis

A tower of bricks will break down at critical heights if it is not built on strong foundations. When bricks are not in alignment, the overall structure is weakened. In the same way, teams

that pass critical decision points, or stage gates, without making decisions on a common basis risk conflict as the decisions are implemented. Making decisions on a common basis is intuitively good practice yet many teams fall into difficulty after passing through important stage gates or producing deliverables without having reached agreement across the team. For example, a team working on improving the ski-experience were split between its initial focus of a more comfortable ski-lift and helping skiers better plan their day by providing better information on the slopes. As a key deadline loomed the five person team voted with two for each direction and one remaining neutral. The deadline forced the neutral member to choose a direction although the two members who voted the other way were not convinced and the tension was raised as the team proceeded.

Making decisions on a common basis is perhaps more important for NPD teams in the class setting where the members are peers and there is no clear leadership.[24] In industry NPD teams where a project manager may impose a decision on other team members this may be of less consequence (though this research suggests it is not the most productive practice).

The following three principles are to help NPD teams avoid having to make decisions without a common basis.

Manage time for iteration and learning

When decisions need to be made, frame differences are quickly made salient. Only when these differences are made salient to team members can they begin to be resolved. Teams that manage their time to allow for iteration and the gathering and sharing of more information after key discussions help resolve frame differences before key decisions need to be made. Indeed, poor time management is one of the principal factors affecting teams that follow the Backtrack path (Chapter 06).

---

[24] I also discussed this point in chapter 04

This principle therefore reveals that time management is more critical to a team's success than it may seem. Making hasty key decisions does not just increase the chance of the team being wrong about what needs are really important, it also increases the likelihood that differences in perspectives on the team will not have been fully resolved – either frame conflicts remain or, more dangerously, different perspectives have not yet been brought into the open. This supports Song et al.'s (2003) observation that higher performing teams had high levels of shared understanding just before key decision points or stage gates, but highly divergent perspectives between stage gates.

Another way to manage time for iteration and learning is to follow IDEO's mantra of "fail early and fail often to succeed sooner" (Kelley and Littman 2001 and 2005). While the explicit benefit from this approach is that it allows more iteration to frame the situation according to the needs of users, this research suggests that it also has the benefit of helping the design team learn from these failures and develop a shared understanding.

Manage knowledge gaps on the team

When a team member brings specialist technical or market knowledge about the project area a team has a substantial knowledge gap – i.e., one or more members know many relevant things that other members don't. Knowledge gaps lead to very different framing of the problem. In essence, the pseudo-frames the team members arrive with are very different. If left too long these gaps can divide the team as members opinions are not incorporated in critical decisions or they find their ideas repeatedly rejected. While a team should strive to see the world through its users' eyes it is also important to strive to see the project through the eyes of your team members. An effective practice to uncover and bridge these knowledge gaps is the simple act of interviewing knowledgeable team members. This can help keep teams abreast of differing perspectives and knowledge. This explicit discussion of team members' knowledge is in line with Schön and Rein's (1994 170) recommendation that designers need to *"probe the meanings that lie behind the messages they receive from other*

222

designers, and probe other designers' interpretations that they *receive."* In other words, if sharing richly is a measure to deal with learning more than we can tell, interviewing your team members is a method to deal with knowing more than we can tell. Teams should make an explicit effort to make that implicit specialist knowledge more explicit.

Take the time to discuss

Long discussions often have more value than they seem. They are typically seen as necessary, but painful, rites to make important decisions about user needs, concepts and product features. Yet, this research shows that they also serve the purpose of getting team members on the same page. While it may seem that a long discussion only led to one decision, the actual value in terms of highlighting different frames, making conflicts explicit and negotiating perspectives is actually much greater.

Use the discussions on team mission and vision as time to get the team on the same page – air differences in assumptions, values and expectations so they don't rear their heads in problematic ways later on.

Design teams also need to take time to develop a common understanding of key terms, including what user needs really mean, and any words teams may develop during the project. Using the words of research participants, when possible, helps forge a shared meaning while cutting down on dilution and paraphrasing.

Aiming for unanimous consensus on key decisions will also assist the team as it moves forward. Unanimous decisions require the team to be on the same page and encourage focusing on real user data and taking the time to discuss until agreement is reached. Voting, in particular, other than to promote discussion can be a harmful practice when followed through. A team divided by three votes to two needs to conserve time for iteration and information seeking to resolve the conflict before moving forward.

Theme 4: Drive innovation through real needs

Design teams often desire to create innovative products. The desire to be innovative often translates into a product that is different and novel, but without necessarily being useful – the team ends up with a fun story, but one that doesn't resonate with its target market. The most effective way to create innovative products is to not to strive for novelty but to design products that meet eventual users real needs. Trying to meet users' unmet needs will often result in an innovative product, while striving for an innovative product says nothing about the needs it may or may not meet.

A product the design team sees as innovative is necessarily their own evaluation of the product where what matters is how the target market sees it. As discussed in Chapter 01, the innovative technology of the Segway didn't help regular users warm to it. As Berkun (2007) points out, customers don't care about innovation, they care about their needs being met. Usability advocates mantra to encourage a focus on the user of "Your technology's showing," (Krug 2000) could usefully be translated as "Your innovation's showing." This theme is also echoed by Wai and Mortensen (2007) when they argued that persuasive technologies, to be effective, should be boring. They illustrate with the example of the Nike + iPod running product, "a revolutionary device that pretends to be just a better way to go for a run while listening to music." Meeting real needs helps teams create a product that people really want rather than a product the design team thinks is cool – *Drive innovation through real needs* – not the other way around.

Keep it real: Drive development from research data

The most effective means to ensure you are solving real needs is to *keep it real* by driving product development from the raw research data. Focusing on what you hear and see in your research to drive your decision-making helps you focus on what your users need and not just what the design team thinks is needed. This is challenging for a design team that often assume knowledge about the target market and its needs. Not focusing on real user data

however, leads to two significant pitfalls. First, it increases the chances you will be wrong about what people need, if you haven't heard or seen it in your research you cannot be sure it's true. And second, it leads to time-consuming and stressful disagreements within the team. The more the team can focus on the data in the front of it, the easier it is to be on the same page. When a development decision needs to be made on the basis of what team members think about their target market for which there is no data, the argument easily becomes intractable with no way of coming to common ground. Stay on the same page by keeping it real.

Look for the story behind the product

One of the reasons why teams often aim for innovative products rather than more mundane, need-meeting products is not appreciating the value of having found the right story behind the product. A powerful story can reframe our understanding of a product making new benefits visible and allowing effective selection between alternative concepts. For example, the healthy noodle team was frustrated after choosing its concept direction, as one member commented, "Wow! We could have thought of that idea like the night before." However, it was their deeper understanding of the needs of their users and why this concept resonated with them that both allowed them to select their direction and also provide a compelling message around their final offering – one based around recreating a traditional meal through fresh ingredients. In a similar way, Huggies Pull-Ups are only a minor change from traditional diapers – they have an elasticized waistband and they are sealed at the sides. Yet it was a fundamental shift in understanding that diapers are not just waste disposal products, but children's clothing, and that children's clothing symbolizes future success, that allowed this product concept among the many others to be chosen and marketed effectively – "I'm a big kid now." Powder Net's basic technology did not substantially change, but the team's understanding of how to pitch its value to the business market did.

The message is that even if the final product looks like the original idea, finding the story behind the product is worth the work it takes in user research. Understanding, or finding, the story that makes a product resonate with users allows the team to select between concepts and increases confidence that the path is the right one.

Test, test, test

It's in user testing and implementation that differences in frames between users and designers, and between team members, are made explicit. Teams that do not test walk a tightrope of guessing games. It's easy for a product to succeed in the minds of the team that designs it, but testing helps keep the focus on what really works. In many cases, just attempting to make the concepts concrete is enough of a test for your concepts to learn an important insight. One team member working on a travel bag for frequent flyers commented:

> *"There was definitely a point where we had false clarity in the project. We thought we had it all figured out and some great ideas, but when we went to making them we found the details often tripped us up. It's kind of like writing pseudo code and thinking you have it all done before trying to write the real thing and finding that a lot of things didn't work.*

> *So after we sat down to making these products and found out they weren't feasible there was a time when we were confused and just scrambling to get something together - something that was cool and useful at the same time."*

Another design coach commented about his experience with one team that learned from its testing:

> *"I had a team that was going to reinvent the cereal box. They came up with a good range of solutions. Their favorite was one where you tip it over and it gives you a fixed volume. They we're like, 'This is brilliant. We're done.' Now the industry thinks the PET bottle is the answer but it's too expensive,*

226

so you can't outsell the cardboard box. So I said, 'Why don't you go back out and test with your product and the PET bottle as a control.'

The PET bottle hammered them. Totally smashed them. They were stunned. But I was proud of those guys. They said "We have to start over." In the end they came up with a very real solution but really they were disappointed because it didn't have that flash factor. But it's the obvious stuff that matters."

In other words, testing helps ensure that a team is focusing on real needs over innovation.

<center>***</center>

Having presented the four themes and design principles I now turn to simple team practices to help design teams elicit differences of framing during team meetings and a lightweight method to support designing with metaphor.

Simple team practices: "This project is about…"

Pugh's Concept Convergence (PCC) (Pugh 1991), though intended to help teams make design decisions, actively assists in encouraging the kinds of conversation that both make assumed knowledge explicit and provokes discussion towards developing shared understanding. Like brainstorming, which was found to also serve several useful organizational functions beyond idea generation such as preserving corporate memory (Sutton and Hargadon 1996), the utility of PCC is more than its explicit purpose. For example, Frey et al. (2007) explain how Pugh's method should proceed when some experts disagree:

"In Pugh's method, a discussion proceeds in which the experts on both sides communicate their reasons for holding their views. In many cases, this resolves the issue because either: 1) facts are brought to light that some

> *individual experts did not previously know, 2) a clarification is made about what a design concept actually entails, or 3) a clarification is made about what the criterion actually means.*"

However, as we saw earlier, Pugh's tool is probably only used by a small percentage of firms (Salonen and Pertulla 2005), perhaps because of its appearance of complexity, and it is typically only turned to in the concept selection stages of the process.

ID^2 – Innovation, Development, Diffusion (Legardeur 2001; Legardeur et al. 2003; Hey 2002) – a tool similar in appearance to PCC, was however explicitly designed to facilitate discussion, negotiation and understanding between actors in a project in the upstream phases of a design project. The tool includes functions to allow actors to comment, question, link or raise an alarm about different features and concepts. However, the software tool is designed to be used remotely and asynchronously. There remains a need for lightweight tools that can be employed at any stage of a project in a face-to-face design team meeting. In this section I present an illustration of such a tool, the rationale behind it, and the benefits of it in action.

This project is about…

The "This project is about…" tool was designed to support the framing cycle proposed in Chapter 05 (also Hey, Joyce, and Beckman 2007). The framing cycle has the four stages of: Pseudo-frame setting; individual frames made explicit; conflicts among individual frames made salient; and common frame negotiated. The cycle implies that to negotiate a common frame, frame differences must first be made explicit and the conflicts made salient. I observed a common cause of difficulties was when teams first did not make their individual frames explicit, and, consequently, conflicts could not be made salient. In other words, differences were never brought into the open and so the team remained unaware that differences were even present.

Use of the tool, designed to facilitate these important stages, is extremely simple.

1. Each team member takes a small number of Post-Its.

2. At the top of a Post-It members write "This project is about…"

3. Each team member then completes the sentence on the Post-It writing large and clearly to limit the number of words possible and to facilitate sharing. Team members can write on additional Post-Its starting each with the words, "This project is about…"

4. Post-Its are then stuck to a wall, or the center of a table, and each member shares his or her sentence(s).

5. The team discusses the differences, if any, between the Post-Its.

6. The team attempts to write one Post-It that all members can agree on.

The process is shown diagrammatically in Figure 8.1.

Figure 8.1   The simplified "This project is about…" process

The tool's simple features perform several important functions:

- Team members are not always clear on their framing of the situations. Writing their thoughts down forces them to make their framing explicit (to themselves and others)

- The deliberately vague prompt allows for different interpretations by members allowing members to pick out what they see as important. For example, some members will focus on the higher goals they see as important, others will focus on the specific needs they see as most important. Open interpretation encourages team members to share what they think is most important.

- Using Post-Its with the goal of sharing requires members to focus their thoughts, getting to the heart of the issue as they see it and cutting out the minutiae – there is not room on a Post-It for more.

- Working individually before sharing encourages identification of conflicts as members don't know what others will write until they see it.

- The explicit differences on the Post-Its encourage the team to come to a shared agreement before they move-on. If they don't come to agreement at least the team is now conscious of the frame conflicts as they move forward.

The tool was also inspired by the simple observation that the clearest evocations of a team's framing of its project in interviews was in sentences that began, "This project is about…"

In action

The tool was used as part of a facilitation session for one team designing a product involving young children and the Internet – Kid Net. The original inspiration for the project concerned leveraging the collective knowledge of parents to help create lists of web sites to protect kids from. After speaking with many parents and children the team had identified many different needs regarding children and the Internet that went beyond the original project vision. I facilitated an exercise with the team using the "This project is about…" tool.

Forced to cut to the essence of their project each member took several minutes to complete his or her Post-Its and two members took more than one Post-It. Responses included:

- This project is about allowing children to explore the Internet the way they want to

- This project is about providing Internet training wheels for children

- This project is about protecting children from the dangers of the Internet

- This project is about giving parents confidence to let their kids explore the Internet

- This project is about making a kid-friendly entrance to the Internet

When the Post-Its were shared in the center of the table the team was surprised by the diversity of responses. Some members felt strongly for or against each view. A discussion ensued as to why each member had put forward his or her view. The team referred to its research data to settle differences of opinion. In some cases, on seeing other perspectives, team members quickly disregarded their own Post-It in favor of others.

Encouraging the team to create one unified vision caused it to rate the importance of each view. For two members the perspective of the parents had not been fully realized. At the end the team settled upon:

> *This project is about giving parents confidence to introduce their children to*
> *the Internet*

All of the team members agreed with the statement as representing the most important goal of their project. More importantly, in a lightweight and inclusive way, the tool provoked a full turn of the framing cycle – making individual frames explicit; making conflicts salient; and negotiating a common frame.

Considerations in practice

It is possible for conflicts not to become salient during the exercise when team members choose different levels of abstraction for their sentences. For example, one member may write, "This project is about lighting offices more pleasantly," and another may write, "This project is about improving the productivity of office workers." In this case, the first member has framed the project at a more specific level than the second. According to Patnaik's Need Hierarchy (Patnaik 2004) the first member has framed the project around an activity-level need and the second around a broader context level need.

This situation can leave conflicts unidentified even though they may be present. When this is the case, abstraction levels can be matched by asking *How* on the broader level statements, and *Why* on the more specific statements. For example, "Why do people need more pleasant lighting?" – is it because they need to improve productivity, or for some other reason. And if the team asked, "How would they improve the productivity of office workers?" has it been decided that improved lighting is indeed the best way. By asking these questions conflicts are once again made salient and the team can find a framing that they can agree on.

When a team struggles to produce one shared response the discussion can be the most productive as they identify what the points of contention are. Later in the project the most effective ways of making the decision will be to turn to the research data the team has collected. This provides grounded common data the team can appeal to.

Summary

The "This project is about…" tool provides a means for teams to negotiate the stages of the framing cycle making their individual frames explicit, the conflicts salient and fostering discussion towards a shared frame.

The tool is provided here as an illustration of a simple, lightweight team practice explicitly designed to help teams deal with framing issues in NPD projects.

In this dissertation I also presented a study of metaphor use as a framing tool. Metaphor was seen to be a useful framing tool; however, its use could be improved through a simple method that better enabled teams to successfully identify compelling metaphors. Below I present a simple metaphor design process, its initial evaluation, and a tool to support this metaphor design process.

Supporting metaphor use in design

This work was born out of the insight that, despite well documented cases of metaphor use in design, there is little guidance for teams who wish to use it. The process of developing, or finding, the metaphor is difficult to reconstruct. The instances of metaphor use are often accompanied by a sudden creative insight or a suggestion from a team member and not from a repeatable process. If your team does not have that creative association then metaphor use will remain sporadic at best. Together with Erik Kolb, I set out to develop a tool that could assist in finding suitable metaphors (Kolb et al. 2008). To develop the tool it was necessary to delineate more clearly a process for generating metaphors. The process is also standalone and able to be used with or without the support of the tool. Below I discuss this metaphor design process and its evaluation in an undergraduate design education course to positive results. I then describe the tool, meta4acle, for generating metaphors that can be used to support the metaphor design process.

A metaphor design process

The metaphor design process was developed from a reverse analysis of successful metaphor cases reported in the literature. The process has four primary stages and was produced as a worksheet, shown in Figure 8.2. The worksheet walks teams through the following stages:

1. Desired **Attributes** – Choose up to five attributes you're looking for in your product

2. Distant **Domain** – Choose a domain distant from your own

3. Find one or more **Design Metaphors** – Choose something in the chosen domain that shares some of the attributes you're looking for

4. Generate **Concepts** – Use features of the metaphor to generate design concepts

Figure 8.2   Design Metaphor worksheet

In the first stage the team or designer, selects the attributes they require in their offering. Typically, these attributes will be based on key user needs (e.g., relaxing, comfortable) or technical requirements (e.g., quiet, small) of the product or service.

The intent in the second stage is to deliberately force a search for new metaphors in a domain *distant* from the target concept for their project. A domain is a collection of semantically related concepts. For example, top-level domains include Nature, Work and Transport. A project to do with lighting in student dormitories, for instance, might belong to a domain of Housing, and should therefore search in a distant domain, for example, Nature. Requiring distant domains increases the chance of novel associations that are more likely to provide unexpected insights for the project and to differentiate the eventual offering from competitors.

The search for design metaphors in stage three is challenging. In practice it involves running through a mental checklist of concepts within the distant domain that share some or all of the desired attributes. While this stage is the most mentally difficult and has the most potential for uncertainty, in practice I observed individuals using the process were able to find interesting and relevant metaphors within ten minutes. The worksheet instructs the team members to record their metaphors, and, while the association is fresh in their mind, make a note of why they seem appropriate.

The final stage is optional as in many cases the choice of a suitable metaphor in stage three may already prove useful by providing a common means of communication for the team and a new perspective for understanding, or reframing, its design situation. However, the metaphor can be of further use in generating concepts by asking what useful features of the source concept selected are not present in any current solutions or products.

Testing the metaphor design process

The method was employed as a design exercise in an NPD module of an undergraduate engineering design class. As an introductory design class there were two five-week project modules, each with approximately 50 students. Two sessions of introducing and using the tool were performed during class time. In the first session teams shared one form between them, while in the second each team member worked on their own form. The students were already divided into project groups from 4 to 6 people and the teams participated in the exercise after they had performed initial user research, and gathered and prioritized needs for their project. These needs could therefore serve as the basis for the attributes. The teams then continued their projects to produce a final tested prototype and final presentation. The students were not required to use metaphors in their final project.

During the exercise itself a number of teams developed promising metaphors. For example, a team developing clothing to protect farm workers from pesticides used anti-virus software as a metaphor from the computing domain. Another team aiming to improve the environment of a campus building chose a metaphor from the domain of sports: box seats – "a quiet, comfortable version of a normally loud and chaotic experience." Other examples of metaphors from completed worksheets included two teams both working on developing a portable music player for the gym. One team understood their offering as a PowerBar (a sports nutrition bar) because when you're tired at the gym you need an energy boost, so you reach into your pocket and get energy from the music you listen to. The other employed the metaphor of a meadow, because with all the distractions of the gym the effect of your music player should be to draw you into the serenity and calm of a meadow. Each metaphor drew attention to different needs that each product had identified and the framing led the teams in different directions.

I reviewed the final project presentations for influence of metaphor use in their final product. 7 out of the 31 design teams who participated in the exercise were clearly influenced by a metaphor in the development of their final project: 5 of the 16 teams from the first session

and 2 out of 15 teams in the second session. For example, the Sunlite team developed a dormitory lighting system that drew inspiration from a sunflower with a product providing natural lighting and access to power outlets at desk level. Another team, also developing dormitory lighting drew inspiration from the metaphor of a firefly to provide environmentally friendly, controllable and pleasant lighting. A third team drew inspiration from a bird of paradise that transforms his wings into an alluring display. The bird of paradise metaphor helped inform a design for a bed that transformed into a comfortable and attractive futon during the day.

Differences in metaphor use between the two sessions may be attributed to distributing forms to all team members in the second session. Having just one form per team makes finding a metaphor a team exercise with greater buy-in buy all members into the result. Despite the difference the results, particularly from the first session, are encouraging and the process is worthy of further investigation.

meta4acle: generating compelling metaphors for design

As I observed during the design metaphor exercise, the most difficult and uncertain step was that of searching within a domain for suitable metaphors – source concepts that embody many of the same attributes desired in an offering. Meta4acle is a software tool to assist designers in this difficult step of finding, among the myriad of possible concepts available, one that is useful as a metaphor for the team. The tool was developed in collaboration with Erik Kolb.

The process for using the tool is similar to that of the design metaphor worksheet:

1. The design team inputs information about the desired characteristics or attributes of a suitable metaphor from a limited vocabulary

2. The tool performs a ranking from a database of potential source concepts to order those sources that possess the highest match of desired attributes

3. The tool returns to the most suitable source concepts together with the reason, in terms of attribute scores, for their selection

4. The team then selects from the suggested sources a metaphor they feel is appropriate

For more details of implementation and evaluation see the paper, "Meta4acle: Generating compelling metaphors for design," (Kolb et al. 2008). The key differences between the *pen and paper* method and using meta4acle are that the desired attributes are rated numerically in terms of relevance (0-10) from a limited vocabulary of adjectives, and the search for and ranking of possible source concepts is performed automatically by the tool. The tool searches over a database populated with potential source concepts from each domain and hand-evaluated against the selected adjectives. When meta4acle performs a search, a utility value is calculated by multiplying the input adjective value with the adjective value for each source concept in medium or far distant domains (Equation 1). This calculation provides a predicted utility value for each potential metaphor source that is used to order them. The source concepts with the highest utility are returned as possible metaphors.

$$U_s = \sum_{i=0}^{i} r_i w_i \qquad (1)$$

U_s = target concept utility

r_i = team's attribute rating

w_i = database attribute rating

i = attribute

Figures 8.3 and 8.4 show two screenshots from the prototype tool implemented in Excel with data from a project to help travelers sleep on planes. Figure 8.3 allows the team to input information about its project and rate the relevance of 42 selected adjectives. Figure 8.4 shows the results of a search by meta4acle showing ten possible metaphor sources.

Figure 8.3   Meta4acle – the input mask

Figure 8.4   Meta4acle – the output mask, suggesting possible metaphor source concepts

In our preliminary evaluation using data from three randomly selected past NPD design projects (from those selected in Hey, Linsey, et al. (2008)) as input we found that in each case meta4acle recommended source concepts that made suitable metaphors, and more

239

interestingly, the tool also recommended metaphors from more distant domains than the design teams' actual choice of metaphor used in their projects.

Conclusions

In this chapter, I built on the models and research developed in this thesis to make recommendations for effective design team framing activities. I structured the contribution around two primary directions: increased understanding of framing activities and their consequences; and the development of simple team practices. With regards to understanding I presented four themes – Learn, don't confirm, Share richly, Make decisions on a common basis, and Drive innovation through real needs – and corresponding design principles to help design teams understand the consequences of their early stage design activities. I also presented the "This project is about…" tool as an illustration of the kind of simple team practice that can be developed to encourage productive dialogue about design team framing. Finally, I presented a simple process and a tool developed to support the use of metaphor as a framing tool.

An alternative approach that would complement increased understanding and simple team practices is simply an improved awareness of the importance of framing in design and the less obvious consequences of framing activities. Addressing awareness is less direct and could perhaps best be approached through careful coaching of design projects or explicit attention to framing activities in design curriculum. An alternative approach is a tool that helps designers learn about framing activities and possible pitfalls without having to learn about them firsthand. One possible tool to this end based on the format of "Choose your own adventure" books is presented in the Appendix. The book allows NPD students to choose their own design path through a series of choices and to quickly learn the, often unanticipated, consequences of their actions.

Another consideration with the recommendations presented in this chapter is the effect of making implicit practice explicit. The themes, design principles, choose your own design path education tool and "This project is about…" tool presented here belie an assumption that more explicit understanding of design team framing can lead to better team performance. However, making implicit practice explicit is not without its dangers. Asking a tennis professional to explain his or her serving action brings the implicit (or tacit) knowledge about the swing to the forefront of his or her mind. Thinking about how he or she does it, can, however, interfere with the swing itself. For example, Valkenburg, (2000), makes specific recommendations for the role of the project manager to become a 'frame coach', 'reflection guard' and 'move helper'. In advocating the adoption of the role of 'frame coach' Valkenburg is encouraging teams to be aware, and reflect on, their own framing practice. I don't know of any experimental results of this recommendation but we should acknowledge that, as with the tools presented here, its positive benefit is not assured. The effect could also vary depending on the expertise of the designers.

Onwards

In the final chapter I shall briefly summarize the major contributions and studies performed in this thesis towards more effective design team framing.

09 Summary and Conclusions

What have we learned?

My goal in this thesis was to improve the success rate of New Product Development (NPD). To address this challenge I studied NPD teams to help them produce products that people want. But finding unmet needs and opportunities for design is difficult. And getting to agreement about what it is an NPD team should produce is made more difficult by the diverse backgrounds and perspectives brought by members of multidisciplinary teams. Therefore, two key challenges NPD teams face are framing the design situation around real user needs, and getting everyone on the team in agreement about that framing. Given this context I set out to explore the following research questions:

1. What role does framing play in successful new product development?

2. How do design teams settle upon a suitable frame for their design situation?

3. What tools could help support design teams to better understand and apply the framing process towards successful design?

I chose to address these questions by collecting data from a middle-ground between ethnographic field studies in industry and lab experiments: a combination of student design teams together with an industry case study and interviews with professional designers. This approach allowed me to provide new insights into the framing process through the study of over 60 multidisciplinary, graduate, project teams working over a thirteen week semester.

I began the thesis by presenting prior studies that emphasize the importance of effective framing in design and the development of shared understanding within a design team. I then presented my own evidence for the importance of these challenges from an analysis of lessons learned from a graduate, multidisciplinary NPD class. The study also pointed to the new skills required of modern designers and the benefits and challenges of working in multidisciplinary teams.

To address the research questions I performed two extensive descriptive studies of NPD projects. Both studies further illuminated the complex nature of design team framing. In the first study, I identified the key design activities that impact framing, including writing a project proposal, developing a mission statement, selection of research areas, digestion and analysis of user data, and setting categories in ideation and brainstorming. The study highlighted useful and harmful practices, as well as common framing pitfalls for design teams. The study also led to the development of the Framing Cycle. The model provides a lens on how teams successfully negotiate a common frame for their design situation – making individual frames explicit; making the conflicts salient; and negotiating these conflicts to a common frame.

The second study, conducted on a broader range of teams, introduced the Design Path framework to help understand the effects of design team activities on finding a frame matched with their users' needs and developing shared understanding within the teams. I found three common design paths for NPD teams I termed Back Roads, Backtrack and Direct. I verified the applicability of the Design Path framework through an in-depth case study of the early stages of an industry product development company.

Metaphor is also an important tool for framing in design, and metaphor plays a key role in structuring our understanding of the design process itself. To investigate metaphor's role I performed an analysis of the language in design textbooks, finding that different views of

243

design are proposed by different authors with the dominant metaphor being Design Is Search. A second metaphor study explored when and how metaphor and analogy are used within the design process. The study showed that metaphor is more commonly used in the early stages of design as a means to frame and understand the design situation, while analogy is used more often later in the process as a means to generate new concepts.

To support effective framing, I presented recommendations for design teams in the form of four themes and twelve design principles. The four themes are – Learn don't confirm; Share richly; Make decisions on a common basis; and Drive innovation through real needs. The themes and principles provide concrete guidelines for design teams. They also improve our understanding of common design activities including unexpected benefits and potential pitfalls.

I also highlighted a need for simple team practices to help design teams negotiate the framing cycle and employ useful existing framing tools such as metaphor. I demonstrated a simple team tool to help teams navigate the framing cycle. To support the use of metaphor as a framing tool I presented a lightweight process for designing with metaphor. The process was tested to encouraging results with an undergraduate design class. Finally, to support the most difficult stage of this process, finding a compelling metaphor, I presented work in progress on a software tool, meta4acle, that facilitates this step.

Future research

My research leaves open many important directions for further study into design team framing.

The lessons learned study pointed to a need for better frameworks to help manage the large amounts of data that design teams collect. There is a need for frameworks that help teams

organize, prioritize and understand users and their needs to reduce the uncertainty and time required for this stage in the process.

There is also a keen need for tools to help share research data richly in a short amount of time. My research illustrated the dangers of performing research separately and paraphrasing research results in terms of reduced shared understanding of the team. Yet, collecting data together and sharing richly takes time. Methods that help resolve this conflict are a promising research direction.

My research helped understand the process of design team framing, yet questions remain about the effects of the characteristics of specific projects on team framing. Projects vary in size, complexity, physical hardware or software, target market, and time-scale, to name a few variables. Studies that further examine effective framing with different task characteristics would make an important contribution.

Another key variable whose effect on framing remains little understood are team personalities and leadership styles. Design teams operate with diverse combinations of personalities and leadership styles that will affect the framing activities and the development of shared understanding within the team. Determining the consequences of these variables on design team framing is an exciting research challenge.

Team framing activities in the user-centered design process remain somewhat disconnected from systematic design methods such as TRIZ (the Theory of Inventive Problem-Solving). Another direction, therefore, would be to effectively integrate the early stage framing activities of the user-centered design process with the technical and creative problem-solving tools of systematic design methods (e.g., Van Pelt and Hey 2006).

Finally, the impact of team framing will no doubt also depend on the organizational context of product development. Important questions include how does framing vary across different

industries and how is it affected within different corporate cultures and constraints? Extending this research to study the effects of the themes and recommendations in different organizational contexts would be an important step forward.

10 Bibliography

Adams, James L. 1986. *Conceptual Blockbusting: A Guide to Better Ideas*. 3rd ed. Boston, Massachusetts, United States: Addison-Wesley.

Agogino, Alice M., Shuang Song, and Jonathan H. G. Hey. 2005. Triangulation of Indicators of Successful Student Design Teams. In *Proceedings of the Harvey Mudd Design Workshop V: Learning in Engineering Design*, Claremont, California, United States.

Agogino, Alice M., Shuang Song, and Jonathan H. G. Hey. 2007. Triangulation of Indicators of Successful Student Design Teams. *International Journal of Engineering Education* 22, no. 3:617-625.

Akin, Omer. 1978. How do architects design? In *Artificial Intelligence and Pattern Recognition in Computer Aided Design*, Ed. Jean-Claude Latombe, 65-103, New York, New York, United States: North-Holland Pub. Co.

Allen, Thomas J. 2007. Architecture and Communication among Product Development Engineers. *California Management Review* 49, no. 2:23-41.

Altshuller, Genrich. 1999. *The Innovation Algorithm*. Trans. Lev Shulyak and Steven Rodman. Worcester, Massachusetts, United States: Technical Innovation Center, Inc.

Ancona, Deborah G., and David F. Caldwell. 1992. Demography and Design: Predictors of New Product Team Performance. *Organization Science* 3, no. 3:321-341.

Badke-Schaub, Petra, Andre Neumann, Kristina Lauche, and Susan Mohammed. 2007. Mental models in design teams: a valid approach to performance in design collaboration? *CoDesign* 3, no. 1:5-20.

Ball, Linden J., Tom C. Ormerod, and Nicola J. Morley. 2004. Spontaneous Analogizing in Engineering Design: A Comparative Analysis of Experts and Novices. *Design Studies* 25, no. 5:495-508.

Bateson, Gregory. 1972. *Steps to an ecology of mind*. New York: Ballantine Books.

Beckman, Sara L., and Michael Barry. 2007. Innovation as a Learning Process: Embedding Design Thinking. *California Management Review* 50, no. 1:25-56.

Berkun, Scott. 2007. *The Myths of Innovation*. Sebastopol, California, CA: O'Reilly Media.

Bernard, H. Russell, Peter D. Killworth, and Lee Sailer. 1982. Informant accuracy in social-network data V: An experimental attempt to predict actual communication from recall data. *Social Science Research* 5:30-66.

Beyer, Hugh, and Karen Holtzblatt. 1998. *Contextual Design: Defining Customer-Centered Systems*. San Francisco, California, United States: Morgan Kaufmann.

Bierhals, Reimer, Ilona Schuster, P. Kohler, and Petra Badke-Schaub. 2007. Shared mental models—linking team cognition and performance. *CoDesign* 3, no. 1:75-94.

Boehm, Barry. 1995. A Spiral Model of Software Development and Enhancement. *IEEE Engineering Management Review* 23, no. 4:69-81.

Boos, Margarete. 2007. Optimal sharedness of mental models for effective group performance. *CoDesign* 3, no. 1:21-28.

Boroditsky, Lera. 2000. Metaphoric structuring: understanding time through spatial metaphors. *Cognition* 75, no. 1:1-28.

Brassard, Michael, and Diane Ritter. 1994. *The Memory Jogger II: A Pocket Guide of Tools for Continuous Improvement and Effective Planning*. Salem, New Hampshire, United States: GOAL/QPC.

Broden, Nancy, Marisa Gallagher , and Jonathan Woytek. 2004. Use of Narrative in Interaction Design. *Boxes and Arrows*. http://www.boxesandarrows.com/view/use_of_narrative_in_interactive_design.

Bruner, Jerome Seymour. 1990. *Acts of meaning*. Cambridge, Massachusetts, United States: Harvard University Press.

Bucciarelli, Louis L. 1988. An ethnographic perspective on engineering design. *Design Studies* 9, no. 3:159-168.

Bucciarelli, Louis L. 1994. *Designing Engineers*. Cambridge, Massachusetts, United States: MIT Press.

BusinessWeek. 2006. Inside Lenovo's Design Quest. *BusinessWeek: Online Magazine*, September 25 http://www.businessweek.com/magazine/content/06_39/b4002403.htm (Accessed May 3, 2008).

Cardozo, Richard N et al. 2002. Perspective: experiential education in new product design and business development. *Journal of Product Innovation Management* 19, no. 1:4-17.

Carroll , J.M, and Wendy A. Kellogg. 1988. Interface Metaphors and User Interface Design. In *Handbook of Human-computer Interaction*, Ed. Martin Helander, 67-85, Amsterdam : Elsevier Science Publishers B.V.

Casakin, Hernan P. 2006. Assessing the use of Metaphors in the Design Process. *Environment and Planning B: Planning and Design* 33, no. 2:253-268.

Chatman, Jennifer A., Jeffrey T. Polzer, Sigal G. Barsade, and Margaret A. Neale. 1998. Being different yet feeling similar: The influence of demographic composition and organizational culture on work processes and outcomes. *Administrative Science Quarterly* 43, no. 4:749-780.

Christiaans, Henri. 1992. Creativity in design. PhD, Technical University of Delft, Delft, Netherlands.

Clarke, Arthur Charles. 1962. *Profiles of the Future: An Inquiry Into the Limits of the Possible*. New York, New York, United States: Harper & Row.

Cobb, Corie L., Alice M. Agogino, and Sara L. Beckman. 2007. A Longitudinal study of Learning Outcomes in New Product Development. In *Proceedings of ASME IDETC Design Education Conference*, Las Vegas, Nevada, United States.

Cobb, Corie L., Jonathan H. G. Hey, Melissa Lock, Alice M. Agogino, and Sara L. Beckman. 2008. NPD education seen from the Real World: a longitudinal study. *Journal of Product Innovation Management*.

Constantine, Larry L., and Lucy A. D. Lockwood. 1999. *Software for Use: A Practical Guide to the Models and Methods of Usage-Centered Design*. Boston, Massachusetts, United States: Addison-Wesley.

Cooper, Alan. 2004. *The Inmates Are Running the Asylum*. Indianapolis, Indiana, United States: Sams Publishing.

Cooper, Alan. 1995. The Myth of Metaphor. *Visual Basic Programmers Journal*.

Cooper, Robert G. 1998. Predevelopment activities determine new product success. *Industrial Marketing Management* 17, no. 3:237-247.

Corporate Design Foundation. 2008. Multidisciplinary design programs. *Multidisciplinary design programs*. http://www.cdf.org/education/multidisciplinary.html.

Cross, Nigel. 2000. *Engineering Design Methods: Strategies for Product Design*. Chichester, England: John Wiley & Sons.

Deese, J., and Roger A. Kaufman. 1957. Serial effects in recall of unorganized and sequentially organized verbal material. *Journal of experimental psychology* 54, no. 3:180-7.

DeGrace, Peter, and Leslie Hulet Stahl. 1990. *Wicked Problems, Righteous Solutions: A Catalogue of Modern Software*. Upper Saddle River, New Jersey, United States: Prentice Hall.

Design Council. 2008. *Design Index: The Impact of Design on Stock Market Performance*. London, England: Design Council http://www.designcouncil.org.uk/en/About-Design/Research/Design-Index/.

Dickens, Linda, and Karen Watkins. 1999. Action Research: Rethinking Lewin. *Management Learning* 30, no. 2:127-140.

Diller, Steve, Nathan Shedroff, and Darrel Rhea. 2005. *Making Meaning: How Successful Businesses Deliver Meaningful Customer*. Berkeley, California, United States: New Riders Press.

Dong, Andy. 2005. The latent semantic approach to studying design team communication. *Design Studies* 26, no. 5:445-461.

Dorst, Kees. 1997. Describing Design: A Comparison of Paradigms. PhD, Technical University of Delft, Delft, Netherlands.

Dorst, Kees. 2008. Design research: a revolution-waiting-to-happen. *Design Studies* 29, no. 1:4-11.

Dorst, Kees, and Nigel Cross. 2001. Creativity in the design process: co-evolution of problem-solution. *Design Studies* 22, no. 5:425-437.

Dougherty, Deborah. 1992. Interpretive barriers to successful product innovation in large organizations. *Organization Science* 3, no. 2:179-202.

Dreyfus, Hubert L. 2002. Intelligence without representation – Merleau-Ponty's critique of mental representation. *Phenomenology and the Cognitive Sciences* 1, no. 4:367-383.

Dunbar, Kevin N., and Jonathan A. Fugelsang. 2004. Causal Thinking in Science: How Scientists and Students Interpret the Unexpected. In *Scientific and Technological Thinking*, Ed. Michael E. Gorman, Ryan D. Tweney, David C. Gooding, and Alexandra P. Kincannon, 57-80, Hillsdale, New Jersey, United States: Lawrence Erlbaum Associates.

DX Summit. 2004. Reinvigorating Innovation. In *DX Summit*.

Dym, Clive L., Alice M. Agogino, Ozgur Eris, Daniel D. Frey, and Larry J. Leifer. 2005. Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education* 94, no. 1:103-120.

Dym, Clive L., and Patrick Little. 2003. *Engineering Design: A Project-Based Introduction*. 2nd ed. New York, New York, United States: John Wiley.

Dyson, James. 1997. *Against the Odds: An Autobiography*. London, England: Orion.

Eisenhardt, Kathleen M, and Behnam N Tabrizi. 1995. Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry. *Administrative Science Quarterly* 40, no. 1:84.

Elliot, Richard, and Nick Jankel-Elliott. 2003. Using ethnography in strategic consumer research. *Qualitative Market Research* 6, no. 4:215-223.

Elliott, Ame. 2008. Grounded Leaps: Methodological Choices for Driving Innovation. In *presentation at Design Futures talk series*, University of California at Berkeley.

Eris, Ozgur, and Larry J. Leifer. 2003. Facilitating Product Design Knowledge Acquisition: Interaction between the expert and the team. *International Journal of Engineering Education* 19, no. 1:142-152.

Fisher, Kimberley. 1997. Locating Frames in the Discursive Universe. *Sociological Research Online* 2, no. 3. <http://www.socresonline.org.uk/socresonline/2/3/4.html>.

Frey, Daniel D. et al. 2007. An Evaluation of the Pugh Controlled Convergence Method. In *Proceedings of the 19th International Conference on Design Theory and Methodology*, Las Vegas, Nevada, United States.

Gabora, Liane. 2002. Cognitive mechanisms underlying the creative process. In *Proceedings of the 4th conference on Creativity & Cognition*, 126-133, Loughborough, United Kigdom: ACM http://portal.acm.org/citation.cfm?id=581710.581730 (Accessed May 4, 2008).

Gasson, Susan. 1998. Framing design: a social process view of information system development. In *Proceedings of the International Conference on Information Systems*, 224-236, Helsinki, Finland: Association for Information Systems http://portal.acm.org/citation.cfm?id=353073 (Accessed May 12, 2008).

Gaver, William. 2007. Cultural commentators: Non-native interpretations as resources for polyphonic assessment. *International Journal of Human-Computer Studies* 65, no. 4:292-305.

Gavetti, Giovanni, and Jan W. Rivkin. 2005. How Strategists Really Think. (cover story). *Harvard Business Review* 83, no. 4:54-63.

Gentner, Dedre, and Donald R. Gentner. 1983. Flowing waters or teeming crowds: Mental models of electricity. In *Mental Models*, Ed. Dedre Gentner and Albert L. Stevens, 99-129, Hillsdale, New Jersey, United States: Lawrence Erlbaum Associates.

Gentner, Dedre, and Arthur B. Markman. 1997. Structure Mapping in Analogy and Similarity. *American Psychologist* 52, no. 1:45-56.

Gibson, James J. 1977. The Theory of Affordances. In *Perceiving, Acting, and Knowing*, Ed. R. Shaw and J. Bransford, Hillsdale, New Jersey, United States: Erlbaum.

Glesne, Corrine, and Alan Peshkin. 1992. *Becoming Qualitative Researchers: An Introduction*. White Plains, New York, United States: Longman.

Goffman, Erving. 1974. *Frame Analysis: An Essay on the Organization of Experience*. Boston, Massachusetts, United States: Northeastern University Press.

Hatler, Mareca, and Charlie Chi. 2005. *Wireless Sensor Network Market Dynamics*. http://www.onworld.com.

Heilemann, John. 2001. Reinventing the Wheel. *Time Magazine*, December 2 http://www.time.com/time/business/article/0,8599,186660,00.html (Accessed May 2, 2008).

Hertzfeld, Andy. 1981. Bicycle. *Folklore.org: Macintosh stories: Bicycle*. http://www.folklore.org/StoryView.py?project=Macintosh&story=Bicycle.txt.

Hey, Jonathan H. G. 2002. Development of a new tool to guide innovation during upstream project phases. Masters, University of Bath.

Hey, Jonathan H. G., and Alice M. Agogino. 2007. Metaphors in Conceptual Design. In *Proceedings of the 19th International Conference on Design Theory and Methodology*, Las Vegas, Nevada, United States.

Hey, Jonathan H. G., Caneel K. Joyce, and Sara L. Beckman. 2007. Framing innovation: negotiating shared frames during early design phases. *Journal of Design Research* 6, no. 1-2:79-99.

Hey, Jonathan H. G., Julie Linsey, Alice M. Agogino, and Kristin L. Wood. 2007. Analogies and Metaphors in Creative Design. In *Proceedings of the Harvey Mudd Design Workshop VI: Design and Engineering in a Flat World*, Claremont, California, United States.

Hey, Jonathan H. G., Julie Linsey, Alice M. Agogino, and Kristin L. Wood. 2008. Analogies and Metaphors in Creative Design. *International Journal of Engineering Education* 24, no. 2:283-294.

Hey, Jonathan H. G., Alan P. Van Pelt, and Alice M. Agogino. 2006. An Analysis Of Student Reflections From a Multidisciplinary New Product Development Class. In *Proceedings of the 3rd Symposium on International Design and Design Education*, Pennsylvania, Philadelphia, United States.

Hey, Jonathan H. G., Alan P. Van Pelt, Alice M. Agogino, and Sara L. Beckman. 2007. Self-Reflection: Lessons Learned in a New Product Development Class. *Journal of Mechanical Design* 129, no. 7:668-676.

Hey, Jonathan H. G., Jonathan Yu, and Alice M. Agogino. 2008. Design Team Framing: Paths and Principles. In *Proceedings of the 20th International Conference on Design Theory and Methodology*, New York, New York, United States.

Hill, Andrew, Andy Dong, and Alice M. Agogino. 2002. Towards Computational Tools for Supporting the Reflective Team. In *Artificial Intelligence in Design '02*, Ed. John S. Gero, 305-325, Dordrecht, Netherlands: Kluwer Academic Publishers.

Hyman, Barry I. 1998. *Fundamentals of Engineering Design*. New Jersey, United States: Prentice Hall.

Iansiti, Marco. 1995. Shooting the Rapids: Managing Product Development in Turbulent Environments. *California Management Review* 38, no. 1:37-58.

Jansson, David G., and Steven M. Smith. 1991. Design fixation. *Design Studies* 12, no. 1:3-11.

Jones, John Christopher. 1981. *Design Methods: Seeds of human futures*. Chichester, England: John Wiley & Sons.

Kelley, Thomas, and Jonathan Littman. 2005. *The Ten Faces of Innovation*. New York, New York, United States: Doubleday Publishing.

Kelley, Tom, and Jonathan Littman. 2001. *The Art of Innovation*. New York, New York, United States: Currency/Doubleday.

Kemper, Steve. 2005. *Reinventing the Wheel: A Story of Genius, Innovation, and Grand Ambition*. New York, New York, United States: Harper Collins.

Khurana, Anil, and Stephen R. Rosenthal. 1997. Integrating the Fuzzy Front End of New Product Development. *Sloan Management Review* 38, no. 2:103-120.

Kilduff, Martin, Reinhard Angelmar, and Ajay Mehra. 2000. Top Management-Team Diversity and Firm Performance: Examining the Role of Cognitions. *Organization Science* 11, no. 1:21-34.

Kim, W. Chan, and Renée Mauborgne . 2005. Blue Ocean Strategy: From Theory to Practice . *California Management Review* 47, no. 3:105-121.

Kleinsmann, Maaike. 2006. Understanding Collaborative Design. PhD, Technical University of Delft, Delft, Netherlands.

Klimoski, Richard, and Susan Mohammed. 1994. Team Mental Model: Construct or Metaphor? *Journal of Management* 20, no. 2:403-437.

Koberg, Don, and Jim Bagnall. 1981. *The All New Universal Traveler: A Soft-systems Guide to Creativity, Problem-Solving, And The Process Of Reaching Goals*. Los Altos, California, United States: William Kaufmann Inc.

Kolb, David A. 1984. *Experiential Learning: Experience as the Source of Learning and Development*. New Jersey, United States: Prentice-Hall.

Kolb, Erik, Jonathan H. G. Hey, Alice M. Agogino, and Hans-Jurgen Sebastien. 2008. Meta4acle: Generating Compelling Metaphors for Design. In *Proceedings of the 20th International Conference on Design Theory and Methodology*, New York, New York, United States.

Kövecses, Zoltan. 2002. *Metaphor: A Practical Introduction*. New York, New York, United States: Oxford University Press.

Krug, Steve. 2005. *Don't make me think!: a common sense approach to Web usability*. Berkeley, California, United States: New Riders Press.

Lakoff, George. 2004. *Don't Think of an Elephant!: Know Your Values and Frame the Debate*. White River Junction, Vermont, United States: Chelsea Green Publishing.

Lakoff, George, and Mark Johnson. 1980. *Metaphors We Live by*. Chicago, Illinois, United States: University of Chicago Press.

Lakoff, George, and Mark Johnson. 1999. *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. New York, New York, United States: Basic Books.

Landauer, Thomas K, Peter W Foltz, and Darrell Laham. 1998. An Introduction to Latent Semantic Analysis. *Discourse Processes* 25, no. 2/3:259-284.

Lanzara , Giovan Francesco. 1983. The Design Process: Frames, Metaphors, and Games. In *Systems Design For, With, and by the Users*, Ed. Ulrich Briefs, Claudio Ciborra, and Leslie Schneider, 29-40, New York, New York, United States: North-Holland Publishing Company.

Laurel, Brenda. 2003. *Design Research: Methods and Perspectives*. Cambridge, Massachusetts, United States : MIT Press.

Lawler, John M. 1999. Metaphors We Compute By. In *Figures of Thought for College Writers*, Ed. Dona J. Hickey, 411-422, Mountain View, California, United States: Mayfield Publishing.

Lawson, Bryan R., and Kees Dorst. 2005. Acquiring Design Expertise. In *Computational and Cognitive Models of Creative Design VI*, Ed. John S. Gero and Mary Lou Maher, 211-230, Sydney, Australia: Key Centre of Design Computing & Cognition, University of Sydney.

Legardeur, Jeremy. 2001. Méthodes et outils pour l'innovation produit/process: Le cas de l'intégration des matériaux composites SMC. Institut National Polytechnique de Grenoble.

Legardeur, Jeremy, Jean-Francois Boujut, and Jonathan H. G. Hey. 2003. Information sharing for knowledge creation during early design phases. In *Proceedings of the 10th ISPE International Conference on Concurrent Engineering*, Madeira, Portugal.

Leonard, Dorothy, and Jeffrey F. Rayport. 1997. Spark innovation through empathic design. *Harvard Business Review* 75, no. 6:102-113.

Lim, Beng-Chong, and Katherine J. Klein. 2006. Team mental models and team performance: a field study of the effects of team mental model similarity and accuracy. *Journal of Organizational Behavior* 27, no. 4:403-418.

Linsey, Julie S., Matthew G. Green, J. T. Murphy, Kristin L. Wood, and Art B. Markman. 2005. Collaborating to Success: An Experimental Study of Group Idea Generation Techniques. In *Proceedings of the 17th International Conference on Design Theory and Methodology*, Long Beach, California, United States.

Linsey, Julie S., Jeff Laux, E. F. Clauss, Kristin L. Wood, and Art B. Markman. 2007. Increasing Innovation: A Trilogy of Experiments towards a Design-By-Analogy Methodology. In *Proceedings of the 19th International Conference on Design Theory and Methodology*, Las Vegas, Nevada, United States.

Liston, Kathleen , Martin Fischer, and John Kunz. 2000. Requirements and Benefits of Interactive Information Workspaces in Construction. In *8th International Conference on Computing in Civil and Building Engineering*, University of Stanford, California, United States.

Lundholm, Carl Gustaf. 2003. The use of metaphors in product design: An overview of design activities from a metaphor perspective. http://design.ntnu.no/forskning/artikler/2003/Lundholm.pdf.

MacQueen, Kathleen M., Eleanor McLellan, Kelly Kay, and Bobby Milstein. 1998. Codebook Development for Team-Based Qualitative Analysis. *Cultural Anthropology Methods* 10, no. 2:31-36.

Madsen, Kim H. 1994. A guide to metaphorical design. *Communications of the ACM* 37, no. 12:57-62.

Madsen, Kim Halskov. 1989. Breakthough by Breakdown: Metaphors and Structured Domains. In *Systems Development for Human Progress*, Ed. Heinz-Karl Klein and Kuldeep Kumar, 41-53, New York, New York, United States: North-Holland Publishing Company.

Maglio, Paul P., and Teenie Matlock. 1999. The conceptual structure of information space. In *Social Navigation of Information Space*, Ed. Alan J. Munro, Kristina Hook, and David Benyon, 155-173, London, England: Springer-Verlag.

Mariampolski, Hy. 2005. *Ethnography for Marketers: A Guide to Consumer Immersion*. Thousand Oaks, California, United States: SAGE Publications.

Mariampolski, Hy. 1999. The Power of Ethnography: Qualitative Research for the 21st Century. *Journal of the Market Research Society* 41, no. 1. <http://find.galegroup.com/itx/infomark.do?&contentSet=IAC-Documents&type=retrieve&tabID=T002&prodId=EAIM&docId=A54115852&source=gale&srcprod=EAIM&userGroupName=ucberkeley&version=1.0>.

Marks, Michelle A, Mark J Sabella, C Shawn Burke, and Stephen J Zaccaro. 2002. The impact of cross-training on team effectiveness. *The Journal of applied psychology* 87, no. 1:3-13.

Marshall, Nick. 2007. Team mental models in action: a practice-based perspective. *CoDesign* 3, no. 1:29-36.

Mathieu, John E, M. T. Maynard, Tammy L. Rapp, and P. M. Mangos. 2006. Interactive effects of team and task shared mental models as related to air traffic controllers' team efficacy and effectiveness. In *Proceedings of the Annual meeting of the Academy of Management Conference*, Atlanta, Georgia, United States.

McDonnell, Janet, Peter Lloyd, and Rianne C. Valkenburg. 2004. Developing design expertise through the construction of video stories. *Design Studies* 25, no. 5:509-525.

McDonough, William, and Michael Braungart. 2002. *Cradle to Cradle: Remaking the Way We Make Things*. New York, New York, United States: North Point Press.

Melican, Jay P. 2000. Describing user centered designing: how design teams apply user. research data in problem solving. PhD, Illinois Institute of Technology, Chicago.

Minsky, Marvin. 1975. A Framework for Representing Knowledge. In *The Psychology of Computer Vision*, Ed. Patrick Henry Winston and Berthold Horn, 282, New York, New York, United States: McGraw-Hill.

Mohammed, Susan. 2001. Toward an Understanding of Cognitive Consensus in a Group Decision-Making Context. *Journal of Applied Behavioral Science* 37, no. 4:408-425.

Mohammed, Susan, Richard Klimoski, and Joan R. Rentsch. 2000. The Measurement of Team Mental Models: We Have No Shared Schema. *Organizational Research Methods* 3, no. 2:123-165.

Mohnkern, Ken. 1997. Beyond the interface metaphor. *SIGCHI Bulletin* 29, no. 2:11-15.

Motorola. 2008. Motorola Pebl Phone. http://www.motorola.com/motoinfo/product/details.jsp?globalObjectId=87.

Muller, Michael J., and Sarah Kuhn. 1993. Participatory design. *Commununications of the ACM* 36, no. 6:24-28.

Nemeth, Charlan J. 1986. Differential contributions of majority and minority influence. *Psychological Review* 93, no. 1:23-32.

Nielsen, Jakob. 2008. Bridging the Designer–User Gap. *Jakob Nielsen's Alertbox*. http://www.useit.com/alertbox/designer-user-differences.html.

Nonaka, Ikujiro. 1991. The Knowledge-Creating Company. *Harvard Business Review* 69, no. 6:96-104.

Ochs, John B. 2007. Integrated Product Development at LeHigh University. http://www.lehigh.edu/ipd/ .

Osborn, Alex Faickney. 1953. *Applied imagination: principles and procedures of creative thinking*. New York, New York, United States: Scribner's Sons.

Otto, Kevin N., and Kristin L. Wood. 2001. *Product Design: Techniques in Reverse Engineering and New Product Development*. New Jersey, United States: Prentice Hall.

Ovans, Andrea. 1998. The customer doesn't always know best. *Harvard Business Review* 76, no. 3.

Owen, Charles. 1993. Considering Design Fundamentally. *Design Processes Newsletter* 5, no. 3:1-5.

Owen, Charles. 2001. Structured Planning in Design: Information-Age Tools for Product Development. *Design Issues* 17, no. 1:27-43.

Page, Albert L., and Gary R. Schirr. 2008. Growth and Development of a Body of Knowledge: 16 Years of New Product Development Research, 1989-2004. *Journal of Product Innovation Management* 25, no. 3:233-248.

Page, Scott E. 2007. *The Difference: How the Power of Diversity Creates Better Groups, Firms*. Princeton, New Jersey, United States: Princeton UniversityPress.

Pahl, Gerhard, and Wolfgang Beitz. 1984. *Engineering Design: A Systematic Approach*. Trans. Ken Wallace. London, England: Springer London.

Patnaik, Dev. 2004. System Logics: Organizing Your Offerings to Solve People's Big Needs. *Design Management Review* 15, no. 3:50-57.

Patnaik, Dev, and Robert Becker. 1999. Needfinding: The Why and How of Uncovering People's Needs. *Design Management Journal* 10, no. 2:37-43.

Patton, Michael Quinn. 2002. *Qualitative Research and Evaluation Methods*. 3rd ed. Thousand Oaks, California, United States: Sage Publications Inc.

Pink, Daniel H. 2006. *A Whole New Mind: Why Right-brainers Will Rule the Future*. New York, New York, United States: Riverhead Books.

Polanyi, Michael. 1966. *The Tacit Dimension*. New York, New York, United States: Doubleday Publishing.

Pugh, Stuart. 1991. *Total Design: Integrated Methods for Successful Product Engineering*. Reading, Massachusetts, United States: Addison-Wesley.

Quittner, Josh. 2002. Apple's Latest Fruit. *Time Magazine*, January 27 http://www.time.com/time/covers/1101020114/cover.html (Accessed January 1, 2008).

Raijmakers, Bas, William W. Gaver, and Jon Bishay. 2006. Design documentaries: inspiring design research through documentary film. In *Proceedings of the 6th conference on Designing Interactive systems*, 229-238, University Park, Pennsylvania, United States: ACM Press http://portal.acm.org/citation.cfm?id=1142405.1142441 (Accessed May 4, 2008).

Raymond, Eric S. 2001. *The Cathedral and the Bazaar: Musings on Linux and Open Source by an*. Sebastopol, California, CA: O'Reilly.

Reagans, Ray, and Ezra W. Zuckerman. 2001. Networks, Diversity, and Productivity: The Social Capital of Corporate R&D Teams. *Organization Science* 12, no. 4:502-517.

Reddy, Michael J. 1979. The Conduit Metaphor: A case of frame conflict in our language about language. In *Metaphor and Thought*, Ed. Andrew Ortony, 284-324, Cambridge, England: Cambridge University Press.

Rein, Martin, and Donald A. Schön. 1991. Frame Reflective Policy Discourse. In *Social sciences and modern states: national experiences and theoretical*, Ed. Peter Wagner, Carol H. Weiss, Björn Wittrock, and Hellmut Wollmann, 262-289, Cambridge, England: Cambridge University Press.

Rittel, Horst W. J. 1984. Second Generation Design Methods. In *Developments in design methodology*, Ed. Nigel Cross, 317-327, Chichester, England: John Wiley & Sons.

Rittel, Horst W. J., and Melvin M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4, no. 2:155-169.

Rivlin, Gary. 2003. Segway's Breakdown. *Wired*, March.

Roth, Bernie. 2007. Reflections on design thinking. In *presentation at Harvey Mudd Design Workshop VI*, Claremont, California, United States.

Rothwell, Roy. 1972. *Factors for Success in Industrial Innovations: Project SAPPHO – A Comparative Study of Success and Failure in Industrial Innovation*. Brighton, England: University of Sussex.

Royce, W. W. 1987. Managing the development of large software systems: concepts and techniques. In *Proceedings of the 9th international conference on Software Engineering*, 328-338, Monterey, California, United States: IEEE Computer Society Press http://portal.acm.org/citation.cfm?id=41765.41801 (Accessed May 1, 2008).

Ryokai, Kimiko, Stefan Marti, and Hiroshi Ishii. 2005. Designing the world as your palette. In *CHI '05 extended abstracts on Human factors in computing systems*, 1037-1049, Portland, Oregon, United States: ACM http://portal.acm.org/citation.cfm?id=1056808.1056816 (Accessed May 4, 2008).

Salonen, Mikko, and Matti Pertulla. 2005. Utilization of Concept Selection Methods – A Survey of Finnish Industry. In *Proceedings of the 17th International Conference on Design Theory and Methodology*, Long Beach, California, United States.

Sandhu, Jaspal S., P. Altankhuyag, and D. Amarsaikhan. 2007. Serial Hanging Out: Rapid Ethnographic Needs Assessment in Rural Settings. In *Human-Computer Interaction. Interaction Design and Usability*, 614-623 http://dx.doi.org/10.1007/978-3-540-73105-4_68 (Accessed May 3, 2008).

Schön, Donald A. 1979. Generative metaphor: a perspective on problem setting in social policy. In *Metaphor and Thought*, Ed. Andrew Ortony, 254-283, Cambridge, England: Cambridge University Press.

Schön, Donald A. 1984. Problems, frames and perspectives on designing. *Design Studies* 5, no. 3:132-136.

Schön, Donald A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. New York, New York, United States: Basic Books.

Schön, Donald A., and Martin Rein. 1994. *Frame Reflection: Toward the Resolution of Intractable Policy Controversies*. New York, New York, United States: Basic Books.

Schuler, Douglas, and Aki Namioka, ed. 1993. *Participatory Design: Principles and Practices*. Lawrence Erlbaum Associates.

Schunn, Christian D., and Kevin Dunbar. 1996. Priming, analogy, and awareness in complex reasoning. *Memory & Cognition* 24, no. 3:271-284.

Seybold, Patricia B. 2001. Get inside the lives of your customers. *Harvard Business Review* 79, no. 5:80-89.

Simmons, Annette. 2006. *The Story Factor: Secrets of Influence From the Art of Storytelling*. New York, New York, United States: Basic Books.

Simon, Herbert Alexander. 1969. *The sciences of the artificial*. Cambridge, Massachusetts, United States: MIT Press.

Simon, Herbert Alexander. 1973. The structure of ill-structured problems. *Artificial Intelligence* 4:181-201.

Sleeswijk Visser, Froukje, Remko Van Der Lugt, and Pieter Jan Stappers. 2007. Sharing User Experiences in the Product Innovation Process: Participatory Design Needs Participatory Communication. *Creativity and Innovation Management* 16, no. 1:35-45.

Smith-Jentsch, Kimberly A, John E Mathieu, and Kurt Kraiger. 2005. Investigating linear and interactive effects of shared mental models on safety and efficiency in a field setting. *The Journal of applied psychology* 90, no. 3:523-35.

Song, Shuang, and Alice M. Agogino. 2004. An Analysis of Designers' Sketching Activities in New Product Design Teams. In *Proceedings of the 16th International Conference on Design Theory and Methodology*, Salt Lake City, Utah, United States.

Song, Shuang, Andy Dong, and Alice M. Agogino. 2003. Time Variation of Design "Story Telling" in Engineering Design Teams. In *Proceedings of the 14th International Conference on Engineering Design*, Stockholm, Sweden.

Sproull, Lee S., and Kay Ramsay Hofmeister. 1986. Thinking About Implementation. *Journal of Management* 12, no. 1:43-60.

Squires, Susan Elaine, and Bryan Byrne. 2002. *Creating Breakthrough Ideas: The Collaboration of Anthropologists and*. Westport, Connecticut, United States: Bergin & Garvey.

Stasser, Garold, and William Titus. 1985. Pooling of unshared information in group decision making: Biased information sampling during discussion. *Journal of Personality and Social Psychology* 48, no. 6:1467-1478.

Stocking, George W. Jr. 1983. The ethnographer's magic: Fieldwork in British anthropology from Taylor to Malinowski. In *Observers Observed: Essays on Ethnographic Fieldwork*, Ed. George W. Jr. Stocking, 70-120, Madison, Wisconsin, United States: University of Wisconsin Press.

Stubblefield, William A. 1998. Patterns of change in design metaphor: a case study. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, 73-80, Los Angeles, California, United States: ACM Press/Addison-Wesley Publishing Co. http://portal.acm.org/citation.cfm?id=274656 (Accessed May 4, 2008).

Stumpf, Simone C. 2001. Analysis and representation of rhetorical construction of understanding in design teams' experiential learning. PhD, University of London.

Stumpf, Simone C., and Janet T. McDonnell. 2002. Talking about team framing: using argumentation to analyse and support experiential learning in early design episodes. *Design Studies* 23, no. 1:5-23.

Sutton, Robert I., and Andrew Hargadon. 1996. Brainstorming Groups in Context: Effectiveness in a Product Design Firm. *Administrative Science Quarterly* 41, no. 4:685-718.

Terra Media. 2008. Media quotations. *Media quotations*. http://www.terramedia.co.uk/quotations/Quotes_S.htm .

257

Ullman, David G. 1992. *The mechanical design process*. New York, New York, United States: McGraw-Hill.

Ulrich, Karl T., and Steven D. Eppinger. 1995. *Product Design and Development*. New York, New York, United States: McGraw-Hill.

Ulrich, Karl T., and Steven D. Eppinger. 2005. *Product Design and Development*. New York, New York, United States: McGraw-Hill.

Valkenburg, Rianne. 2000. The Reflective Practice in product design teams. PhD, Technical University of Delft, Delft, Netherlands.

Valkenburg, Rianne, and Kees Dorst. 1998. The reflective practice of design teams. *Design Studies* 19, no. 3:249-271.

Van Pelt, Alan P., and Jonathan H. G. Hey. 2006. Using Triz and Human-Centered Design for Consumer Product Development. In *Proceedings European TRIZ Association (ETRIA) World Conference*, Kortijk, Belgium.

Wai, Conrad, and Pete Mortensen. 2007. Persuasive Technologies Should Be Boring. In *Persuasive Technology*, 96-99, Heidelberg, Germany: Springer Berlin http://dx.doi.org/10.1007/978-3-540-77006-0_12 (Accessed May 5, 2008).

Wallas, Graham. 1926. *The Art of Thought*. New York, New York, United States: Harcourt, Brace and Company.

Waller, Mary J., Naina Gupta, and Robert C. Giambatista. 2004. Effects of Adaptive Behaviors and Shared Mental Models on Control Crew Performance. *Manage. Sci.* 50, no. 11:1534-1544.

Wegner, Daniel M. 1987. Transactive memory: A contemporary analysis of the group mind. In *Theories of Group Behavior*, Ed. Brian Mullen and George R. Goethals, 185-208, New York, New York, United States: Springer-Verlag.

Wegner, Daniel M., T. Giuliano, and P. Hertel. 1985. Cognitive Interdependence in Close Relationships. In *Compatible and Incompatible Relationships*, Ed. William John Ickes, 253-276, New York, New York, United States: Springer-Verlag.

Weick, Karl E. 1993. Organizational redesign as improvisation. In *Organizational Change and Redesign: Ideas and Insights for Improving Performance*, Ed. George P. Huber and William H. Glick, 450, New York, New York, United States: Oxford University Press.

Weick, Karl E. 1979. *The Social Psychology of Organizing*. New York, New York, United States: McGraw-Hill.

Whelton, Michael. 2004. The development of purpose in the project definition phase of construction projects – Implications for project management. PhD, University of California at Berkeley.

Whelton, Michael, and Glenn Ballard. 2002. Wicked problems in project definition. In *Proceedings of the International Group for Lean Construction 10th Annual Conference*, Brazil.

Wong, Alison H. 2008. The Product Design Process: A Graphic Novel. http://ahwong.com/comics.html.

Wright, Paul Kenneth. 2000. *21st Century Manufacturing*. New Jersey, United States: Prentice Hall.

Wright, Peter, and John McCarthy. 2008. Empathy and experience in HCI. In *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*,

637-646, Florence, Italy: ACM
http://portal.acm.org/citation.cfm?id=1357054.1357156&coll=GUIDE&dl=GUIDE&C
FID=8769660&CFTOKEN=31930253 (Accessed May 5, 2008).

Yang, Maria C. 2007. Design Methods, Tools, and Outcome Measures: A Survey of
Practitioners. In *Proceedings of the 19th International Conference on Design Theory
and Methodology*, Las Vegas, Nevada, United States.

Yin, Robert K. 2003. *Case Study Research: Design and Methods*. Beverly Hills, California,
United States: Sage Publications Inc.

Ylirisku, Salu, and Jacob Buur. 2007. *Designing with Video: Focusing the User-Centred
Design Process*. Heidelberg, Germany: Springer Berlin.

Zirger, Billie Jo, and Modesto A. Maidique. 1990. A model of new product development: an
empirical test. *Management Science* 36, no. 7:867-883.

11 Appendix

Additional information

Contents

- Project List

- Sample team evaluation survey

- New product development alumni survey

- Finding framing data collection and analysis

- Design path interview coding

- Design path classification protocol

- Choose your own design path tool

- Human subjects approval

- Reflection

Project list

Table A1   Project teams included in the Chapter 05 Finding Framing study

#	Year	School	Team size	Team name
1	2005	Berkeley	4	Reducing obesity in the young
2	2005	Berkeley	5	Communicating in emergencies
3	2005	Berkeley	5	Growing old gracefully
4	2005	Berkeley	4	Safer stoves
5	2005	Berkeley	5	Emergency Water Supply
6	2005	Berkeley	5	Healthy meals for schools
7	2005	Berkeley	6	Enhancing packaging
8	2005	Berkeley	5	DriveConnect
9	2005	Berkeley	5	Improving communication for the hearing impaired
10	2005	Berkeley	5	Child floating clothing
11	2005	Berkeley	4	Childhood poisoning
12	2005	Berkeley	5	In touch in the developing world
13	2005	Berkeley	6	Increasing pet adoptions
14	2005	Berkeley	6	Better bus information
15	2005	Berkeley	4	Wireless handheld learning
16	2005	Berkeley	5	Connecting non-profits and volunteers
17	2005	Berkeley	4	Address book agenda
18	2005	Berkeley	5	Web site for connecting graduates
19	2005	Berkeley	5	Improving the supermarket experience
20	2005	Berkeley	5	Supporting youth in underprivileged areas

21	2005	Berkeley	5	Wine-tasting for dummies
22	2005	Berkeley	5	A clean and safe toaster
23	2006	MIT	6	Bathroom storage
24	2006	MIT	7	Green and clean garbage
25	2006	MIT	7	Spice bottles 2.0
26	2006	MIT	7	Perfect salted glasses
27	2006	MIT	7	Alphabet games
28	2006	MIT	7	Car door opener
29	2006	MIT	9	Adventure headcam
30	2006	MIT	7	Clean water pack
31	2006	MIT	7	Space-saving bottle
32	2006	MIT	6	No-mess bagel spreader

Table A2   Project teams included in the Chapter 06 Design Paths study

#	Year	School	Team size	Team name
1	2004	Berkeley	4	Bike safety 1
2	2004	Berkeley	4	Bike safety 2
3	2004	Berkeley	5	Clubbing storage for girls
4	2004	Berkeley	5	Surprise sun protection
5	2004	Berkeley	4	Local transport wheels
6	2004	Berkeley	5	Car smileys
7	2004	Berkeley	5	GiftDisc
8	2004	Berkeley	5	Auction site wedding list
9	2004	Berkeley	4	Soccer sack
10	2004	Berkeley	5	WaterMeter
11	2004	Berkeley	5	Vineyard wireless cold response
12	2004	Berkeley	5	Untangle wires
13	2004	Berkeley	4	On-time bus information
14	2004	Berkeley	5	Mile high sleeping
15	2004	Berkeley	4	The perfect temperature duvet
16	2004	Berkeley	5	Business travel luggage
17	2004	Berkeley	4	Preventing powder ski loss
18	2005	Berkeley	4	Reducing obesity in the young
19	2005	Berkeley	5	Communicating in emergencies
20	2005	Berkeley	5	Growing old gracefully
21	2005	Berkeley	4	Safer stoves
22	2005	Berkeley	5	Emergency Water Supply

23	2005	Berkeley	5	Healthy meals for schools
24	2005	Berkeley	6	Enhancing packaging
25	2005	Berkeley	5	DriveConnect
26	2005	Berkeley	5	Improving communication for the hearing impaired
27	2005	Berkeley	5	Child floating clothing
28	2005	Berkeley	4	Childhood poisoning
29	2005	Berkeley	5	In touch in the developing world
30	2006	Berkeley	5	Healthy instant noodle
31	2006	Berkeley	5	Greencycling
32	2006	Berkeley	5	Comfortable chemistry
33	2006	Berkeley	5	Restaurant games
34	2006	Berkeley	4	Airport seating
35	2006	Berkeley	5	Family friendly fast food
36	2006	Berkeley	4	Migrant worker protection
37	2006	Berkeley	5	Extreme photographer pack
38	2006	Berkeley	5	CAD Estimation
39	2006	Berkeley	5	DVT destroyer
40	2006	Berkeley	5	Info kitchen
41	2006	Berkeley	4	A million friends
42	2006	Berkeley	4	FutureBook
43	2006	Berkeley	4	C-Suite lunches
44	2007	Berkeley	6	SIGNALS
45	2007	Berkeley	6	Household energy information
46	2007	Berkeley	6	Wine-buying woes

47	2007	Berkeley	5	Leaving library laptops
48	2007	Berkeley	5	Linking musers to choosers
49	2007	Berkeley	6	Kid Net
50	2007	Berkeley	5	Solar on the move
51	2007	Berkeley	4	Overheating in heatwaves
52	2007	Berkeley	6	Feedback
53	2007	Berkeley	4	Earthquake family connector
54	2007	Berkeley	6	Oski cycle
55	2007	Berkeley	6	Safe bike zones
56	2007	Berkeley	6	Digital recipe reel
57	2007	Berkeley	6	Better bike rack
58	2007	Berkeley	6	Lavacleaner
59	2007	Berkeley	6	Cell phone choice

Table A3   Project teams included in the Chapter 07 Metaphor and Framing study

#	Year	School	Team size	Team name
50	2006	Berkeley	5	Healthy instant noodle
51	2006	Berkeley	5	Greencycling
52	2006	Berkeley	5	Comfortable chemistry
53	2006	Berkeley	5	Restaurant games
54	2006	Berkeley	4	Airport seating
55	2006	Berkeley	5	Family friendly fast food
56	2006	Berkeley	4	Migrant worker protection
57	2006	Berkeley	5	Extreme photographer pack
58	2006	Berkeley	5	CAD Estimation
59	2006	Berkeley	5	DVT destroyer
60	2006	Berkeley	5	Info kitchen
61	2006	Berkeley	4	A million friends
62	2006	Berkeley	4	FutureBook
63	2006	Berkeley	4	C-Suite lunches

Sample team evaluation survey

Variations of this team evaluation survey were used throughout the years of the study. The primary goal of the survey was to give the team members the opportunity to reflect on their performance and give feedback to each other anonymously. Individual and team level reports were created for both mid-semester and final team evaluations and returned to the teams with a short comment from faculty (if there were few difficulties), or a more in-depth intervention if required. Survey text from Fall 2007 follows.

1. Team Survey

This survey prompts you to reflect on how your project has been going, and give anonymous, honest feedback to your team. It is based on a survey instrument used in professional new product development settings. Completing the team feedback survey is an assignment, however, the content of your responses will NOT affect your grade in any way. This survey is part of the course each year for three reasons:

1. It provides anonymous feedback on how you are viewed by your team. This is a unique opportunity for you to receive extensive peer or 360 degree feedback, and see how you are viewed by others in a team project setting. The value to your teammates depends on your honest, straightforward, and thorough responses. Responses are aggregated, so that individual answers will not be identifiable.

2. It provides you with a chance to reflect on the process and what has worked or not worked for you to date. This is an important process for you to go through, so take your time & be honest with yourself in answering.

3. It provides the faculty with insight into your projects. The faculty want to see your impressions of the class, your project, and your team. They depend on your accuracy & thoroughness to help identify areas for improvement and assistance, and get insight into the

way you have been thinking about the NPD process. Again, the information you provide in this survey is NOT used in any way in determining your project or class grade.

The survey should take 30 mins or less to complete. You do not need to finish it in one sitting. (Each time you move onto the next page, your work is saved.)

1. Your Name:

_____

2. Your Team

This section allows you to provide your thoughts on your team as a whole. This feedback will be averaged with that of your teammates', and returned to your team anonymously.

2. Did all members of the group share in the team's responsibilities?

(Some members did not work at all; A few members did most of the work; The work was generally shared by all members; Everyone did an equal share of the work)

3. Satisfaction: if you had a chance to change your project (product or service) or your team, would you want to?

(Would want very much to change; Would rather change than stick with the same...; May want to change but not sure; Would make no difference to me; May want to stay but not sure; Would rather stick with the same...; Would want very much to stick with the same...)

Product/Service

Team

3. Team Communication

4. On average, how many HOURS PER WEEK would you estimate your team spends interacting in each of the following ways? IMPORTANT: Answer using numbers only (e.g.

"1.5" not "one to two hours") (We are interested in the relative importance of these communication methods; you are not being evaluated on the number of hours you report)

Face-to-face meetings: _____

Email: _____

Telephone: _____

Online collaboration system: _____

Doing user research: _____

Working on your own: _____

Other (give hours & describe): _____

5. Team Communication

(Strongly disagree; Mostly disagree; Disagree somewhat; Not sure; Agree somewhat; Mostly agree; Strongly agree)

I feel like I am really part of my team.

We make decisions as a team.

We are effective at sharing information with each other (e.g. research findings, ideas, thoughts on the project).

I feel comfortable sharing my own thoughts/ideas.

4. How does your team think?

(1. strongly disagree; 2. moderately disagree; 3. slightly disagree; 4. Neither; 5. slightly agree; 6. moderately agree; 7. strongly agree)

We would probably all say that we buy into our team's mission statement.

My team has clearly articulated values and decision-making norms.

We have stated the concrete goals of our team.

My team is clear on what "solution" (product or service concept) we're trying to create.

It seems like my team doesn't have a strong common goal to unite us.

We are explicit about what's within the scope of our project concept, and what's outside of it.

We tend not to set our team's goals and values out loud or on paper.

I don't think anybody really feels the same way about what we're trying to do.

We are really on the same page about what problem we want to solve with our project.

5. Roles and responsibilities

This section allows you to comment on the different roles and responsibilities within your team. Please rate each person, including yourself.

7. Team member 1

Contributes useful ideas

Does more than their fair share of work

Has strong preconceived ideas about what we're going to develop

Is excessively dominating in group discussions

Delivers work when promised/needed

Has the respect of the group

Has influence within the group

Is on the same page as me about what's important to our project

Is willing to change his or her mind based on what's learned

Communicates ideas clearly/effectively

Is fully engaged in discussions during meetings

Takes a leadership role in some aspects of the project

Keeps an open mind / was willing to consider other's ideas

[Repeats for each team member]

11. All Teammates

13. Please distribute 100 pts. among your team's members, including yourself, for their overall contribution to the team's efforts (including work, communication, problem solving, etc.). The total points must add up to 100.

Team member 1: _____

Team member 2: _____

Team member 3: _____

Team member 4: _____

Team member 5: _____

Team member 6: _____

15. Please provide one reason why you assigned each role.

Team member 1: _____

Team member 2: _____

Team member 3: _____

Team member 4: _____

Team member 5: _____

Team member 6: _____

16. Please select the name of the member who you think provided the most leadership.

_____

12. Reflection

You're almost done!

Before completing this last page, we suggest that you take a short break. Reflect on your experience in the design process so far, then give your thoughtful answers to the following four questions.

These answers are for the faculty and will not be included in the team feedback report. Of course, your team may wish to share parts of what you discover in this process, but these answers will be kept confidential.

17. **Please describe briefly what you learned about the NPD process and working on a cross-disciplinary team during this assignment.** (1-2 sentences or more)

18. **Please write a brief description of any problems or conflicts you encountered in working with your team and how they were resolved.** Please be sure to mention any difficulties you've had in getting 'on the same page' and specifically how that was resolved (if it was!). (1 paragraph)

19. **If there's anything else you would like to communicate to the faculty or anonymously to your team you may write it here.** (optional)

13. Thank you!

You're done! Your thoughtful responses will be valuable to you and your team. The team will receive the results as soon as we can process them.

Close this window to exit the survey.

New product development alumni survey

This survey was used in the last part of Chapter 04. The survey was web-based but is shown in a printed form for convenience.

Figure A1   New product development alumni survey page 1

Managing the New Product Development Process Alumni Feedback

✱ 3. Please indicate the extent to which you agree with each of the following statements about the Managing the New Product Development (NPD) class.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Overall the NPD course was useful for my undergraduate/graduate study.	○	○	○	○	○
2. Overall the NPD course has been useful for what I have done since leaving school.	○	○	○	○	○
3. I would recommend this class to anyone who has an interest in product development.	○	○	○	○	○
4. I am presently using specific lessons from the class in my daily work.	○	○	○	○	○

✱ 4. How did this course change your interest in new product development?

○ Substantially Increased

○ Increased

○ Remained the Same

○ Decreased

○ Substantially Decreased

5. We are interested to know a little about how some of the elements of the NPD process are carried out at your company. Please briefly explain how you approach each of the following. You may answer generically for your company or for a specific project on which you have worked.

Understanding customer and user needs	
Concept generation	
Concept selection	
Project team formation	

6. We're really interested to hear any other comments you have about the topics covered in the class and their relevance to you.

3. Team Project

In this section, we want to understand the importance of the team project you did in the class and the role it played in your overall experience of the class.

✱ 7. What project did you work on in the class?

Figure A2   New product development alumni survey page 2

Managing the New Product Development Process Alumni Feedback

* 8. Please rate the following:

	Highly Effective	Effective	Neutral	Ineffective	Highly Ineffective	Don't Recall or Not Applicable
1. Was the class project an effective learning experience while you were in school?	○	○	○	○	○	○
2. Have the lessons you learned from the class project been effective in your work since leaving school?	○	○	○	○	○	○

* 9. Did your team ever consider taking the product or service you developed any further after the class ended?

○ Yes (Go to Question 10)

○ No (Skip to Question 12)

10. If you DID pursue your product or service beyond the class, how far did you get in the process? Did you or are you pursuing additional funding or entering business plan competitions?

11. If you ARE still pursuing the project, how has your team changed since the class?

12. If you DID NOT pursue taking your product or service to market, please tell us why.

* 13. Overall did you feel more engaged in this class compared to others you took?

○ More engaged than most   ○ About the same   ○ Less engaged than most

14. What do you remember most from your project experience that has been helpful in your work since the class? Can you give any examples?

4. Summary Thoughts

Here you can add more information about what you learned from the class as well as what you would suggest be added to the class in future years.

Figure A3   New product development alumni survey page 3

275

Managing the New Product Development Process Alumni Feedback

15. Describe at least two tangible takeaways about new product development or innovation that you received from the course.

16. From your experience to date with new product or service development what would you add to the course that can help the current students in their careers?

17. We welcome any other comments you would like to make about the class itself or innovation in general.

5. Background and current work

This final section will help us better understand your background and the work you do now.

* 18. In what year did you take the New Product Development class?

* 19. What program were you affiliated with when you took the NPD class?

- ( ) Bioengineering
- ( ) Chemical Engineering
- ( ) Civil and Environmental Engineering
- ( ) Electrical Engineering/Computer Science
- ( ) Industrial Design
- ( ) Industrial Engineering
- ( ) Materials Science
- ( ) MBA
- ( ) Mechanical Engineering
- ( ) Nuclear Engineering
- ( ) School of Information Management and Systems
- ( ) Other (please specify)

* 20. What industry do you currently work in?

* 21. Which of the following best describes the functional area in which you work?

* 22. What is your current job title?

Figure A4   New product development alumni survey page 4

23. Please provide a short description of the responsibilities you have in your position.

6. Thank you and follow up

Thank you for your participation in this survey. If you would like to stay in touch with us, please provide your preferred e-mail address below.

Thanks for your time,

Sara Beckman
beckman@haas.berkeley.edu

Alice Agogino
agogino@berkeley.edu

Leslie Speer
leslie.speer@sjsu.edu

Corie Cobb
ccobb@berkeley.edu

Jonathan Hey
jono@berkeley.edu

24. Preferred E-mail address

25. Would you be interested in participating in a follow up phone interview?

○ Yes

○ No

○ Maybe

Figure A5   New product development alumni survey page 5

Finding framing data collection and analysis

Data collection protocol for MIT

Data collected at the MIT new product development class followed the data collection at Berkeley. It was assisted by Jessica Dolak. Below are the key tasks included in the data collection protocol:

1. List of people and projects – class roster, project name, major, contact details

2. Collection of design documents and deliverables: hard and soft copies – collation of electronic deliverables in a database and binder of physical deliverables

3. Tracking of individual and team submissions and grades

4. Administer surveys – initial survey of experience in NPD; short check-in survey; midsemester team evaluations; end of semester team evaluations

5. Video recorded interviews and observations – observation of natural team meetings followed by short semi-structured team interviews

6. Videos of final and intermediate project presentations

7. Updates and progress – monthly conference calls to discuss progress and difficulties

8. Final project rankings – judge and faculty assessments

Interview guide

The following questions were used as an interview guide for interviews at UC Berkeley and MIT. Interviews generally covered the majority of the initial questions, but remained flexible to learn about what the teams found valuable to discuss.

Table A4   Interview guide for the finding framing study

Definitely Ask…

[Optional follow-ups…]

1   When you first heard of the project what were your expectations for what you'd be creating?

<people may well have different opinions, particularly from the project proposer – allow everyone who wants to, to answer>

2   Just briefly, can you talk me through the research that you've done up until now, from the early stuff, to the most recent?

[This is a tricky one – what were you hoping to find out from your research?]

3   Have there been any surprises for you as a team from your research? things that you didn't expect to hear or find out that have had an impact on your project

[How has the research you've performed changed your view of the project overall?]

[How has the research you've done with users changed your view of the project? <follow it up if it seems important> How has it changed what you choose to focus on? Has it changed any key aspects of the project?]

4   Are there any moments or events during your research that changed your view of the project?

[How has the scope of the project changed since the initial vision? What prompted these changes?]

5   How has the direction of the project changed from the initial proposal? What were the key events that caused these changes?

[What led you to focus on X?]

[Can you walk me through how you decided to focus on X?]

6   Do you feel that everyone on your project is aligned? Why not? *<probe for specifics – this may be a sensitive question, so use your judgment>*

[What was the hardest decision you've had to make as a team? Can you tell me how that ended up being made?]

[What have you found most difficult with regards deciding on the direction of the project?]

7   Was there a time when people had different views on the project direction? Tell me about that.

[What has been the biggest disagreement on your team?]

8   Imagine I don't know anything about your product – can you describe what it is and what is great about it in one sentence?

[How do you feel about the project experience overall? (happy, frustrated, bored, excited…)
<particularly probe on any aspects they are frustrated with or found difficult>]

9   I'd like to ask each of you about your goals for this project. How will you know if you've succeeded when the class is done?

<Attempt to get each of them to answer>

10   If you were to do the project again, what would you do differently?

11   So my last question is, given the meeting I've observed, the responses to these questions and the files and assignments you have posted, would you say I would have a good understanding of your project and the process you used to get there? Are there any gaping holes in my knowledge? Would I be missing some defining information or events?

Less important questions if things are going well…

When you were finding people for interviews how did you select who to talk to?

Several teams have said they found it difficult when to stop research. How has your team dealt with this?

Did your team create a mission statement for your product? Have you used it/Was it helpful?

Can you tell me about the actual process you used to come up with the mission statement? Has it changed much since the first draft?

Would you tell me the biggest challenges you see in actually developing the product?

Now would you tell me what you see or have found as the biggest challenges regarding the process you're using and the direction of the project?

Data analysis protocol

To find framing in the data collected we looked for instances where the key elements of a frame would change: a desired end state or goal (mission; prioritization of needs); relative importance and relevance of features (identification of needs); boundaries to the design situation (problem scope, solution scope, resource constraints, stakeholders); criteria for evaluation (of new information, features, and possible solution concepts). As the analysis continued additional important elements were added particularly regarding differences between individuals. The following issues were considered:

Table A5   Data analysis protocol for the finding framing study

Theme	Description
Related to direction	
Mission statement	Discussion, evaluation, use (referring to), and evolution of a mission statement or similar document
Needs	Discussion over, identification, selection, translating, phrasing and sorting of needs
Constraints	Time, scheduling, resources that the team sees as limiting their possibilities
Stakeholders	Discussion, disagreement, identification and selection of relevant stakeholders including who to speak with.
Related to process	
Use of tools	Actual tools used by the teams during meetings, including physical tools such as Post-Its, pens, whiteboards, computers, projection, flipcharts. Benefits and difficulties of using them.
Frameworks	Any frameworks successfully or unsuccessfully used such as position maps, typologies, metaphors, venn diagrams, timelines, decision matrices and such.
Confusion	Times when the team had difficulty or confusion over what they should be doing next or whether what they were doing now provided value

Use of physical space	How the local environment supported or hindered the meetings

Related to different perspectives

Disagreements on direction	When team members had different ideas for the 'direction' of the project, e.g. "It's hard to describe in words what you really mean by a product or a picture or something. You don't really know if the other person understands you're the same way"
Tension and conflict	Emotion such as frustration or boredom that affected the team, e.g. "We had a lot of conflict between disciplines – engineers are totally different from designers and we had quite a few debates."
Language	Unique words introduced by the team and discussion over the meaning of words in use by the team, e.g. "What do we really mean by easy to use?"

Related to research

Sharing of research information	How research was shared in meetings and using communication tools e.g. transcripts, lists of needs, email, photographs, stories.
Sorting of research information	What teams did with the research information – how it was managed after it was collected

Design path interview coding

The following is the coding scheme followed for the design path study. I present the themes identified and example quotes from each, primarily from interviews, though several are from written survey responses. Two researchers developed this coding scheme building on that developed for the finding framing study. Both researchers reviewed each interview. The intent was not to replicate identical coding between researchers but to be inclusive, i.e., if one researcher highlighted a quote the other didn't it was included in the discussion.

Table A6   Data analysis for the design path study

Theme	Example quotes

With regard to understanding the needs of your target market

Theme	Example quotes
Initial framing	▪ "I think that people had a different picture in their head as to what this final thing would look like."
	▪ "actually, at that time our mission is very broad like all kinds of extreme sports."
	▪ "there were two things, there was the sensor or the clothing prototype and we had to kind of decide … it was very vague and Alice kept saying it's up to you all and so as a team it was … everybody had different … I was more towards the sensor, being a technical person"
	▪ "He had already at the time proposed it, I'm sure you remember he proposed a solution rather than a problem. Said we were already thinking of luggage you can sit on."
Surprises	▪ "A lot of it is based on doctor's impressions and I was really surprised that really the patient doesn't get a say in it as well. So whatever, if the doctor wants to give you medicine to treat it he gives you medicine. If he thinks you're ready for a procedure then you get a procedure. There's not really a lot of say you have in it."
	▪ "I mean like the manufacturer I just spoke to. You know they have such targeted ways of doing their work and like they don't … like they don't get that specific in the design process. And I was surprised to hear that but that was … kind of the truth."

	▪ "we all kinda had the wind kinda knocked out of us as a group when we had to just change gears"
Performing user research (including how it was done and how much)	▪ "It was nice when two people could do the interviews too then, like the preschool teacher, both of them would hear her. We got different things out of it. They notice different things."
	▪ "We couldn't ask up front very quantitative questions it was very sort of qualitative which meant that every single person gave us a completely different answer. And so I think what we recognized was to some extent this is such a new concept for a lot of people that it's hard to even ask them how they feel about it because they can't see it and they don't know what our vision is – we didn't even know what our vision is at that point."
	▪ "but we didn't do any extensive research or asking experts about it"
Different learrnings	▪ "we all latched onto different stuff."
	▪ "I think we still haven't all learned the same thing from our conversations"
	▪ "I think we came to different conclusions from the things that people were telling us."
Sharing user research	▪ "I'd much rather trust my teammate to capture the information and to communicate to us"
	▪ "but for certain parents that I spoke with I don't really feel everyone needs to read it to pull out the key issues and so you know there's a lot of repetition in different parents. You don't need to read everyone's."
	▪ "everybody did it a little differently. Some people just like wrote down a summary of the interview. I don't think they transcribed it."
Choice of target market	▪ "We didn't really interview any executives which is one of the many reasons that we decided that executive lunchbox is not the best way to go with this project."
	▪ "We spoke to a lot of people … I don't know what the typical group does but it was harder. Like you're trying to do a design for some consumer product you can go and just get your buddy to sit down with you for thirty minutes and ask them as a consumer. For us we had to be really targeted. We had a big circle at the beginning and I spoke to a couple people who were in the manufacturing end. Some of us spoke to designers. And then from there as we got a little bit more targeted I think we kinda let dim the light a little bit to do it"
	▪ "How can you say their needs are any more important than this other group? At some point I think you just have to throw a dart and see where it lands."

Prioritizing needs	▪ "And a lot of them will feel very different. Like one says it has to make a lot of noise and the other person says it shouldn't make any noise at all. So it kind of made, going and talking to a lot of people a little bit frustrated cause at the end of the day you want to go and talk to people to help identify what the needs are. But when you're getting fifty percent saying one thing and fifty percent saying the exact opposite, and you're valuing your time then going in and doing a lot of that isn't a good use of your time."
	▪ "Different types of people preferred different ones depending on their needs so I think that was very hard to figure out. Which one, which emotional need is important and I don't think that you can say that one is more important than the other."
	▪ "I think there might be a bigger problem here. These [interviews] just opened my eyes."
Evaluations by users	▪ "they just didn't have the … like they just didn't have an opinion at all about it."
	▪ "The parents just didn't get it. We said it was a safety device, so they didn't understand how it could also be a toy."
	▪ "when we talked to customers they didn't … it didn't jump out at them like as we hoped. Like we didn't see that need come through."

With regard to the team's shared understanding

Different values	▪ "I thought if I am going to have to do all this work I am going to work on something that I believe had potential versus something that's a complete class exercise."
	▪ "there was a little bit of um disagreement about our goal in the sense that I was always interested in kind of actually creating a business out of it and everyone else was more interested in kind of fulfilling the requirements of the class and getting a good grade or whatever."
	▪ "my interest is in emerging technologies and emerging wireless communications in consumer electronics…I really had no particular interest if it was kitchen or the living room, direction, where the device was going to be was none of my interest. But the technology behind it was important."
Knowledge differences	▪ "he had worked at a company developing the medical devices he showed in class so he had all this background knowledge and we had none"

- "So I knew the field pretty well and so I figured, let's propose it and see what would happen if we try to do it as a consumer product."
- "I think for us it is, we … they … there was such a gap in the amount of knowledge on the subject."

Strong agreement
- "we all jumped on board the story that we wanted to sell"
- "I think we're all agreed up to this point."
- "none of the interviews that we've done have lead us to that conclusion so we might just have to strike it."
- "Currently, the team is on the same page and we have not gotten into any disagreements."

Differences in perspective
- "While we were talking about what solutions would be and maybe putting words up on the board and maybe even draw to the best of our abilities after like another week of trying to work on that one concept, it would take like a week to realize that we still had different ideas to what this thing would look like in the end. And even now when we're talking about the final thing is going to look like in the end, it's still different between like my head and probably everyone else's head."
- "I think we recognized that we had to and if we didn't iterate on the concept selection that we were going to not even all be on the same page about what path we were going down."
- "that's when it became really apparent that we were asking very different questions cause we had such divergence of ideas. Like Jesse only asked questions about the refrigerator which was obviously very very different from the rest of us."

Split decisions
- "We gathered the points and it was like if he chooses the bag then we're two and two and we're not going anywhere so we just said like you decide which one."
- "the info school students were keen on addressing that need, and the engineers wanted to make the better lift."
- "or we could just flip a coin." <laughs>

Team conflict
- "we got into heated discussion but not in a negative way just like we would get very deep"
- "I just feel like the whole underneath the sink just came out of nowhere and just like one person started using that word in every meeting and suddenly we need to design under the sink? And then I was just like I wasn't so … I think it was my problem with how the idea was borne and I didn't think I resolved it too well with the group but every meeting I was like Ughhh.

- "Our team had a communication breakdown which we resolved by meeting to discuss our conflicts without discussing anything about our project. We were able to focus on our interpersonal issues. This brought us closer together and strengthened our team and lead to the success of our final product."

Tension points
- "We were there for so long and it was … we got there at five PM and it was already a long day so I think we stayed there until like nine, ten and all of us were very crabby at the end after arguing for a very long time …"
- "up to that point we never really had like a contentious discussion I would say. Real time like the group had take sides or had started to become polar in a way"
- "Some of us were rather for developing a new type of bike rack, others rather wanted a new type of lock. At first we kept these two directions because it was a source of richness as far as creativity is concerned. But we needed to take one direction eventually and we did not really agree on that. In the end arguments of feasibility in the timeframe of the course convinced everyone to go for a new lock, and not a new rack."

Emotion
- " had an idea that didn't get carried forward and I got hurt about it so what I did was I renamed one of the ideas that was being carried forward my idea"
- "we've been trying to keep this wide but it's really frustrating."
- "we did have one time of conflict. Bryan was upset after the last survey about what the other group members thought of his effort. Although we had an uncomfortable conversation discussing it, he definitely contributed a lot more the second half of the class. Over time, we found that everyone seemed to develop their own niche to contribute to the process."

Focusing (selecting and narrowing)
- "one of the huge challenges throughout this process is that there was just too many things to take into account so how to navigate that was one of our biggest challenges and I think at various points we just eliminated those things, like took them off the table for a little while and I think that was successful."
- "But you know I think it was we had to do that for our [sanity?] … so that we had to do what we did well rather than doing a lot of stuff really really at a surface level."
- "we met with our coach at his office and laid it all out on the floor for that and we basically kind of like aired our feelings like I don't want to do this because of XYZ. I felt like that was a good time, like a good forward movement for us then at the end I think it came out like two or three and

our coach was just kind of 'alright, pick one,' and you know you're stuck with it kind of thing. I don't know I think that was a good focusing moment for us."

Assumptions and filters	▪ "when talking to doctors it was very clear that physical and mechanical removal was the only way to go"
	▪ "we have to think of our capabilities to get this done within ten weeks."
	▪ "it's safe to assume that the people who'd buy this would also…"
Metaphors (process and content)	▪ "they're right at that hill and you just want to put the brakes on them."
	▪ "We felt like we were boiling the ocean and everything that she described, exactly what we went through, this sort of wave of data and context crashed on top of us"
	▪ "Prototypes are our friends."

Important events

Key decisions	▪ "in the beginning we didn't really know that there were two different styles and then we had this one big discussion I think the night before the trade show where it turned out we talked about two different things"
	▪ "I don't know if 'flip-flops' is the right word as much as this sudden requirement to narrow dramatically in like an hour that really led to like kind of … this maybe, arbitrary, not so much arbitrary but just like 'we have to do this now!' Just like, you know? And this happened probably like three times which is like way too much considering we made like three decisions in the semester."
	▪ "I think that some of the major decision points or catalysts came whenever we went back to the users and whenever we talked to Sara, the two conversations in particular, the one where they said we weren't really listening to our users' needs, I thought that was a big eye opener and we were like, Yeah you're right. We kind of went from the needs to – we did the needs and then apparently we did the personas and independently we did the concept testing and we didn't actually look from one to the other."
Stories	▪ "I had dinner with my cousin who I haven't seen in a while and he had a bunch of little kids with him. Uh, dinner took too long and the kids were getting antsy. Things were getting thrown at me or thrown down to the ground and the parents were getting irritated. And they ultimately left dinner before the food ever came and cut our time short. And I've seen similar circumstances happen on an airplane. So at that time I thought

wouldn't it be cool if there was a toy that did this."

- "we went through the whole process of saying I like this and this and this and this and we narrowed it down and a prototype was already done so I was expecting just a nicely done version of the prototype and the actual renderings that came out was rather different wasn't it? It was missing straps and it didn't have the features. The volumes of the compartments were totally different. So it seems like there's a last minute desire to sort of beautify it to a certain extent. I don't mean to discriminate but I was surprised as to how different it was to what I thought … what I expected it to have."

- "I interviewed one professor that had the most amazingly vehement reaction to the entire institution of education content. I really didn't quite know what to do with it. I mean she was so irate and disenchanted with the way the content revision mechanism had taken place at the university. Then she basically said, "Yeah you're going to try to do something but you're not going to change anything." She was totally hopeless and it was really weird … then she apologized after the fact 'I'm sorry! Let's have the interview again duh duh duh,' but I was shocked by the nerve that the interview struck and also how strongly people feel about this topic."

Time management
- "I think we also set up more regular meetings in the beginning which is probably good because it allowed for us to have sort of the open air time so it allowed us to talk about a lot of these things."

- "But I don't think we had either the opportunity nor the time to go in and actually ask them again to talk more about that at that point so I think that would have been interesting."

- "to stay on track I feel like we need a list of prioritized needs today."

Design path classification protocol

In this section I present details of the protocol used to help follow the different paths of the design teams and classify them into Back Roads, Backtrack and Direct. The researchers asked a series of questions of the team's situations as it moved through the process in approximately these phases: the initial project assessment; during the gathering and digesting of user research; deciding on a final direction; and the final outcome of the project. The data sorted into the themes and the raw data was used to answer as many of the following questions as possible. Even with the volume of data collected it was not possible to be confident about the answer to all questions. However, in most cases, there was sufficient confidence with the answers to other questions that team placements could be confidently made.

Initial project assessment:

- Did the team have a clearly defined product in mind or was it a broad and open mission?

- Did the team members agree on this original mission?

- Did the team share similar values but have no clear product direction?

- Did the team members have the same goal for the project?

- Is there a knowledge gap within the team?

Gathering and digestion of research

- Did the team members learn similar things from their research?

- Did they perform their research together?

- Was the team's thorough research?

- Did they share richly and take time to learn from each other's reserch?

- Did they set out to confirm their original needs?

290

- Did they learn anything new?

- Did team members agree on a new framing and target user or where they more confused?

- Did they do a substantial number of interviews?

- Did they learn from users who weren't simply friends of the team?

Project direction decisions

- Did the team reach unanimity on decisions?

- Did they let the research data or user testing make the direction decisions?

- Were decisions split between the team or were they resolved?

- Did they backtrack to their original product vision?

- Did they learn from research testing and perform another iteration?

- Did the team bridge any knowledge gaps?

- Did a strong leader pull the team along?

Final outcome

- Did they test their product with real users?

- Did they receive positive feedback?

- Was all the team united behind their final outcome?

Through looking for information in the data collected to understand the answers to these questions it was possible to place the teams at different positions in the framework throughout their projects. Identification of the profiles of the team's path was done by aggregating the positions chosen by the two researchers.

To illustrate how these considerations guided the placing of the teams below is the path for the More Blood Donors team with corresponding data points labeled with each position and the source of each data point, Figure A6.
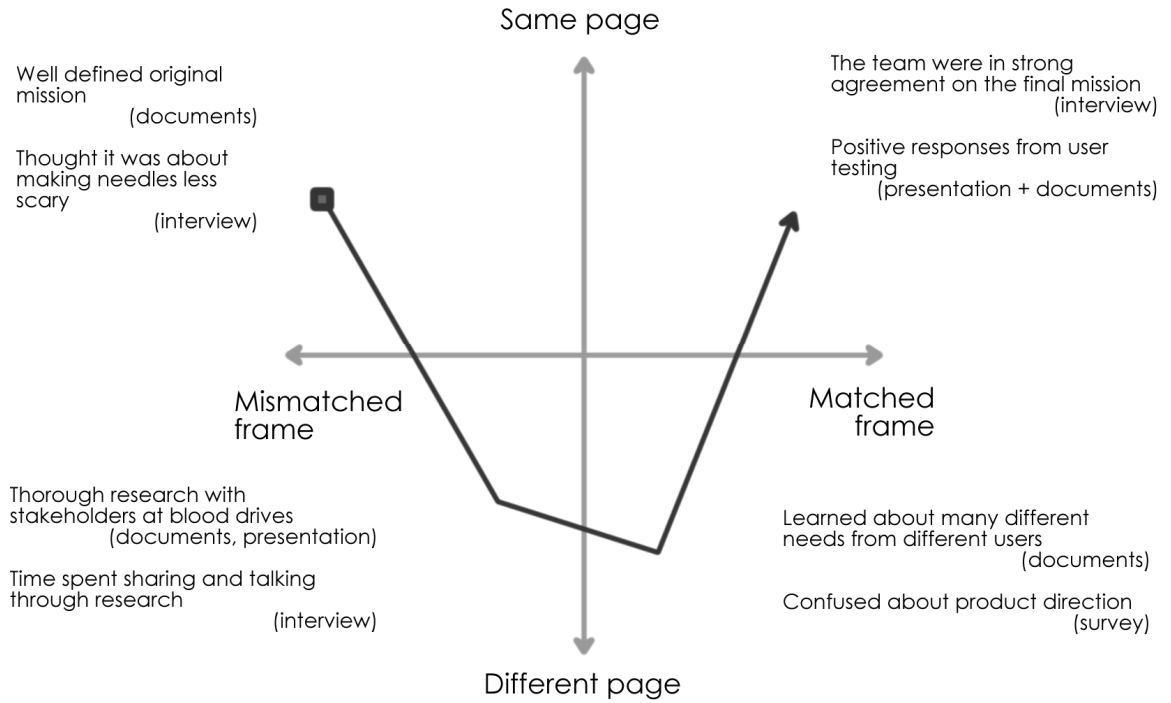
Same page

Well defined original
mission
    (documents)

Thought it was about
making needles less
scary
    (interview)

The team were in strong
agreement on the final mission
    (interview)

Positive responses from user
testing
    (presentation + documents)

Mismatched
frame

Matched
frame

Thorough research with
stakeholders at blood drives
    (documents, presentation)

Time spent sharing and talking
through research
    (interview)

Learned about many different
needs from different users
    (documents)

Confused about product direction
    (survey)

Different page

Figure A6   Example of design path classification

292

Choose your own design path tool

Raising awareness of the importance of issues of design team framing helps teams learn about both good practices and pitfalls without having to make errors first-hand – an attempt, as much education is concerned, to shorten the path to experience by just a little. Just as there are many possible principles to carry out the themes in the previous section, there are many ways to raise awareness of the issues involved in design team framing. In this section I illustrate one possible path for increased awareness using the design of an educational tool *Choose your own design path*, developed in collaboration with Jonathan Yu. I describe the basic features of the tool, the process to design the tool and illustrate how the tool is used.

The Choose your own design path tool

The *Choose your own design path* tool was developed based on the realization following the analysis of many teams' experiences that NPD, as experienced, is a series of sequential decisions. Although user-centered design processes require iteration, at each meeting decisions are made with regards to who to speak with, what questions to ask, how to generate concepts, how to share research data, how to select between concepts, how to conduct user testing and who to test with and so on. The Choose Your Own Adventure series of books follows a similar model where the reader, identified with a character, at each page is able to select a choice of action for the character – should they take the left fork in the road or the right? *Choose your own design path* is built following this basic scheme. It was also inspired by a graphic novel of the NPD process based on the MIT NPD class developed *"as a tool to help students unfamiliar with the product development process, teaching the main steps and familiarizing students with working in groups and with deadlines"* (Wong 2004).

Importantly, the *Choose your own design path* tool is based on a series of linear process decisions. While clearly a design team needs to make numerous product-based decisions throughout the design process, this tool is focused on learning about the consequences of process-based decisions.

The *Choose your own design path* tool has several advantages over traditional tools for raising awareness such as lectures or traditional books. It is more interactive, providing greater engagement and ownership over one's design path while at the same time allowing participants the opportunity to see previously abstract forces in real, practical terms. The decision-making required to continue in the book encourages reflection. The lightweight format is quick to absorb and allows NPD students to experiment with many possible paths. In this way they can see possible outcomes not just of their decisions, but also of the alternatives. The book format also increases awareness without requiring the presence of multidisciplinary team members. Last but not least, reading through the paths is enjoyable.

Development of the tool

The tool was developed around a team whose path was well known and understood, the healthy noodle team. By necessity this team can only have experienced one of the many possible paths. Together we mapped out the key decision points that affect design team framing, derived from both Chapters 05 and 06, and illustrated the actual path the healthy noodle team took. This turned out to be the skeleton around which the rest of the design tool was designed.

Key decision points need to reflect important framing issues and through their selection illustrate the consequences of different choices. The key decision points included:

1. Early discussion of the target research participants

2. Performing research alone or together

3. Sharing richly or paraphrasing

4. Developing frameworks for managing research data

5. Taking the time to define new words

6. Selecting the innovative concept or the 'real' one

7. Basing concept selection on research data

Even with only 7 decision types the map of paths increase almost exponentially. Allowing only 2 decisions per path a maximum number of paths would be $2^7 = 128$ possible design paths, and therefore distinct scenarios to envision. To keep the task manageable, and the teams path more varied, not all paths follow the same succession of decisions and we arranged for paths to meet each other – i.e., some situations can be accessed by more than one route. This left 30 unique situations to write. Figure A7 shows the map of decisions.
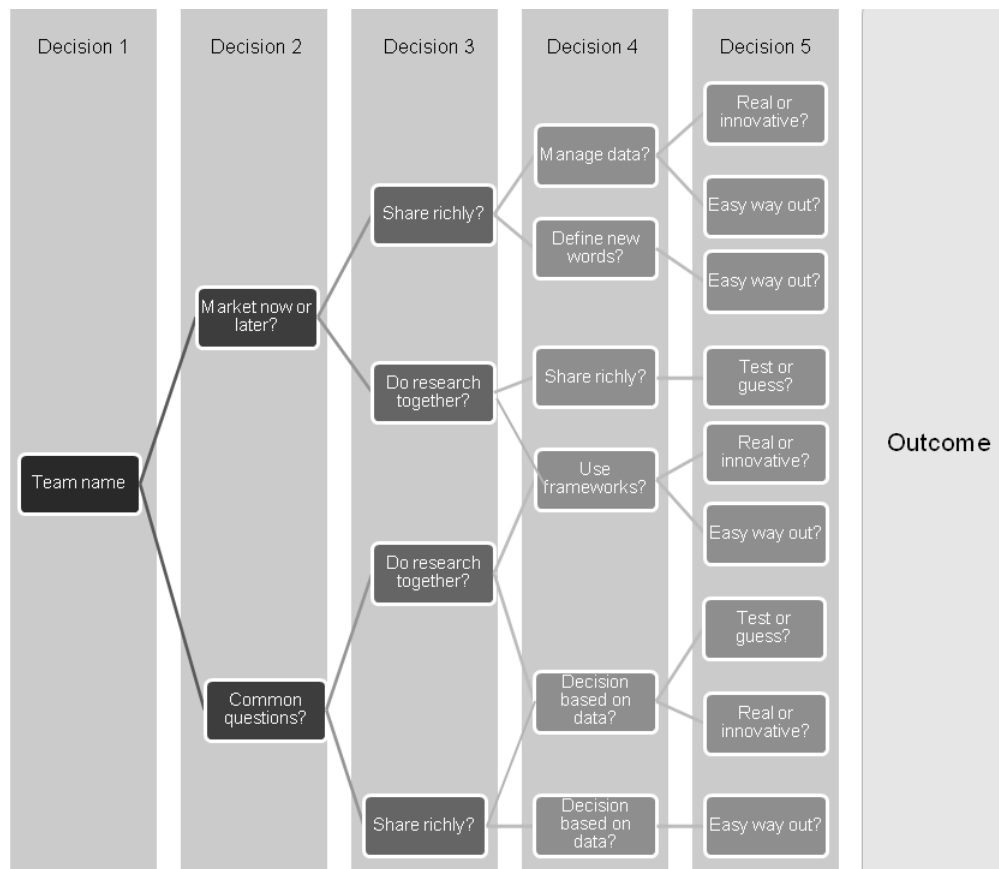

Figure A7   Decision tree for 'Choose your own design path' tool

Writing was an iterative process beginning with the actual team path and then expanding to include the possible consequences of decisions they didn't take, derived from the stories of

other teams in similar situations. To ensure these situations were realistic we again returned to situations experienced by other teams but changed the project details to conform to the healthy noodle project. We continually reread the different paths to ensure that the story for each flowed correctly.

Each new situation was designed using the following template: illustrate the consequences of the team's previous decision; provide context for the new design decision with possible directions; illustrate some pros and cons for each; provide two choices leading to a new page. To prevent ourselves from being too restricted, "context" pages were inserted in between certain "decision" pages in order to expand certain relevant subjects without being constrained by page limits.

Macro level feedback is provided by the overall outcome of the design path after the final decision. According to the design teams we observed, paths lead to one of three possible outcomes – high-performing, average performance and low performance. These criteria are founded on the overall experience of the team members after completing the project as well as the reception to the final product by users. In keeping with typical distributions, the majority of paths lead to average performance.

The tool in action

Figure A8 illustrates one choice in the adventure. In the first page the team is trying to decide on how it should start its research. One team member proposes the team splits up and team members speak with people they think are close to the market. Another team member isn't so sure and thinks they should take some extra time now to discuss exactly who they should try to speak with. The page explains the advantages of each approach – gaining many different perspectives, or staying more focused but with more time spent now up front. The core issue is one of developing shared understanding of their target market. The reader is left to decide whose suggestion to follow.

If the team chooses to split up now the reader learns that the team interviewed a wide array of different users. It turned out people had very different ideas. And the flexibility also led most people to speak with friends and family. As people describe their findings they gloss over the details. One member is frustrated they didn't learn much and wants to meet the next day to go over the data in more depth. Another member says it would be better to spend the time getting some ideas out. The decision is put to the reader again. This time the core issue concerns the disadvantages of paraphrasing research, partly caused by an attitude of confirming – the team already thinks they know what is important – rather than learning.
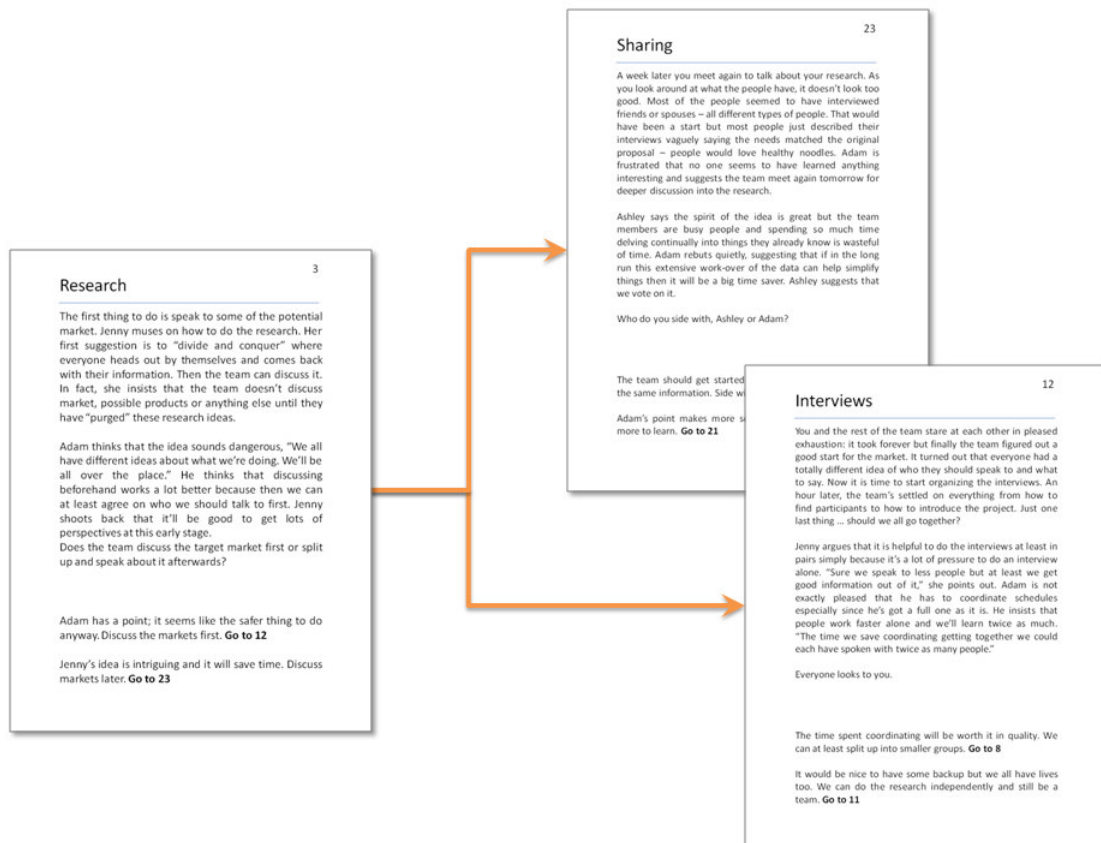

Figure A8   Choose your own design path choice

Alternatively, if the reader chose to discuss the market before heading out for research he or she learns that there were some very different ideas about target markets. It was hard work but seemed to be time well spent. The next thing to decide is how they should do their

interviews; should they do them individually and speak with more people, or should they take time to organize heading out in groups, but speak with fewer participants. The reader can decide. The core issue here is learning about the benefits for maintaining shared understanding when research is performed together, against the trade-off of quantity of research.

This example shows just one of the many decision points a reader will encounter. At each stage readers are presented with some, often ambiguous, consequences of their previous decision. Many times these consequences will be unexpected. They are then presented with the context for a new decision and arguments for and against each. The story is written to simulate many of the real constraints of the class NPD setting including scheduling conflicts and different motivations of the team members. Ultimately, the team is a novice team learning about the outcomes of their actions. For experienced readers however, the adventure highlights benefits and disadvantages of different actions, helping make explicit what may be their implicit practice. The reader can use his or her expertise as an advisor for each design decision.

Human subjects approval

Framing in Design and Innovation

CPHS Protocol #: 2006-1-24

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO   SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

OFFICE FOR THE PROTECTION
OF HUMAN SUBJECTS
101 WHEELER HALL, MC: #1340
BERKELEY, CA 94720-1340

(510) 642-7461 FAX: (510) 643-6272

Web Site: http://cphs.berkeley.edu
FWA#00006252

2/6/2006

SARA BECKMAN (beckman@haas.berkeley.edu)
ALICE AGOGINO agogino@berkeley.edu
Haas School of Business
S545 Student Services Building
Berkeley, CA 94720

RE: **Expedited Approval of CPHS Protocol #2006-1-24**
          "Framing in Design and Innovation" - Faculty Research - Haas School of Business

Dear Professor BECKMAN:

Thank you for submitting an application for approval of the above-referenced protocol. Your submission has been reviewed and approved on an expedited basis, under category F(7) of the federal regulations, for one year, or less, effective 2/6/2006. **This approval will expire on 2/5/2007.**

The number of this approval is 2006-1-24. Please refer to this number in all future correspondence.

Approximately 8 weeks before the expiration of the current approval, OPHS will send you a courtesy reminder to submit an application for the continuation of the research. Please be sure to submit the application to the Committee no later than 6 weeks prior to the expiration of the approval or we cannot guarantee a timely review. Current forms are available on our website at: http://cphs.berkeley.edu/content/forms.htm.

Please note that although the Committee has approved your project, you must bring promptly to our attention any changes in the design or conduct of your research that affect human subjects. If any of your subjects experience any untoward events in the course of this research, you must inform the Committee within ten (10) working days.

If you have any questions about this matter, please contact the Office for the Protection of Human Subjects staff at (510) 642 -7461; FAX (510) 643-6272; E-mail: cphs@berkeley.edu.

Thank you for your cooperation and your commitment to the protection of human subjects in research.

Sincerely,

Malcolm Potts, M.B., BChir, Ph.D.
Chair, Committee for the Protection of Human Subjects
Bixby Professor, School of Public Health

MP: jb

Cc: Professor Alice Agogino, agogino@berkeley.edu
          Jonathan Hey, jono@berkeley.edu
          Caneel Joyce, joyce@haas.berkeley.edu
          Graduate Division (degrees@berkeley.edu) – SID#'s 16964821, 16970413

Figure A9   Original UC Berkeley framing study CPHS approval

UNIVERSITY OF CALIFORNIA AT BERKELEY

August 24, 2007

SARA BECKMAN (beckman@haas.berkeley.edu)
Haas School of Business
S5454 Student Services Building MC# 1900
Berkeley, CA 94720

RE: **CPHS Protocol #2006-1-24**
          "Framing in Design and Innovation" - Faculty Research – Haas School of Business

Dear Professor BECKMAN:

Thank you for submitting an application for continued approval of the above-referenced protocol. Your submission has been reviewed and approved on an expedited basis, under category F(7) of the federal regulations, for one year or less, effective 8/23/2007. **This approval will expire on 8/22/2008.**

The number of this approval is **2006-1-24.** Please refer to this number in all future correspondence.

Please note the following:

Please use the stamped, approved consent documents (attached) for all new subjects enrolled in this study.

Continuation/Renewal: Approximately 8 weeks before the expiration of this approval, OPHS will send you a courtesy reminder. Applications for continuation review should be submitted no later than 6 weeks prior to the expiration date of the current approval to allow sufficient time for the renewal process. *Note: It is the responsibility of the Lead Investigator to submit for renewed approval in a timely manner.* In keeping with federal regulations, *if approval expires, all research activity (including data analysis) must cease until re-approval from CPHS has been received.* Before applying, please check current CPHS guidelines, instructions and forms available at http://cphs.berkeley.edu.

Amendments/Modifications: Any change in the design, conduct, or key personnel of this research must be approved by the CPHS *prior* to implementation. (For more information, see "Process for Submission & Review of Applications" and "Application Forms & Informed Consent" on CPHS website).

Adverse Events and Unanticipated Events: If any study subject experiences an adverse and/or unanticipated event involving serious risk, the CPHS must be informed within 48 hours. (For more information on definitions and reporting requirements related to adverse and/or unanticipated events, see "Adverse Events" on CPHS website).

Thank you for your cooperation and your commitment to the protection of human subjects in research.

Sincerely,

Christopher K. Ansell, Ph.D
Chair, Committee for Protection of Human Subjects
Professor, Department of Political Science

CKA: jb

Cc: ALICE AGOGINO (agogino@berkeley.edu)
          JONATHAN HEY (jono@berkeley.edu)
          CANEEL JOYCE (joyce@haas.berkeley.edu)

Figure A10   UC Berkeley framing study CPHS renewal

MIT Committee On the Use of Humans as Experimental Subjects

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
77 Massachusetts Avenue
Cambridge, Massachusetts 02139
Building E32-335
(617) 253-6787

To: Daniel Whitney
E40-243

From: Leigh Firn, Chair
COUHES

Date: 03/15/2006

Committee Action: **Exemption Granted**

Committee Action
Date: 03/15/2006

COUHES Protocol #: 0602001629

Study Title: Framing in Design and Innovation

The above-referenced protocol is considered exempt after review by the Committee on the Use of Humans as Experimental Subjects pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

If there are any changes to the protocol that significantly or substantially impact the rights of human subjects you must notify the Committee before those changes are initiated.

You should retain a copy of this letter for your records.

cc: Tom Duff

Figure A11   MIT framing study COUHES approval

Enhancing New Product Development Education through a Longitudinal Study

CPHS# 2007-3-97

UNIVERSITY OF CALIFORNIA AT BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO   SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

OFFICE FOR THE PROTECTION OF HUMAN SUBJECTS
University of California, Berkeley
2150 Shattuck Avenue, Suite 313
Berkeley, CA 94704 -5940

(510) 642-7461
Fax: (510) 643-6272
Website: http://cphs.berkeley.edu
FWA#00006252

6/14/2007

SARA BECKMAN (beckman@haas.berkeley.edu)
Haas School of Business
S545 Student Services Bldg MC# 1900
Berkeley, CA 94720

RE: **CPHS Protocol #2007-3-97**
          "Enhancing New Product Development Education through a Longitudinal Study" - Faculty Research - Haas
          School of Business

Dear Professor BECKMAN:

Thank you for the application that you submitted to the Committee for the above-referenced project. Your submission has been reviewed and granted exemption, as it satisfies the Committee's requirements under category #2 of the federal regulations. Accordingly, the project is exempt from full Committee review provided that there are no changes in the use of human subjects.

Please note that although your research has been deemed exempt from full committee and subcommittee review, you still have a responsibility to protect your subjects, and the research should be conducted in accordance with the principles of the Belmont Report. Download the Belmont Report at this link:
http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.htm.

If you have any questions about this matter, please contact the OPHS staff at 642-7461; FAX 643-6272; E-Mail ophs@berkeley.edu.

Sincerely,

Malcolm Potts, M.D., BChir, Ph.D.
Chair, Committee for the Protection of Human Subjects
Bixby Professor, School of Public Health

MP: jb

Cc: Graduate Division - (degrees@berkeley.edu)
          CORIE COBB (ccobb@me.berkeley.edu) - SID# 13860035
          JONATHAN HEY (jono@berkeley.edu) - SID# 16964821
          CANEEL JOYCE (joyce@haas.berkeley.edu) – SID #16970413
          ALICE AGOGINO (agogino@berkeley.edu)

Figure A12   UC Berkeley alumni study CPHS approval

302

Reflection

My personal validation of this thesis I have gathered from my increasing understanding of the successful and unsuccessful activities of teams. Although I have not reported on them here, I have repeatedly seen many of the findings borne out in research teams, project teams and simply teams of friends in many situations. Perhaps most satisfying though was my increasing ability to diagnose difficulties and point ways forward for the NPD design teams I helped coach as a teaching assistant. I have also gained a tremendous respect for the challenges of conducting research and those who do it.

This thesis did not turn out what I expected it to be. But it has turned out what I want it to be. I believe that design is the most important way forward for our race as we tackle some of the largest problems we have ever faced. And as design is performed by teams, I believe helping design teams create products and services that meet real needs has some of the greatest potential to make a positive difference in our lives. While this was a large endeavor for me, I know it is just one small step in this direction. But I hope it helps.