From Idea to Implementation: Fostering Creativity and Design Maturity in Novices

by

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S.B. Mechanical Engineering
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Abstract

This thesis explores how novices, in particular students, design products for people and how to foster creativity in students who are accustomed to a traditional engineering curriculum. In a world of messy, ill-definied and "wicked" problems, students must learn how to struggle with and take on these challenges, regardless of the disciplines they choose to pursue in the future. Qualitative and quantitative approaches are taken to observe the efficacy of such methods. Two case studies based in the design classroom are described. First, findings reveal the need to teach students a more nuanced, deeper view of using user-centered methods. Designers cannot haphazardly follow instructions for methods without thinking about implications to the design process. Second, it is important to expose students to fresh, new, design scenarios and to train them to communicate their message through various media. These findings help researchers shed light on the path from the idea to implementation of products designed with end users in mind.

Thesis Supervisor: Maria C. Yang

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> *But he said to me, "My grace is sufficient for you, for my power is made perfect in weakness." Therefore I will boast all the more gladly about my weaknesses, so that Christ's power may rest on me.*
>
> 2 Corinthians 12:9

> *Be joyful always; pray continually; give thanks in all circumstances, for this is God's will for you in Christ Jesus.*
>
> 1 Thessalonians 5:16-18

> *We love because He first loved us.*
>
> 1 John 4:19

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Chapter 1

Introduction

Products, systems, services and artifacts are around us everyday. They may take different embodiments: physical, digital, abstract, social. How are they created? Some group of people made decisions with intent to create something. How do these persons learn to do what they do? What is the best way to train them?

1.1 Thesis

This thesis explores the question of training novices, especially students, to design products for people. How does one mature from a novice designer to an expert designer? I am based in the Mechanical Engineering department with an advisor who also has a dual appointment with the Engineering Systems Division. Naturally, product design and development is the starting place to explore the question. Over the past two years, however, an exploration has been made throughout the Institute in search for where design lives, how people practice design, and the way in which design is taught. These additional experiences have shaped my perspectives and way of thinking.

This thesis seeks characterize the early stages of design process which do not deal with technical measures of performance but with intriguing and complex notions that arise in engaging with relevant stakeholders. Eris talks about the need to understand "the principles that govern *our* behavior as designers" in addition to understanding the technology and the physical world around us [13].

Additionally, improvements are sought out as to good ways of teaching design to these students, most of whom would be considered novices. If this is the time and place for people to first be exposed to design, we want to ensure that the research and models about how people design are as relevant as possible. Regardless of what industry a student may end up working in, our goal as educators is to equip them with experiences that will allow them to adapt to a fast-paced and changing world, out "in the wild" where things are nothing like the situations found on problems sets and in textbooks.

1.2 Motivation

Two broad areas of focus in the research found in this thesis are *user needs* and *design creativity*. A mix of both concepts are then considered in the context of two groups of students, undergraduates who have not had much experience in design and mid-career professionals who have had limited experience in developing consumer products. The classroom setting is a contained and controlled testbed in which to observe, describe, and explain phenomena of and prescribe methods for designers [11]. The terms *novice*, *student*, and *designer* will be used interchangeably throughout the thesis.

1.2.1 User needs

The first area, *user needs*, is motivated initially from a personal experience in a product engineering class. I was deeply involved in dealing with users and stakeholders in developing a product to help the physically challenged handle hygiene matters. The experience was rich and difficult, leaving a lasting impression in my mind. Interaction with others is at the core of our existence. How do novices take steps toward acquiring such skills? Furthermore, when you consider students with a science and engineering background, it becomes even more challenging. How do you teach students how to engage in a dialogue with people to extract needs and gain a sense of empathy and understanding?

1.2.2 Design creativity

The second area, *design creativity*, is extremely relevant in this time and place. "Creativity" will be used to mean the act of creating products that are novel, useful, and unexpected [41]. Products cannot be created without intent or consideration of long term effects on a user or society as a whole. In an attempt to create the latest gadgets, companies might end up trying to fill "necessary holes" and "essential voids" rather than critically thinking about the importance of such holes [32]. How can artifacts be socially, culturally, and environmentally conscious while simultaneously being new and creative?

1.3 Research questions

These high-level questions have guided the research in the past two years:

- Within product design, how do novices mature into expert designers?
- How can we prepare students for what they might encounter in the real-world?
- How do we teach students to determine why, when, and how to engage with users and customers in the product design and development process?
- What is the role of unfamiliarity in design situations?
- What problems in making design choices do students encounter in their journey from idea to implementation?

1.4 Contributions

1.4.1 Multiple ways of analyzing qualitative data from the design process

Through the studies conducted in this thesis, methods will be shown that allow researchers to get a handle on qualitative data. After analyzing the data for the first offerings of the courses, which were the subjects of the research, many lessons were learned about how to best acquire and interpret data. Qualitative data refers to data that cannot just be put through an analysis package and produce a simple a conclusion. Within the context of design research and education, what are good ways to deal with the information learned from studies?

1.4.2 What to teach to novice students?

The author was given the opportunity to test out different activities and curricula for novice students who wanted to learn about product design. What is missing in existing engineering curricula with respect to design that would be useful learn? How can we attempt to fill the gap between novices and experts, and the classroom experience vs. industry [42]? Reflections will be shared about this topic.

1.5 Thesis outline

Outline of the thesis is presented:

Chapter 1 gives an overview of the work presented, including the motivations, goals, and contributions of the work.

Chapter 2 provides a literature review of existing knowledge and practices that deal with how people and groups of people execute the design process.

Chapter 3 describes the background, methods, and findings for the first case study, involving a two week class called 2.97 - Design-a-palooza. The focus of this case study looks at developing activities and design prompts to foster creativity in novice undergraduate students.

Chapter 4 describes the background, methods, and findings for the second case study, involving a graduate level class called ESD.40 - Product Design and Development. The focus of this case study looks at how students engage with relevant stakeholders through the entirety of the design process.

Chapter 5 summarizes the content of this thesis and provides direction for future work.

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Chapter 2

Background

The word "design" means multiple things to many people in a multiplicity of contexts. This chapter will hopefully shed some light and bring the reader to the same page.

2.1 Introduction

This chapter presents a literature review of relevant topics to this research. It will first address high level issues, such as "What is design?" in Section 2.2, dimensions along which to consider "design" in Section 2.3 and the different uses of the term *design research* in Section 2.4. The author encountered much confusion when initially research relevant articles as terms are used in many different ways.

Then, the product design and development process will be covered in 2.5. Next, Sections 2.6.2-2.6.5 address user-centered design principles behind this methodology and how it is applied. Section 2.7 looks at current research in design creativity in engineering design. Section 2.8 considers the development of designers from novice to expert. Section 2.9 discusses ways of incorporating personalities of individuals in design team formings and talks about how such frameworks can help understand individual's tendencies.

2.2 What is design?

What better place to look up the definition of "design" then the *Design Dictionary*, compiled by the Board of International Research in Design [14]. The first section of the entry for "design" reads:

> At the risk of disappointing you, dear reader, it is impossible to offer a single and authoritative definition of the central term of this dictionary—design. Design's historical beginnings are complex and the nature of design, what it is and what it isn't, is the subject of diverse and ongoing arguments as can be seen from the perspectives offered in this dictionary.

It says further about the distinction of the use of "design" in German and English:

> In German, design primarily relates to the creation of form while in English the term is more broadly applied to include the conception—the mental plan—of an object, action, or project.

It reminds the reader of the origins of the word "design" which comes from the Latin *designare*, "meaning to define, to describe, or to mark out. [14]. Additionally, Wikipedia currently lists over 50 disciplines with the word "design" attached to it [1].

Two influential thinkers in the 20th century, Herbert Simon and Donald Schön expressed views on what design entails. Simon talks about design as devising "courses of action aimed at changing existing situations into preferred ones" [47]. Schön contrasts his own view with Simon's, stating that Simon "saw designing as instrumental problem solving: in its best and purest form, a process of optimization" [43]. To Schön, design is "a kind of making", involving "complexity and synthesis" where practitioners "put things together and bring new things into being, dealing in the process with many variables and constraints, some initially known and some discovered through designing." In short, Schön draws upon John Dewey's "view of the designer as one who converts indeterminate situations to determinate ones" [43].

There obviously is not one simple, comprehensive answer to the name of this section. What, then, does design mean for everyday life? Experience designer Nathan

Shedroff says that "design ... focuses on people and seeks to understand what it can offer them to make their lives better in someway" [44]. Design becomes then the process through which products, systems and artifacts are made—the very ones with which we interact everyday. In talking about term "sustainability," Shedroff emphasizes "cultural impacts as well as ecological ones, financial constraints as well as physical limits, and heritage and legacy as well as perspectives about the future." Regardless of what definition of design you choose, it is clear that design has an impact in our world.

2.3 Dimensions of design

Since "design" has so many interpretations, there should be ways to systematically think about design and the context in which it is being considered. Whenever design is talked about, especially in research and academia, it is important to make sure that the author and readers are on the same page. Presented in this section are three ways to frame thinking about design.

First, the cover of the *Design Issues* Reader [29] shows a diagram portraying different aspects of "design". It is reproduced in Figure 2-1. Next, a similar diagram inspired by the previous one and based on the author's research experience is shown in Figure 2-2. There are four components of design. In each component there are 8 examples listed. The four components are: **people, process, product, context.** Finally, a simple way of thinking about design is to ask whether it is being used as a noun or a verb.

2.4 Design Research

Furthermore, there is the term "design research" that appears in literature and academic works. The author encountered much confusion in the beginning of his studies when "design research" seemed to refer to different situations. There are even con-

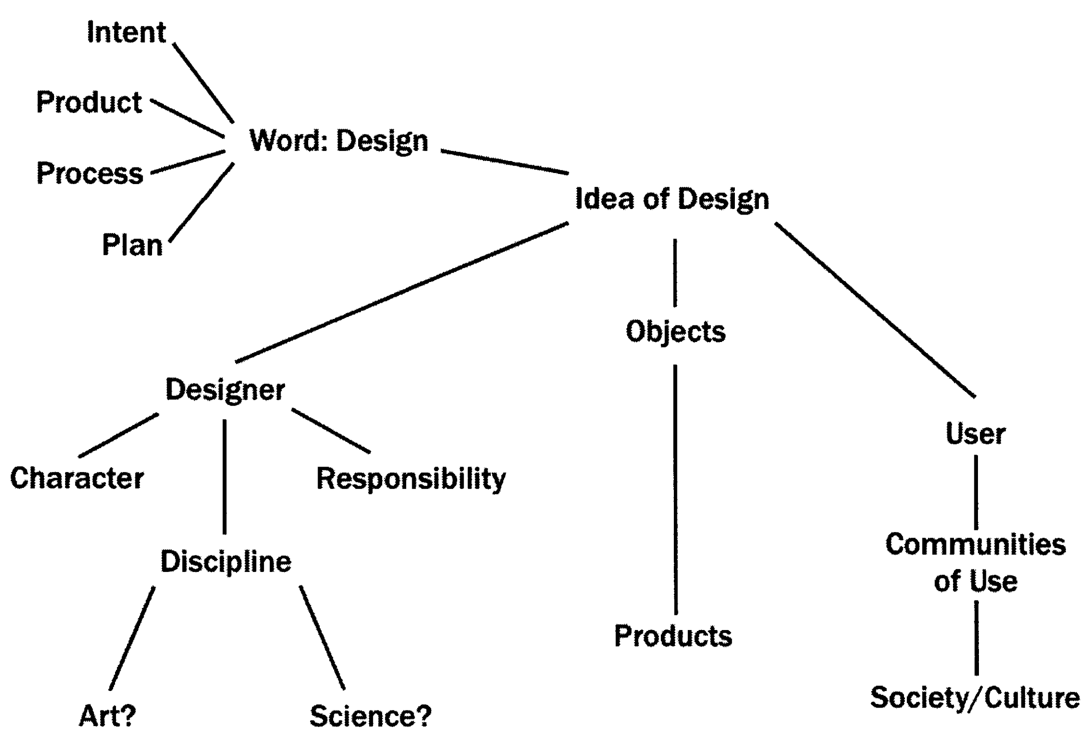

Figure 2-1: Different ways to view "design" Reproduced from [29]

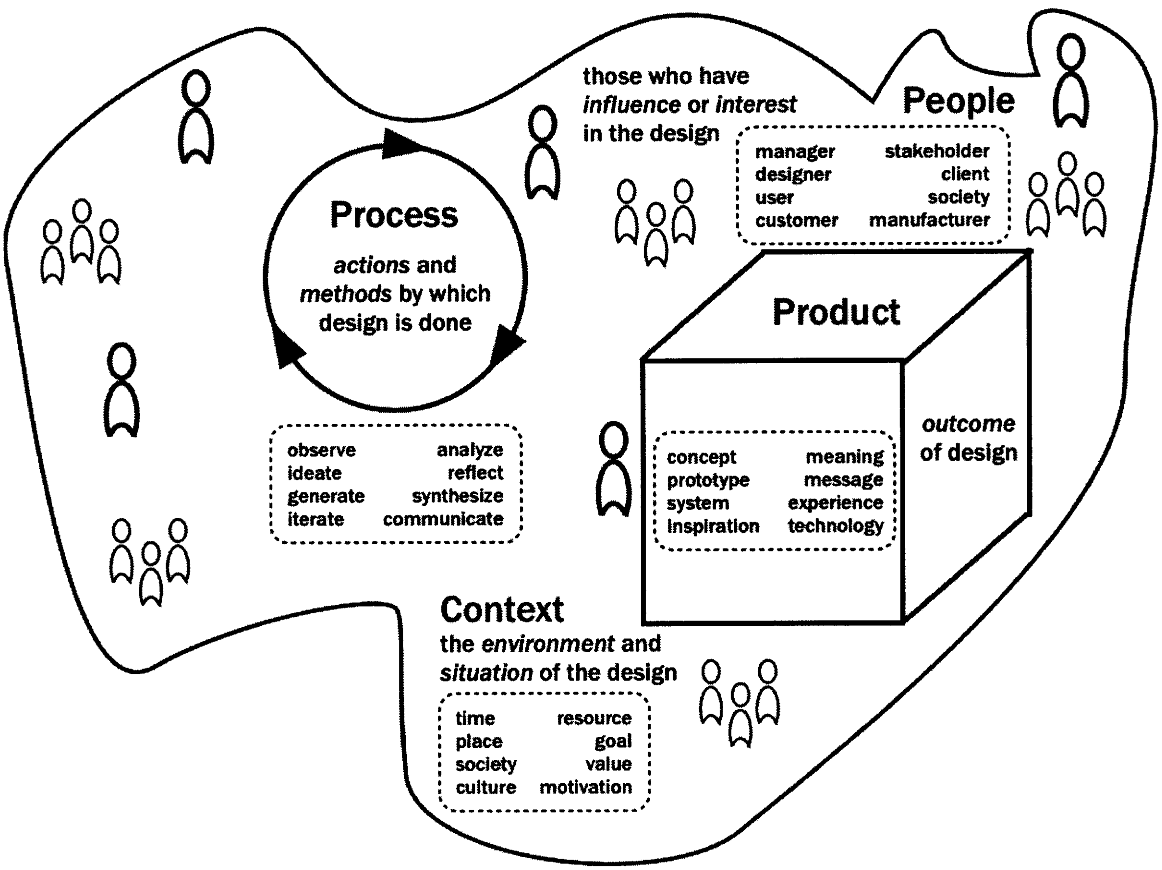

Figure 2-2: Different perspectives to view design in this research

ferences with "design research" in the title which refer to different flavors of research. Examples are: IIT Institute of Design's design research conference and the International Associations of Societies of Design Research Conference [2, 3].

To address the multiplicity of research and design approaches within interaction design research, Fallman creates a triangular model. It has three vertices: design *practice*, design *studies* and design *exploration*. Figure 2-3 shows the triangular model from [15] and Figure 2-4 summarizes Figure 2-3. Additionally, Cross, who might be seen as sitting in the design *studies* corner of Fallman's triangle, speaks of the distinction between the following: scientific design, design science, and the science of design [9].

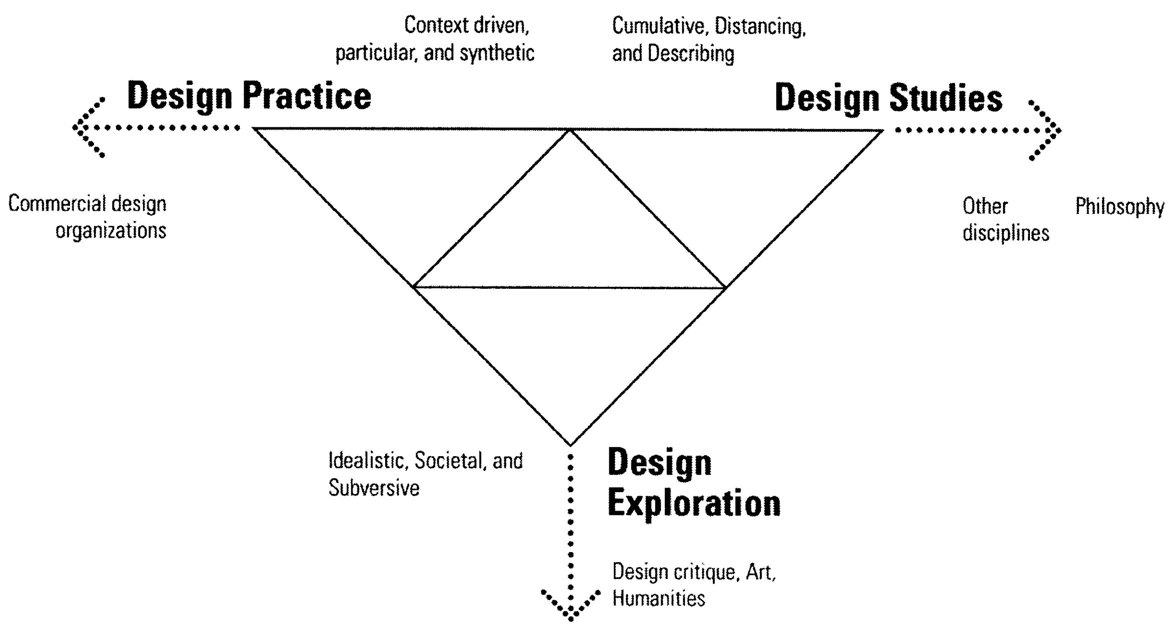

Figure 2-3: Fallman's triangular model of interaction design research. Reproduced from [15]

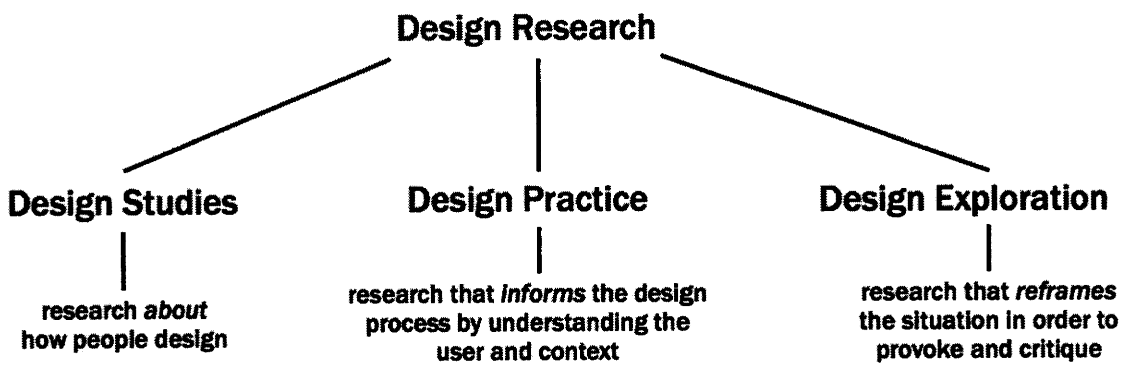

Figure 2-4: Three different components of design research as described by Fallman [15]

2.5 Product Design and Development

Ulrich and Eppinger outline a process for product development, from the initial planning and creation of a need to the end steps of bringing the actual product to market [50]. Components of the different phases shown in Figure 2-5 include but are limited to: *product planning*, *identifying customer needs*, *product architecture*, *design for manufacture*, and *prototyping.*

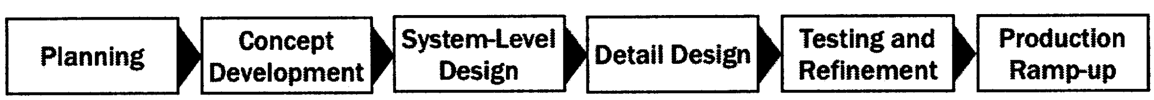

Figure 2-5: Phases of the product development process. Reproduced from Ulrich and Eppinger [50]

2.6 Designing Products with End Users in Mind

This section will talk about the origins of needfinding and how it is applied through various user-centered methods. There are a multiplicity of methods for different situations. Designers must take care when deciding when and how to use these methods.

2.6.1 Needfinding

At the core of design *practice*, or user-centered design, is the notion of needfinding – determining through various means what it is that users need or desire. For product design projects, "the presence of a genuine need" can be essential to success as it can "provide guidance during the design process and criteria for judging the success or failure" at the end [16].

McKim described needfinding four decades ago [30] as a "qualitative research approach to studying people to identify their unmet needs" in order to "help designers get closer to their end users" [36, 46]. Uncovering the needs of others requires the difficult task of gaining empathy with people. First, designers must accurately perceive and recognize those needs to the best of their abilities [39]. Second, people may or may not express their needs explicitly or accurately. One cannot always trust that what a user says matches with what the user is really thinking or whether the user is aware at all of his or her true inclinations. Designers need to be in tune at all levels while they try to gather relevant information from people. Sanders talks about the levels of need expression: observable, explicit, tacit, and latent [39]:

- **observable** needs can be seen by the research from observations
- **explicit** needs can be expressed verbally by the user
- **tacit** needs are known to the user but cannot be expressed verbally
- **latent** needs are subconcious, possibly unknown and inexpressable by the user

One of the pioneers of user-centered design recently noted, however, that perhaps many of the products that are created, are actually filling "necessary holes" and "essential voids" [32]. Needfinding is a messy, complex process which if not done carefully, can be a waste of resources but if done properly, can be fruitful for designers. In a rush to create the "'next best thing" designers may not critically think about the implications of introducing the artifact into the world.

2.6.2 User-Centered Design Methods

There are a variety of methods to use when interacting with relevant stakeholders for the given product or system [7]. For instance, surveys are an expedient way to obtain an aggregate response from many people to discover trends on a subject. However, it may be difficult to determine the rationale behind a large number of responses to set of questions. Interviews and observations can provide rich data and insights from spending time with individuals. Lead users are often used as a representation of the target market since their current strong needs may be a forecasting of future needs for all [52, 51, 28]. There may be limitations, however, to how representative a small sample of advanced users may be of the full potential user population and to the resources it takes to carefully execute the personal interactions well. Many other methods and protocols exist to guide user-centered design process, whether in industry or in the classroom [5, 27, 50, 40].

2.6.3 Landscape of Design Research Methods

Sanders speaks of the landscape of various design research methods, which consider how the user is considered throughout the research (as a partner or as one being observed) and whether the activity is driven more by research or design. This is reproduced in Figure 2-6.

2.6.4 Types of User-Centered Design

As with previous sections that dealt with the terms "design" and "design research", there also is a distinction in how the term "user-centered design" is used, as shown in Figure 2-7. The difference lies in **when** you are considering the user. Is the user being considered about his needs and desires and the designers are determining what to design? Or, is the designer thinking about how the user will interact with the product once it is created?

The left hand portion of Figure 2-7, **before** section was talked about in Section

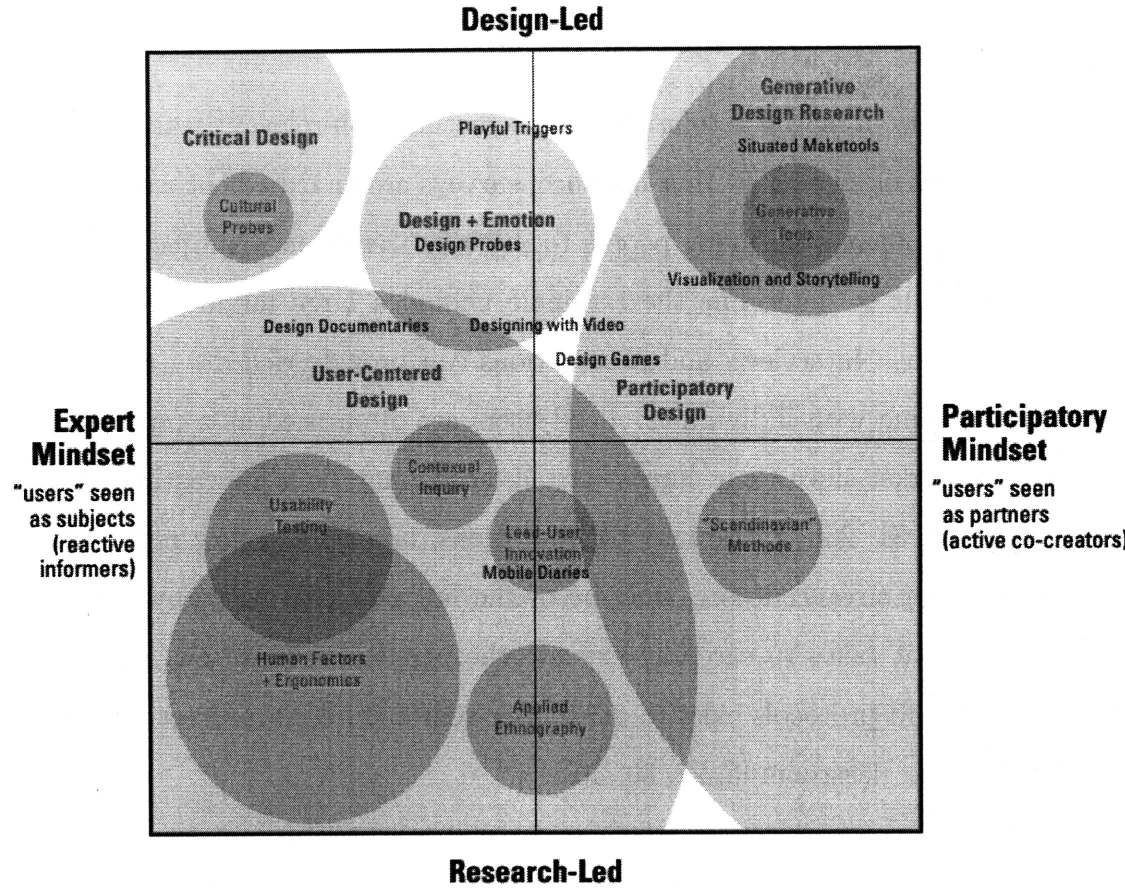

Figure 2-6: Landscape of design research methods. Reproduced from [40]

2.6.1-2.6.5. The **after** section is covered in various works but not specifically in this thesis [33, 31].

2.6.5 User-Centered Design Applied

Techniques for the identification of customer needs and their translation into functional requirements are widely taught in product design and development curricula [50, 34, 49]. Based on the lessons learned from alumni of New Product Development classes at UC Berkeley over several years, Hey, et. al. showed that students value the importance of "gathering and analysis of customer and user needs" [21]. Goodman examined why designers would prefer certain user needs over others [17]. It is important to determine not only whether a method is effective but also why a designer

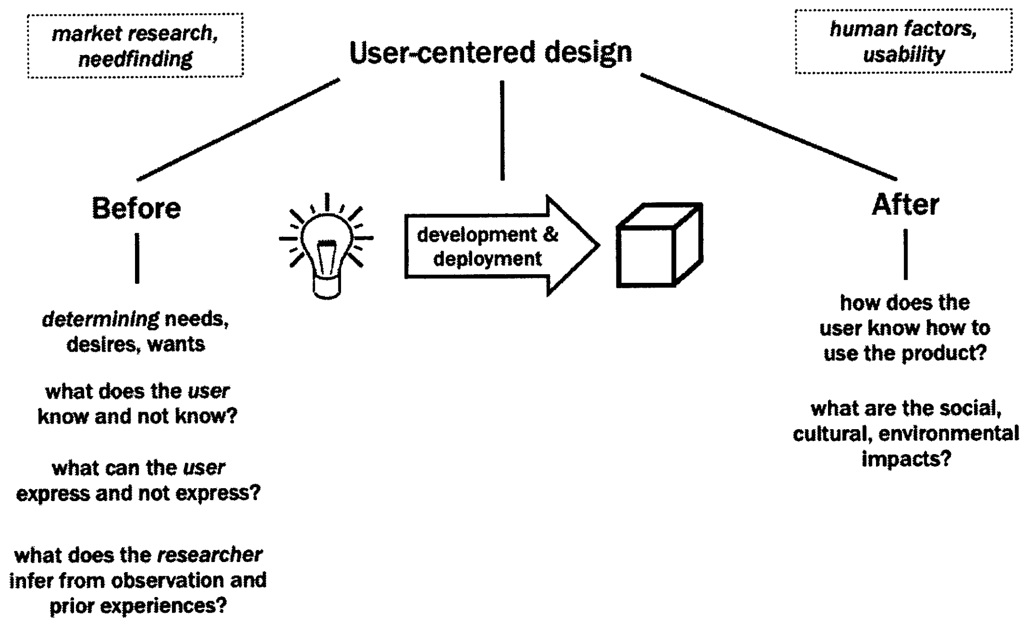

Figure 2-7: Two uses of the term "user-centered design"

would choose to employ a particular technique. In the software industry, Vrendenburg considered the usage of user-centered design processes of practitioners to characterize how methods are used [53]. Yang surveyed designers and engineers to understand the methodologies they used in practice, and found that neeedfinding was found useful by the majority of respondents [56].

2.7 Creativity in Engineering and Design

In a world full of complex problems, from socio-political to technological issues, new and innovative ideas are necessary to tackle problems of intricacy and magnitude. Creative thinking is needed to approach such problems. What about creative thinking in the engineering curriculum, particularly with respect to design thinking? It is not surprising that in engineering education students feel that creativity is not explicitly encouraged in their experience [24]. Students in engineering programs graduate perhaps having gone through design courses with a good deal of learning-by-doing, where they see the principles they have learned in the classroom come to life. Does this approach teach creative thinking?

First, how does the time spent in engineering and design education "practice" (that is, how long students have been taking design courses at the university level) relate to the way students perform in different types of design tasks? Often, projects provide situations with familiar design scenarios and it becomes convenient for students to attach and constrain themselves to a certain solution space. Awkward or unfamiliar design situations forces an individual or group of people to think divergently [37]. Second, how can assignments be designed to create environments where students are put in foreign or awkward circumstances, thus giving them an opportunity to gain experience in creative thinking within an unfamiliar situation that demands ingenuity to overcome [48]?

2.8 Novices and Experts

Cross, et. al. has done much work on novices and experts in design, showing that the ways of thinking and maneuvering about a design problem may differ in experienced and inexperienced students [12, 8, 25]. Additionally, in describing the need to build up the knowledge of design research scientifically and create useful interventions for teaching designers, Dorst adapts Hubert Dreyfus's levels of expertise for the designer: *naïve* to *novice* to *advanced beginner* to *competent* to *expert* to *master* to *visionary* [11].

While this work does not contrast the design action between novices and experts, the focus of the study is on novices. In our studies, these novices are encountering "user-centered" design for the first time. What are best practices in teaching them how to use the methods and the underlying motivations behind them?

2.9 Personality and Team Formation

It is important to consider individuals' personalities and how it might influence how they design. Work has been done on using personality profiles, such as Myers-Briggs Type Indicator (MBTI) for team formation [55, 45]. The case studies in Chapter 3 and 4 do not explicitly account for personality. This data was taken from students but not factored into this particular study.

2.10 Moving forward

2.10.1 *What's missing?*

Of the existing research in how designers interact with users, there is not much, if any research on quantifying and measuring the quality of user-centered methods and the relationships to outcome and other aspects of the design process. This thesis seeks to make progress in this direction.

2.10.2 Conclusions

This chapter gave some background knowledge which motivated the research found in the following two chapters. One can see that this thesis considered knowledge and theories in a variety of fields. When one attempts to make a conclusion in this work, one must be careful to consider all the various factors but in the end judiciously choose what are the important factors to consider. With a common knowledge established, the reader can better understand the motivations and assumptions of this work.

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Chapter 3

Case Study 1 - First Journey through Design

Does engineering education curriculum focus enough on giving exercises to students that force them to confront underdetermined and ill-defined problems?
Can curriculum and assignments be framed in such a way to ease students into becoming comfortable with divergent and creative thinking, thus giving them an opportunity to learn how to formulate and frame the problem?

3.1 Introduction

This chapter describes 2.97 - Design-a-palooza, a two to four week course offered during MIT's Independent Activities Period (IAP) which is the month of January every year. The goal of Design-a-palooza is to introduce the design process to novices. Students acquire a skill set and gain confidence in tackling open ended design challenges. The focus is on observation, ideation, concept generation & selection, prototyping and communication. It is open to anyone interested in all majors and years. For educators, it is an opportunity to try new design activities. Above all, it is a chance for both teachers and students alike to enjoy design without the typical stress of a normal semester.

The content of Sections 3.3.2 and 3.4 were adapted from a workshop paper written by the author and his colleagues [26].

3.2 Origins of 2.97 - Design-a-palooza

In 2007, Master's student Taylor Roan had the desire to teach a class for IAP 2008 as a basis for his Master's research. He was intrigued by the ability or inability of students to estimate the time it takes to do tasks within the design process. The theme for 2.97 was based around short engineering design challenges.

2.97 is a contrasting experience to design courses normally offered in the mechanical engineering department. First, students participate in smaller design projects where they can start afresh and learn from lessons from the previous task. Often in design classes, even though there are milestones throughout the semester, students can easily be overwhelmed and fall behind quickly. There is value in having a large comprehensive experience but there is also something to be gained in being able to try again and start over repeatedly. Students feel more comfortable with trying hard, failing fast and getting back up.

Second, the focus in 2.97 is on the conceptual and early stages of design, which compliments what is traditionally emphasized—the analytical, computational and mechanical. With limited time during the semester, design classes must focus on the latter set of skills. Students often do not get the opportunity to spend enough time on the beginning stages of the design process. 2.97 hopes to provide an opportunity to develop the early stage design skills.

3.3 2.97 January 2008 - Year 1

3.3.1 Logistics

2.97 was offered in January 2008 for three and a half weeks. Lectures were twice a week for two hours and there were lab activities and time to work on design challenges for three hours every day.

The class gave students six relatively brief and very different design challenges, as opposed to traditional courses with one, longer term project. We wanted to examine how students' performance changed as they grew in design experience over the course. Some challenges were typical, such as the egg drop, but many were foreign to students, such as creating an imaginary sport or creating the unuseless Japanese "artform" of Chindogu. The core of the class was designed to emphasize creativity rather than building skills or analytical abilities.

3.3.2 Previous work around Chindogu

At the University of Houston, the departments of Mechanical Engineering and Art collaborated to integrate students from both schools in classes "aimed at strengthening problem solving skills" [37]. They wanted to give the students the opportunity to face problems that exhibited characteristics like they had never seen before. This is important since often engineering design problems can refer to or be based off of known solutions. With an open-ended problem, there are fewer constraints within which to work and therefore decreased likelihood for rote problem solving from existing solutions. In their initiative, chindogu was one of the assignments used.

Chindogu is a form of Japanese design art originally developed by Kenji Kawakami. Kawakami describes chindogu as is the art of "unuseless" invention. Although the adjective "unuseless" implies that a Chindogu is not useless, it cannot be considered useful in an absolute sense either. The art of Chindogu lies in building within this paradox. Chindogu are simple devices that solve real, everyday problems but are somehow logistically or socially unacceptable. For example, there is the "hay fever hat" which is essentially wearing a roll of toilet paper on your head. While the hat would provide easy access every time your allergies bother you, you probably wouldnt want to wear it in public. The University of Houston study concluded with the argument that "learning to process through an awkward set of circumstances cultivates instinct and confidence", thus teaching students how to solve problems without necessarily knowing any previous solutions [37].

3.3.3 Methods for data collection

Webforms were setup for students to input their time tracking. They were asked to predict how much time they expected to spend on a challenge once it was presented to them. Then, they tracked all of their design activity. Certain design activities had quantitative measures, either based on performance of the device or the rankings compared to the other entries.

The final project for Design-a-Palooza, the Chindogu Challenge, was quite atypical, especially for those who had never heard of chindogu before. The assignment focused on concept generation and the communication of the chindogu design through a photograph of the chindogu each pair of students made. Each student had to make 4 total chindogu with 4 different partners. Though the chindogu may not be in accord with the standard definition of a creative product as "something novel and useful," we contend that the functional requirement of "unuselessness" fulfills this definition in chindogu space. A panel of 12 external reviewers scored each chindogu on problem solving, transparency, simplicity, unuselessness, and hilarity. Since this exercise was intended to be a creative task, those 5 categories were selected as a measure related to creativity. All of these factors differentiated the Chindogu Challenge from the previous design tasks in the course.

3.4 Findings from 2.97 2008

Roan's thesis describes many findings and suggestions for future work based on the data from 2.97 2008 [38]. This section speaks about four specific points which relate to creativity in engineering design education.

3.4.1 The Role of a Students Previous Design Experience

In our study, "experience" was a function of age or time spent in school. Out of a class of 11 students, there were 7 engineering students. The ages were evenly spread from 18-23 years old. We assume that the students, regardless of major, had done some number of hands-on building projects throughout middle and high school, in addition to whatever they had done in college thus far.

The first design task showed a statistically significant correlation between experience and performance on the assignment. There was a confidence value of 95% with a value of 0.60 between the two variables, using Spearman's correlation. This "egg structure" challenge, which involved creating a structure out of limited materials, with minimal weight, maximum height and strength, could be approached in a straightforward fashion. The older students had more experience in handling problems in a process that is more linear and formulaic. These logical skills are important to solving problems and not trivial. However, the lack of training in more divergent thinking approaches throughout the additional engineering courses, as shown by [24], for the older students had no effect on their creative ability for the Chindogu task, which was a more open-ended problem.

For the chindogu exercise, there was a statistically significant negative correlation between age, or experience, and how well the student ranked, with 98 % confidence value and a value of -0.69, using Spearman's correlation. The implication of this is that additional education may not do an adequate job of developing creative thinking and possibly has a negative effect since there is a lack of attention on creativity, as younger students seemed more likely to be able to think outside the proverbial box. Once the younger students understood that in Design-a-Palooza crazy ideas were encouraged, they were more likely to think creatively as opposed to those who needed to change from their normal problem solving approaches.

3.4.2 Problem vs. Prompt: Where do I start from?

Pahl and Beitz describes the activities in the first phase of design as "product planning" and "clarifying the task" [35]. Often in engineering and design courses, this first phase is already specified for students in the form of a well defined problem statement. In contrast to typical design assignments, the Chindogu assignment only gave a prompt with the definition of Chindogu. The students needed to first search within the problem space and properly frame an everyday problem that they wanted to tackle. Along the way to building the Chindogu, they might have needed to step back, reframe the problem, and thus go back and forth between problem framing and solution generation [9].

3.4.3 Practice Makes Perfect: Immediate Action After Reflection

In many engineering design classes, smaller milestones are assigned that build up to one, integrated product in the end. In contrast, in Design-a-Palooza a large number of disparate projects were given in order to stimulate design creativity and productivity. Also, a typical design course is over a semester or longer whereas this class lasted a month.

We parallel this to when a pitcher practices, he throws thousands of balls with slight variations to improve; when ballroom dancers practices a routine, they run through the steps over and over again ideally improving each time. Similarly, design students may be able to extend creative abilities by experiencing the design process more than once, trying out more than one method, and leaving time for mistakes and refinement. Several participants in this study said they gained a better understanding of their tendencies, strengths, and weaknesses as a designer by being able to participate in several projects within the short amount of time.

While some mistakes and failures are etched in the memories of students, we have found from our own experiences that often we would make the same sorts of mistakes in our design classes in subsequent courses. Giving students an opportunity to "throw some more pitches" and immediately apply new lessons learned will help develop their design and creative skills.

3.4.4 Acclimation via Creative Camaraderie

In the post-course assessment, one student gave very helpful insights into his experience. When asked about the order of the six design assignments, he made an interesting comment: having the more typical design problems at the beginning helped him ease into the creative demands of the course. If the Chindogu Challenge had come first, he would not have approached it in the same, open-minded fashion. Over the period of the class as the creative demand of each assignment increased, he became more comfortable with thinking creatively.

Also, he mentioned how working with other students on the projects building up to the capstone of the class (Chindogu) helped to create an environment with creative camaraderie where they learned about the working styles of their colleagues. Also, everyone had a shared understanding about the creative expectations and thus were less likely to hesitate to suggest crazy or radical ideas during final project.

In contrast, an opposing view can be taken about when to assign the "wacky and wild" creative assignment of the Chindogu. Perhaps starting off with Chindogu will set the informal tone of the class. This will let students know immediately the nature of the class. Also, there can be more time to help people develop their ideas and the method of communication. That being said, there is an aspect of creating Chindogu that is more intuitive than process driven.

3.5 2.97 January 2009 - Year 2

With the feedback from 2.97 2008, the author and his colleagues brainstormed to figure out the theme and structure for the second offering of Design-a-palooza. A shift towards consumer products and user needs was decided in order to give students a taste of the product development process. It was difficult because of lack of resources and time and not needing students to have prior building experiences. The activities were planned beforehand with many factors in mind. There was a balance between the students being able to focus on a project versus having to juggle many projects at once. A framework was presented to go through the steps of observation, ideation, concept generation & selection, prototyping, iteration, and communication.

3.5.1 Cardboard challenge

The first component of the class was to go from a compelling, unmet user need to a well formed prototype of a product to meet that need. Students were led through the process through various assignments. First, they were asked to observe a location for the sake of observing, learning basic ethnographic and observation skills. Then, the subsequent assignments had each pair of students generate many options for and finally select a specific user group, need or problem, and concept. All groups did not necessarily have a linear process, but the assignments were structured as such.

The material constraints and challenge was to have the prototype made out of cardboard and possibly reuse material. Teams took two different approaches: creating a product concept that would take advantage of the materiality of cardboard and using cardboard as a stepping stone in the prototyping process. Students were given basic training in working with cardboard. As their prototypes developed, they were given advice and additional help as needed.

Figure 3-1 shows the development of one of the products, *MedLinks Utility Belt.* The MedLinks are a group of students on campus at the each living group who promote health and well-being and help with minor medical problems. The existing kit was poorly organized, with items placed in ziplock bags in a large plastic container. The Utility Belt solved the organization problem for the MedLink, providing quick access in potentially time-sensitive situations.

3.5.2 Chindogu

The second component of the class was the Chindogu assignment, similar to 2.97 in 2008. Each student created a total of 3 Chindogu, working with 3 different partners. Figure 3-2 shows the development of one of the Chindogu from the lab to the street side. Students had to properly frame the photograph.

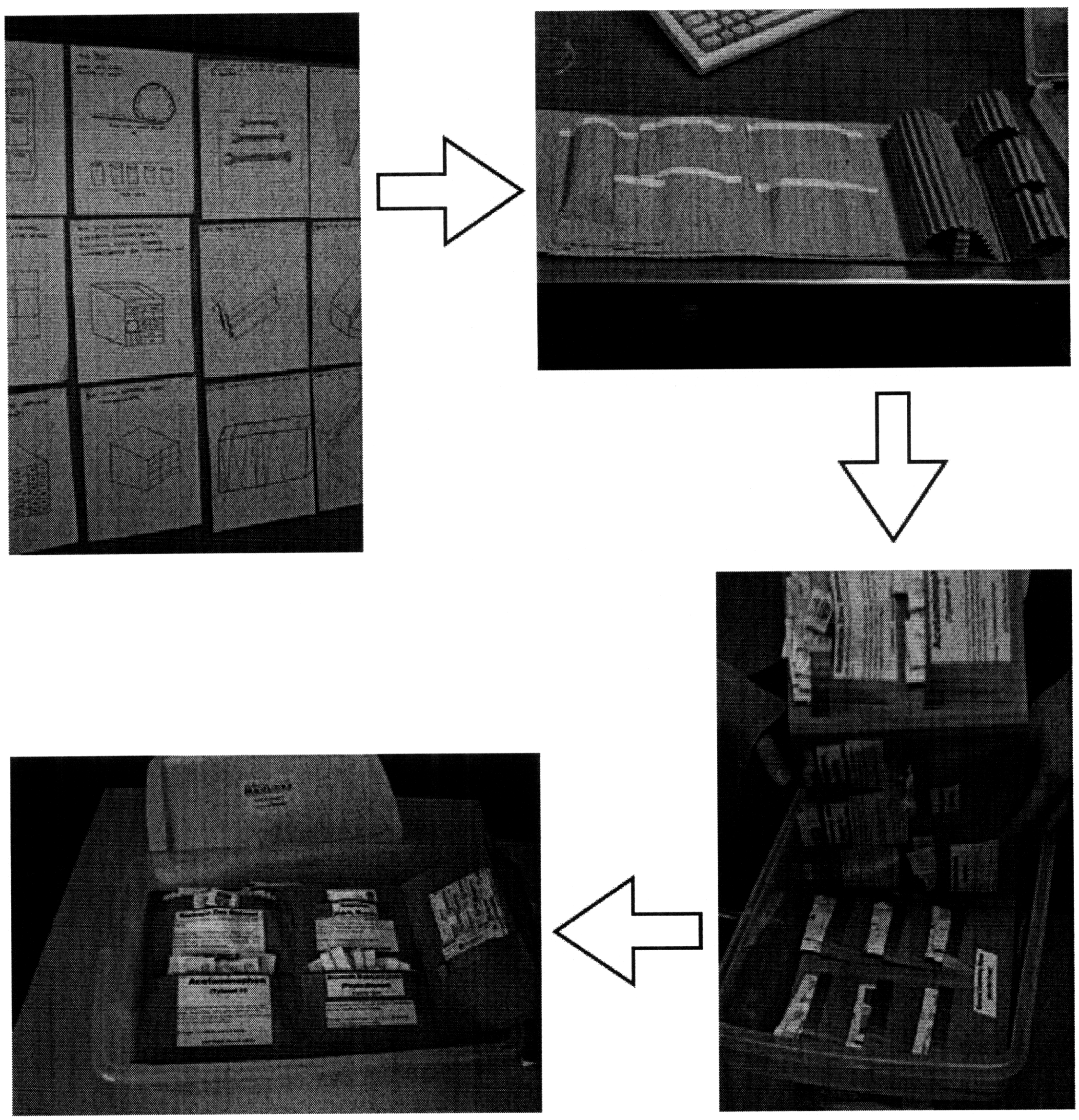

Figure 3-1: MedLinks Utility Belt. Development of the product from concept sketch to prototype to presentation

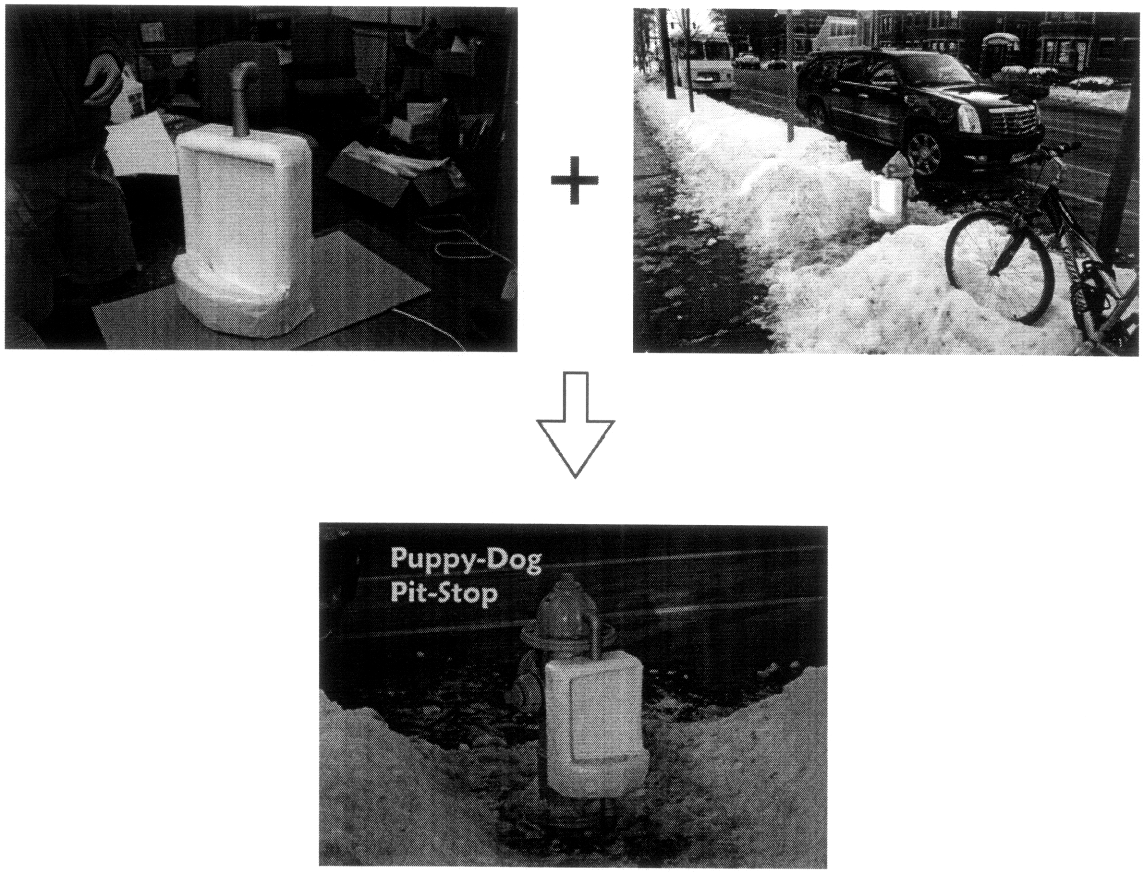

Figure 3-2: Development of Chindogu

3.6 Findings from 2.97 2009

As a final assignment, students were asked to fill out a survey about their experiences in the class and their opinions of their confidence in design and communication ability **before** and **after** taking the class. This section shows preliminary results from the qualitative and quantitative data.

3.6.1 Quantitative survey results

There is a danger in the interpretation of these survey results. Students may have responded in a way to always increase their confidence in abilities since they filled out both the **before** and **after** portions of the survey **after** the class was done. However, one can still see which categories improved the most for students as a whole. The alternative approach would give a survey to students before the class. Then, however, students may not have a good idea of what is meant by, for example, *sketching* or *ideation*.

In Figure 3-3 and 3-4, changes in confidence for communication and design skills are shown. The number represents the average change in response on a scale from 1 to 7. 1 was "not confident" and 7 was "extremely confident."

Change in confidence	
Generating many ideas	1.44
Thinking about multiple projects at once	1.00
Expressing your ideas to others	0.94
Critiquing others' work	0.88
Presenting in a large group (~20 people)	0.69
Putting together a presentation (slides, photos, videos, media)	0.50
Working in teams	0.37

Figure 3-3: Changes in confidence for communication skills

Change in confidence	
Sketching	2.13
Concept Selection	1.38
Prototyping	1.31
Creativity	1.25
Ideation	1.00
Working with physical things	0.81
Being resourceful with materials	0.75

Figure 3-4: Changes in confidence for design skills

3.6.2 Qualitative student feedback

Honest, constructive feedback was requested in order to improve the experience for future students. Five areas in particular are described below.

Definition of design

> *In my opinion, design is still a process which can't be controlled. You still need inspiration and intangible and unteachable intuition to come up with a great idea but the processes and ways of thinking we have learnt this week help direct design and make it more efficient.*

Our goal was not necessarily to have students have a well defined notion of design. We wanted them to appreciate all aspects of design, beyond the mechanical and analytical, with which many of them were most comfortable with. Students realized the importance of being aware of people's needs and the relevance to design.

Being aware of surroundings and audience

One of the ongoing assignments was to write a blog entry to the class about a product they found and to analyze the good and bad aspects of the design.

> *...now I unconsciously think about how things around me are designed and what could be done to make them better. I do it all the time now!*

We began the class with observation exercises where they observed for the sake of observing. Before jumping to the step of finding immediate problems to solve, we wanted students to appreciate the world and people around them. Product design is not about filling the world with products just because it can be made. Students enjoyed the Chindogu assignment where they had to be cognizant of who their audience might be and how viewers may react to what they present.

Communication skills

Planning for the class, we did not expect to have the emphasize on communicating ideas as much as it ended up happening. Much of the feedback given by students appreciated this focus.

> *2.97 improved many of my communication skills, especially generating ideas and sharing them with others. Critiquing others' work is something*

I had never officially done before...I felt free to say whatever I wanted because I knew that the feedback would be both useful to them, and to me as well.

Students did not merely present slides about the progress on their project. They engaged with each other in conversation about the ideas, both giving and receiving feedback. A community of constructive criticism was formed wherein students felt free to talk about each others' ideas. Similar to many themes, 2.97 provided a safe place for failure since it was not the typical design class. More attention to the teaching of these skills will be given for future offerings of the class.

There is also the importance of visual communication and graphic design. Students appreciated this component but also requested more training, such as the basics of photography, for the purpose of the Chindogu assignment, and more time to spend refining the visual artifacts.

Ability to generate many ideas

As shown by the results in Section 3.6.1, the **ability to generate many ideas** had the largest average change in confidence for each students' perception of their skills.

...I had always grappled with sticking to a particular concept, which tends to crowd out other useful ideas. However, the informal structure of the class allowed me to let my mind wander hence at the end of the day I was able learn how to freely ideate.

One of the earlier assignments was to generate 30 different concepts that addressed potential needs. Students initially were hesitant about their abilities to generate a diverse set of solutions. The next day, however, most teams showed up with a variety of ideas and were ready to share with classmates and continue to develop ideas.

Once again, there is not always sufficient time in typical courses for students to have such freedom to diverge in their thinking. An experience like this in 2.97 can prepare students for when they do not have much time to spend in the early stages. Their minds will already be primed for the quick divergent thinking. Students commented that they were surprised at their own ability to generate many ideas. "Defer judgment" is a mantra used in brainstorming and students felt that they had an environment to do so.

Quick design activities

2.97 in 2008 contained more quick, self-contained design activities whereas 2.97 in 2009 only had two such activities. For instance, students were asked to quickly design a water bottle for themselves and share it with the rest of the class.

> *...start each class day off with a 3-min design exercise like the water bottle - it's a great warmup, very fun, very good for learning from others and ultimately surprising yourself with your abilities.*

Having multiple projects, even ones that only last an hour, help students to continue thinking about new situations. In 2009, there were more or less two large projects with various components. Students wished that there was more variety interspersed throughout the two larger projects.

3.7 Moving forward

3.7.1 Creativity in Engineering Education

In this chapter, we initially suggest two questions to frame discussion: is there something about the engineering design curriculum that focuses more on one aspect of design thinking, neglecting other aspects? Second, how can we shape the design tasks to create an environment that fosters creativity?

Based on our experience and observations of the Design-a-Palooza class, we gained insight into the nature of creativity within the realm of design. First, older students who have been through more design and engineering classes are trained to think in a certain way, which may not emphasize divergent and creative thinking enough. Second, the level of definition of the problem will affect the type of design thinking necessary to complete the posed challenge. Third, often classes do not provide an opportunity for the students to act upon the reflections and lessons learned from a design task. Finally, the structure of the class can be shaped in a way to ease students into creative thinking and that the social aspects of design can help to nurture these skills.

We suggest that our findings provide departure points for further discussion on how creativity is important in design and, perhaps more importantly, how we can foster creativity in students. In a time when traditional engineering and design skills have become increasingly computerized or outsourced, educational institutions can gain value in being able to cultivate skills that are indispensable, equipping students to approach any problem they will face.

3.7.2 Teaching 2.97

There are many areas ripe for further investigation with regard to teaching 2.97 - Design-a-palooza. Remaining data will be analyzed, both qualitatively and quantitatively. For 2.97 2010, all the information will be considered to best prepare and plan for the next group of students.

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Chapter 4

Case Study 2 - User Needs Methods for Mid-Career Professional Students

This study investigates the role of user-centered design approaches in design process and outcome within the context of design team projects. Implications for design pedagogy suggest the need to structure product design and development courses to foster a reflective practice while students engage with stakeholders throughout the entirety of the design process.

4.1 Introduction

For many years, user-centered design has been recognized as an approach which focuses on the needs of end-users to guide the design of products, services, and systems [33, 19, 18]. On one level, user-centered design may simply be thought of as a means to create design requirements. However, user-centered design techniques can be utilized at another level to formulate a more nuanced view of users to ensure that design problems are posed appropriately. A great deal of effort may be wasted when design teams attempt problems that are ill conceived in the first place. With a poorly considered problem, efforts to execute and deploy the project may be in vain. Buxton calls this distinction "getting the right design" versus "getting the design right" [6].

This deeper view of users focuses on gaining empathy with those whom are being designed for through finding the underlying motivations of a user, rather than merely "the process of writing the requirements document" [57, 58, 50]. Young illustrates with an example of creating software for helping people manage their retirement funds. What lies beyond finding what a person needs for that software? What are their motivations for investing? Getting to the deeper level of understanding can help designers create "a richer set of tools that support the customer better than just three fields to transfer funds." [58]

User-centered design may also offer benefits for overall design team effectiveness. Researchers on team effectiveness posit that a clear understanding of a team's goals is critical for effective team performance [23]. By establishing a shared set of team goals, teams "'develop direction, momentum and commitment."' Hey, et. al., describes the different paths that design teams can take in developing a shared frame with users [22]. It may be that the process of better defining problems and requirements will lead to more thoughtful, shared team goals. In this way, user-centered design approaches may help teams formulate these requirements and goals, therby helping them perform more effectively.

User centered design has been incorporated in many design curricula in product, software, and user interaction design. The focus tends to be on teaching specific user centered techniques and strategies so that they may be applied to design experiences both in and out of the classroom. The studies conducted in this paper take this approach further by carefully evaluating student's use of these techniques to formulate a better understanding of the students' design process. This chapter examines the role of user-centered design approach in both design process and outcome in a semester-long, graduate level course on product design and development.

It is noted that the terms "designer" and "engineer" can have a multiplicity of meanings in different contexts. For clarity, throughout this paper, students will also be referred to as designers even though their backgrounds are diverse.

4.2 Details of ESD.40 - Product Design and Development

4.2.1 Description of class

The study was based on a product design and development class of 72 mid-career professionals as part of their graduate program in Systems Design and Management at MIT. Eighteen teams of 3-5 students each had one semester to identify an unmet, compelling need and develop a demonstratable prototype of a novel product that solved this need. Teams were given a budget of $800 to spend on materials and manufacturing. Students had backgrounds in engineering and science, and had worked in industry for several years, in areas such as defense contracting, military, and software. Figure 4-1 shows the average time of students spent in industry, time since last degree, and years of experience in particular aspects of the product development process.

Milestones were set throughout the three month semester to simulate deadlines in the real world, as shown in Figure 4-2. Lectures covered pertinent information on the product development process and in particular, instructed students on the basics of user-focused methods described in Table 1. Examples of projects included a container for transporting specialty beverages and systems for improving the home woodworking experience. Several teams have continued commercial development of their projects well beyond the course.

4.3 Key questions

The key questions were as follows:

1. *What are the characteristics of a design that are important to reviewers of design projects?*

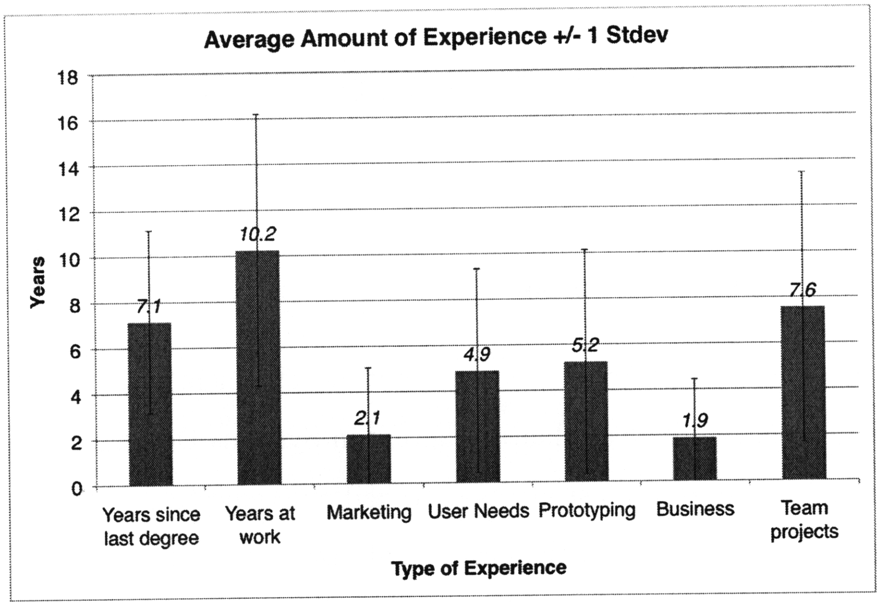

Figure 4-1: Amount of past experience of students

The outcome of design projects can be quantitative, as with engineering performance criteria, but many aspects may be subjective. For such qualitative assessments, panels of expert reviewers may be employed to gain a broader sense of the design's strengths and weaknesses. Reviewers rated several characteristics of a design, including the user need filled by the design and the usability of the design. Which of these characteristics were the most salient markers of a design's overall performance?

2. *Is there a link between the quantity and nature of interactions with users and reviewer ratings?*

   One approach to measuring user-centered design is through the quantity of interactions between designer and user. Do teams who interact more frequently or spend more time with users tend to produce better reviewed products?

3. *Is there a link between the quantity and nature of interactions with users and team effectiveness?*

   Do teams who interact more frequently or spend more time engaging tend to also have teams believe themselves to be more effective?

Stage	Milestone Name	Team Review #
1	*determine potential market/user groups*	
2	*select market/user group*	Team Review 1
3	*assess customer and user needs*	
4	*propose 3 concept ideas*	Team Review 2
5	*select concept*	
6	*product contract*	Team Review 3
7	*implement concept and present business plan*	Team Review 4

Figure 4-2: Milestones for the class

4. *What is the nature of the relationship between team effectiveness and reviewer ratings?*

Team effectiveness is not necessarily linked to stronger performance outcomes [23, 20]. However, specific aspects of team effectiveness might play a role in how well a product is assessed in the end.

4.4 Methods for data collection

Data on user interactions, team effectiveness, and reviewer rankings was collected through a combination of various forms and surveys administered to the teams and reviewers and are described in Sections 4.4.1-4.4.4. Relationships between datasets were made using Spearman correlation for non-parametric populations, as most data was non-Gaussian.

4.4.1 User Interaction Reports

To facilitate and track teams' interactions with users, teams were asked to complete a brief form about each interaction with potential users and customers. An "interaction" was loosely defined as any information-gathering experience with one or more users, such as an interview, survey, or focus group. This form accounted for the number of people interacted with, time spent doing so, and the nature and details of the interaction. These forms draw on Schön's idea of reflection-in-action [42]. Practitioners must think about what they are doing in order to truly learn from their experiences. This framework is composed of a 3-stage cycle in Figure 4-3:

- **prepare** - *thoughtful action in asking*, "What do I want to get out of this interaction?"
- **interact** - *being in the moment*, "How do I best listen to my correspondent(s), both in their actions and speech?"
- **respond** - *thoughtful reflection*, "Now what do I do with this information that I have found?"

First, teams were asked to to prepare before the interaction with the user, in order to stop and think about what they wanted to learn from the interaction. Next, teams were asked to document their interaction. Finally, they summarized their findings from the meeting, whether they wanted to meet with the user again, and how their overall gameplan had been affected. Teams submitted reports and presented the latest findings at each milestone. An example user interaction report is located in Appendix A.

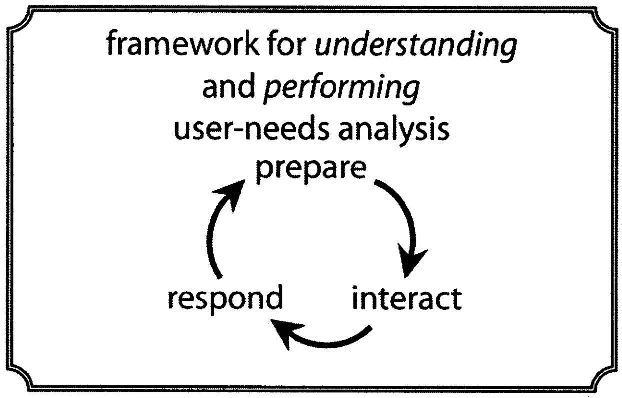

Figure 4-3: Framework for user-needs analysis

4.4.2 Team Effectiveness Survey

To assess each team's performance, students completed team effectiveness evaluations four times in the semester. A 10-question team effectiveness questionnaire adapted from Alexander [4, 54, 10] (see Table 4.1) along with several other questions to assess team performance adapted from a questionnaire developed by David Wallace for a senior capstone design course at MIT. The questionnaire considers both social and task dimensions of teamwork. The aggregate survey results for each team were shared with the team itself with individual identities removed. Teams could then gain a sense of their overall effectiveness as judged by its own members.

4.4.3 Reviewer Ratings

Each project was assessed by an external review panel of 6 designers and engineers. This review panel consisted of professionals with experience in consumer product and system design.

The panel watched 15 minute live presentations by each team on their project and gave feedback via a review form (see Figure 4-4 for short version and Appendix A for full version). The presentations included a description of the user need, the product itself (usually along with a demonstration), and market viability. At the end of the presentations, the top ranked team was awarded $1000. A team's performance by the review panel was not reflected on their team's grade in the class.

The review form consisted of questions designed to evaluate the following:

- whether the product concept was anchored in the mandate of the class (*products must meet a compelling, unmet need*)
- the team's understanding of the potential market and business potential
- the concept based on Sanders' three perspectives on products [39]
- how well the teams implemented and executed the prototype based on their concept
- the teams delivery of their work

4.4.4 User Method Surveys

Pre- and post-surveys were administered at the beginning and end of the semester to gauge an individual student's experience and affinity for various user-centered design methods. Students completed the pre-survey before being presented material on the topic in class. The survey contents included the methods found in Table 4.2. For each method, students were asked to choose one of the following:

- "Not familiar with this"
- "Familiar with this but have never used in a work-related project"
- "Have used this in a work-related project and found it useful"
- "Have used this in a work-related project and found it **not** very useful"

Category	#	Question	
User Need	1	Is this user need compelling, unmet, and clearly defined?	idea
Market Need	2	Is there an understanding of where the product fits in with its competitors?	idea
	3	Is there a viable market for this product?	idea
Product Concept	4	**Usefulness** - How well does the concept meet the user need?	idea
	5	**Usability** - Can a user easily figure out how to use it?	implementation
	6	**Desirability** - Does this product make a user think, "I want this!"?	idea
Business Case	7	Is the a business case for the product plausible?	
Prototype	8	Does the prototype communicate the product concept convincingly?	implementation
	9	Do users respond positively to the product?	implementation
Delivery	10	Was the presentation well structured and delivered?	
Potential	11	Do you believe this project could become a successful product?	

Figure 4-4: Reviewer rating criteria

4.5 Results and Discussion

Figure 4-5 shows correlation coefficients Rs among each of the review questions listed in Figure 4-4. Coefficients in bold are statistically significant ($p < 0.05$). Many correlations were found among the questions. In particular, it can be seen that projects with the highest ratings for *desirability* (Q6) and *an understanding of how they fit in with their competitors* (Q2) tend to have higher scores for other questions as well, suggesting that these two aspects were leading indicators of a product's assessment by reviewers. In other words, teams that tended to be rated well on these two questions tended to perform well overall.

		Reviewer Ratings												
		Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*idea*	*impl.*
Reviewer Ratings	*Q1*	1.00	0.49	0.27	0.73	0.28	0.82	0.30	0.26	0.69	0.90	0.60	0.78	0.55
	Q2	—	1.00	0.66	0.72	0.05	0.65	0.52	0.50	0.59	0.58	0.80	0.85	0.53
	Q3	—	—	1.00	0.42	0.12	0.50	0.71	0.45	0.27	0.39	0.63	0.67	0.43
	Q4	—	—	—	1.00	0.08	0.77	0.38	0.41	0.73	0.84	0.70	0.86	0.60
	Q5	—	—	—	—	1.00	0.47	0.09	0.25	0.46	0.23	0.15	0.29	0.62
	Q6	—	—	—	—	—	1.00	0.51	0.39	0.85	0.80	0.73	0.93	0.79
	Q7	—	—	—	—	—	—	1.00	0.14	0.36	0.37	0.81	0.54	0.34
	Q8	—	—	—	—	—	—	—	1.00	0.32	0.30	0.39	0.53	0.72
	Q9	—	—	—	—	—	—	—	—	1.00	0.73	0.66	0.79	0.82
	Q10	—	—	—	—	—	—	—	—	—	1.00	0.71	0.81	0.58
	Q11	—	—	—	—	—	—	—	—	—	—	1.00	0.80	0.58
	idea	—	—	—	—	—	—	—	—	—	—	—	1.00	0.76
	impl.	—	—	—	—	—	—	—	—	—	—	—	—	1.00

Figure 4-5: Self correlation of reviewer ratings

It was observed that the individual reviewer questions could be divided broadly into two categories. The results are shown in Figure 4-5. The first relates the quality of the product **idea** in Q1-4 and Q6. The second category focuses on the **implementation** of that concept, including the physical embodiment and fit-and-finish of the final prototype, in Q5, Q8, and Q9. The ratings for questions in each of these two categories were averaged and also correlated, and listed as "idea" and "implementation" in the far right columns and bottom two rows of the table. Projects rated as highly desirable (Q6) were also very highly correlated with both *idea* (0.93) and *implementation* (0.79). An understanding where a product fits in with competitors (Q2) also demonstrated strong correlation with *idea* (0.85) though not with *implementation* (0.53), though not as high as for Q6. This implies that desirability of a product is very important in how a product is perceived by external reviewers.

The two questions most directly identified with user-centered design were *user need* (Q1) and *usability* (Q5). *User need* (Q1) showed several statistically significant correlations with other reviewer questions. Surprisingly, *usability* (Q5) showed only one statistically significant correlation. One possible reason for this lack of correlation is that *usability* is often a quality that is apparent in products that are noticeably more refined than prototypes developed in the class. Given the time and resource constraints of the course, most teams were able to present prototypes that could demonstrate basic functionality typical of a preliminary design rather than a full working prototype with a higher degree of finish. Another possible explanation may be due to the way in which the products were presented to reviewers. The product presentations were generally formulated along the lines of an investor pitch which may have little to do with the way a product might be used in a real-world application. If the mindset of reviewers is to see the presentations as elevator pitches, the questions dealing with the *idea* would then be rated better than those questions dealing with *implementation.*

4.5.1 Pre- and Post-Surveys of Individual Experience and Affinity for Specific User-Centered Methods

Figure 4-6 shows individuals' experience with several user-centered methods, whether they liked or disliked the methods, and the correlations of these with reviewer rankings. The goal was to find out if prior experience or interest in any of these methods was linked with improved performance on any of the review criteria. The pre-survey was administered at the beginning of the class. Note that the negative values in Figure 4-6 and 4-7 are indications of **positive** correlations and vice versa because the value of the ratings was flipped. The paragraph below will speak about **negative** correlations from the values in the data which actually represent positive correlations between experience and affinity in user methdods and outcome.

There are a number of mostly negative correlations scattered throughout the questions, indicating that experience or affinity with particular methods is associated with questions, but no clear pattern emerges. However, these results imply other things once the post-survey is taken into consideration (Figure 4-7). The post-survey table

		Reviewer Ratings												
		Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*idea*	*impl.*
Experience	**interv.**	0.02	0.12	0.12	0.00	−0.02	0.05	−0.10	−0.16	0.09	−0.11	−0.21	0.10	−0.01
	surveys	−0.03	0.32	0.17	0.24	0.00	0.20	0.31	−0.01	0.23	−0.09	0.20	0.22	0.14
	wants needs	−0.21	−0.07	0.30	−0.16	0.05	−0.23	−0.07	0.14	−0.38	−0.20	−0.13	−0.09	−0.11
	cardsort	0.31	0.37	**0.52**	0.21	−0.13	0.41	**0.52**	0.00	0.32	0.26	0.44	0.45	0.22
	group task	0.42	0.03	−0.03	0.25	0.39	0.37	−0.13	−0.08	0.20	0.32	−0.01	0.25	0.14
	focus groups	0.30	−0.13	0.26	0.11	0.00	0.21	−0.02	0.05	0.01	0.32	0.00	0.15	0.06
	field studies	0.17	0.18	**0.48**	0.06	0.20	0.34	0.39	0.04	0.40	0.20	0.29	0.30	0.34
	user feedbk	0.30	0.03	−0.11	0.35	−0.01	0.14	−0.14	−0.03	0.32	0.38	0.06	0.14	0.17
	buglist	−0.28	**−0.53**	−0.17	−0.46	0.33	−0.20	−0.17	−0.31	−0.25	−0.44	**−0.47**	−0.32	−0.09
Affinity	**interv.**	0.04	−0.13	−0.34	0.12	−0.05	−0.06	−0.03	−0.16	−0.04	0.18	0.14	−0.12	−0.16
	surveys	−0.19	−0.18	−0.34	−0.24	−0.16	−0.37	−0.02	−0.28	−0.15	−0.06	−0.07	−0.37	−0.31
	wants needs	−0.03	−0.01	−0.47	0.00	−0.43	−0.22	−0.31	**−0.49**	0.00	−0.07	−0.20	−0.17	−0.40
	cardsort	−0.18	−0.08	−0.27	−0.24	0.17	−0.16	−0.11	0.11	−0.10	−0.33	−0.14	−0.20	−0.01
	group task	−0.46	0.00	0.10	−0.27	−0.46	−0.37	0.08	0.15	−0.29	−0.46	−0.20	−0.24	−0.14
	focus groups	−0.33	−0.36	−0.43	−0.22	−0.40	−0.45	−0.26	−0.38	−0.18	−0.22	−0.33	−0.44	−0.33
	field studies	**−0.57**	−0.43	**−0.54**	−0.32	−0.16	**−0.60**	−0.45	−0.14	−0.24	−0.43	**−0.49**	**−0.59**	−0.23
	user feedbk	−0.34	−0.09	−0.27	−0.33	−0.05	−0.24	**−0.50**	−0.25	−0.29	−0.34	**−0.50**	−0.25	−0.33
	buglist	0.07	0.33	0.01	0.11	−0.31	0.01	0.26	−0.29	0.01	0.07	0.29	0.12	−0.22

Figure 4-6: Correlation between pre-survey and reviewer ratings

shows that correlations for focus group affinities, change from non-significant negative correlations to significant negative correlations, suggesting that individuals liked this technique more after their project than before. Affinity for field studies show a somewhat different view, however. Statistically significant negative correlations become positive or non-significant in the post-survey, implying that designers liked this technique **less** after presumably experiencing it in their own projects. This might be because of the effect of "knowing what you don't know." Through their projects, individuals grasp the challenges of conducting field studies that they perhaps did not appreciate before the course.

		Reviewer Ratings												
		Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*idea*	*impl.*
Experience	interv.	0.28	−0.07	−0.08	0.20	−0.13	0.04	−0.12	0.13	0.16	0.18	−0.14	0.06	0.12
	surveys	0.04	0.13	−0.05	0.01	0.13	0.02	0.01	−0.02	0.19	−0.14	−0.06	0.02	0.08
	wants needs	0.03	−0.11	−0.06	−0.21	0.42	0.03	−0.03	−0.18	0.02	−0.09	−0.16	−0.09	0.04
	cardsort	0.40	0.31	0.01	0.19	0.06	0.23	−0.36	0.17	0.30	0.32	0.04	0.29	0.18
	group task	0.18	0.12	0.30	0.25	0.19	0.42	0.36	−0.10	0.29	0.29	0.30	0.34	0.28
	focus groups	0.18	0.44	0.21	0.44	0.32	0.45	0.25	0.17	**0.56**	0.34	**0.47**	0.44	0.45
	field studies	−0.38	−0.33	−0.10	−0.25	−0.26	−0.45	−0.16	−0.13	−0.17	−0.29	−0.31	−0.41	0.20
	user feedbk	0.22	0.15	−0.07	−0.03	0.02	0.07	−0.06	0.11	0.32	0.06	0.13	0.07	0.19
	buglist	0.19	−0.16	0.03	0.04	−0.08	−0.01	−0.09	0.09	−0.15	0.20	−0.12	−0.05	−0.09
Affinity	interv.	−0.34	−0.19	−0.14	−0.29	0.08	−0.24	−0.08	−0.06	−0.08	−0.07	0.04	−0.29	−0.07
	surveys	−0.40	−0.33	**−0.53**	−0.31	**−0.47**	**−0.50**	−0.19	−0.21	−0.30	−0.33	−0.28	**−0.50**	−0.35
	wants needs	−0.20	−0.24	−0.16	−0.12	−0.34	−0.32	−0.16	0.20	−0.23	−0.13	−0.19	−0.23	−0.04
	cardsort	0.01	−0.02	−0.19	−0.01	−0.20	0.11	0.12	−0.39	−0.11	−0.03	−0.01	−0.03	−0.30
	group task	−0.32	−0.26	−0.05	−0.27	−0.13	−0.46	0.05	0.11	−0.37	−0.26	−0.17	−0.40	−0.21
	focus groups	**−0.57**	**−0.53**	**−0.49**	**−0.61**	−0.26	**−0.76**	**−0.59**	−0.20	**−0.71**	**−0.52**	**−0.64**	**−0.73**	**−0.62**
	field studies	**0.48**	0.45	0.33	0.47	0.14	0.39	0.23	0.04	0.17	**0.50**	0.33	0.46	0.08
	user feedbk	−0.04	−0.16	−0.20	−0.15	−0.11	−0.02	−0.04	−0.27	−0.21	−0.10	−0.14	−0.09	−0.25
	buglist	−0.02	0.21	0.34	0.01	−0.26	0.03	0.23	0.04	−0.10	0.03	0.12	0.11	−0.10

Figure 4-7: Correlation between post-survey and reviewer ratings

4.5.2 User Interaction and Reviewer Ratings

The figures below show the quantity of user interaction by each team at each stage of the class. Stage 2 is omitted because that milestone was dedicated only to market research. The figures describe the number of forms submitted, number of people each team interacted with, and the amount of time each team spent in their user interactions.

It was expected that the proportion of interactions would be highest at the beginning of the project, when teams are starting to identify user groups and needs,

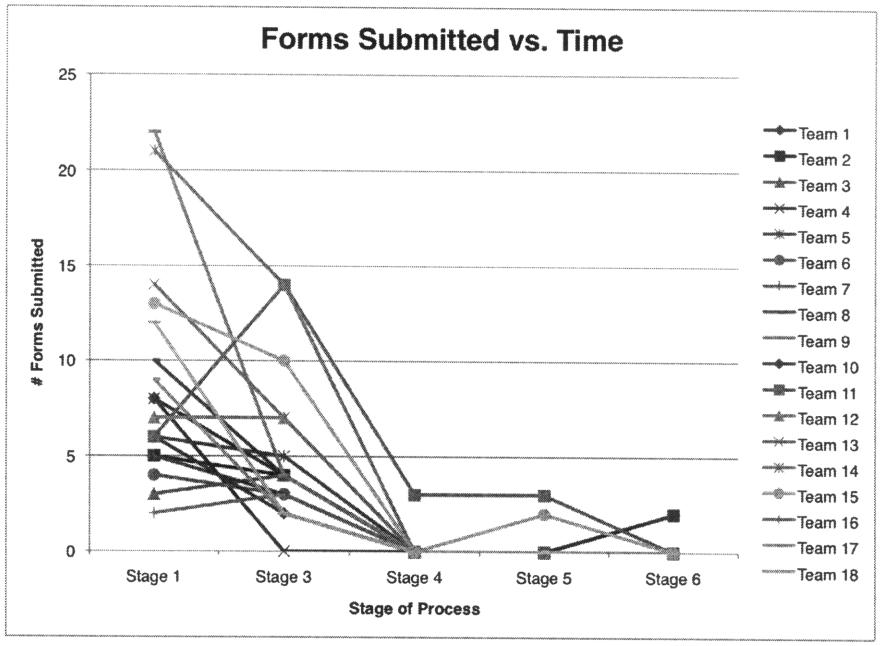

Figure 4-8: Forms Submitted vs. Time

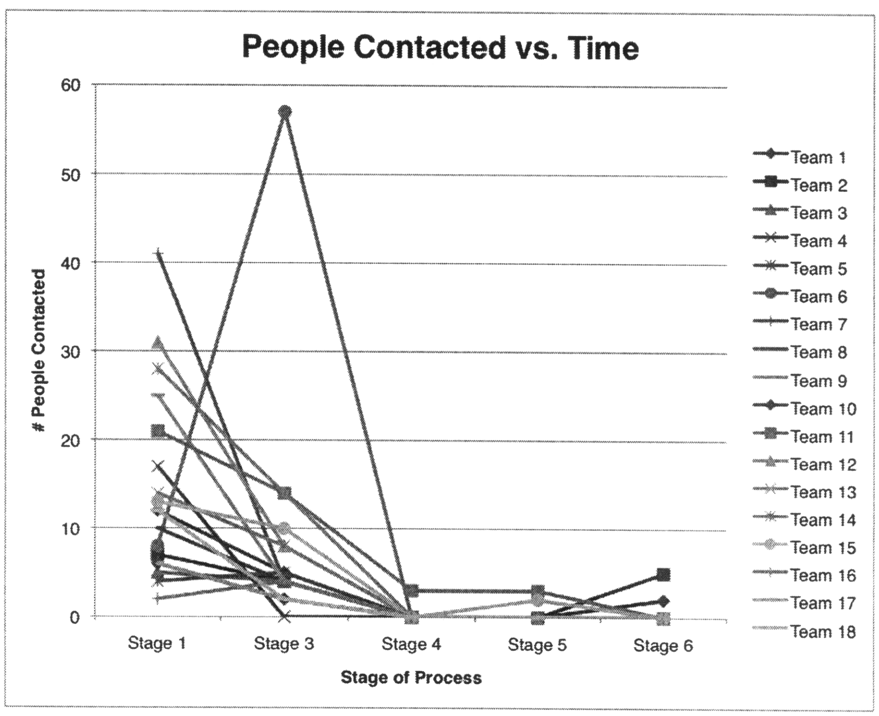

Figure 4-9: People Contacted vs. Time

and then gradually taper off until a concept is selected. It was also hoped that there would be a slight increase in the amount of user interaction later on as teams tried to

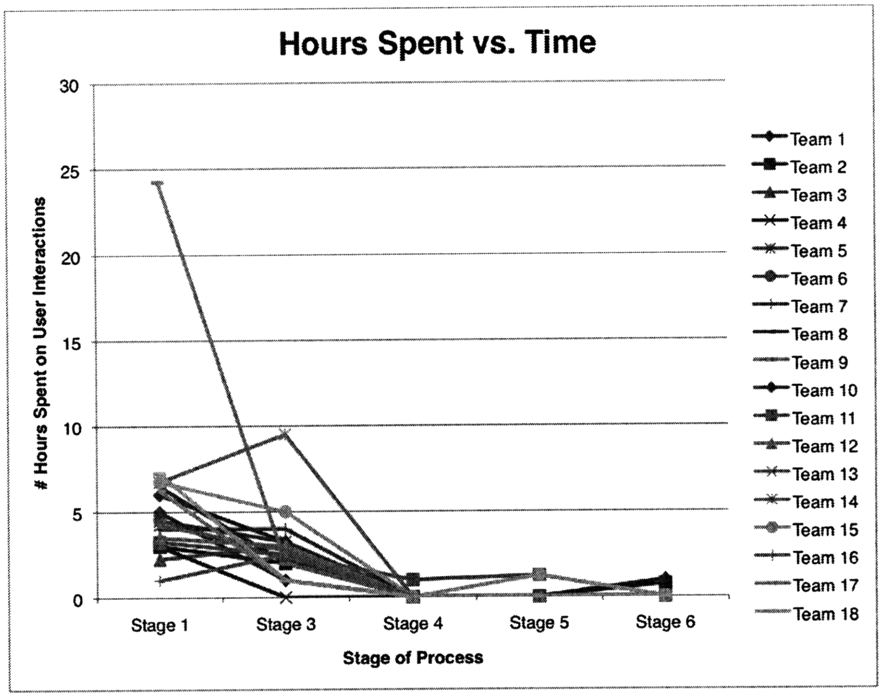

Figure 4-10: Hours Spent vs. Time

get user feedback on their in-process prototypes. Figures 4-8 through 4-10 shows this to be the case, with one exception at the end of stage 2 when no user interaction takes place. In fact, the end of stage 2 is when teams generate 3 concepts to pursue and would presumably be focused not on users but on coming up with possible product ideas. After stage 2, teams do return to talking with users, possibly to get feedback on their concepts before selecting a final concept to pursue in stage 3.

Figure 4-11 shows Spearman correlation coefficients for the reviewer ratings and user interaction reports. Both teams with the high and low overall reviewer rankings spent time with users , so raw user interaction effort alone was not a predictor of success. It can be seen that *prototyping* (Q8) in stage 5 had a significant positive correlation (0.48). In fact, only 2 teams contributed any user interaction reports at this stage. Qualitative analysis of the user interaction reports for these teams who spent time going back repeatedly to the same user(s) during this concept selection stage show an interesting finding. The analysis suggests the value of looping back and forth with the same users to gain feedback on a project, and the importance of establishing and maintaining a dialogue with user(s). It is also observed that many of

		Reviewer Ratings												
		Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*idea*	*impl.*
stage 1	**count**	−0.21	0.09	0.09	0.00	0.11	−0.04	−0.31	0.10	−0.03	−0.02	−0.13	0.02	−0.01
	people	0.00	0.04	−0.08	−0.03	−0.37	−0.04	−0.32	−0.01	−0.14	0.12	−0.10	−0.05	−0.22
	hour	−0.06	0.11	−0.15	0.15	0.14	0.06	−0.27	−0.04	0.22	0.13	−0.01	0.08	0.09
stage 3	**count**	0.27	0.35	0.36	0.19	−0.07	0.10	0.18	0.42	−0.01	0.33	0.40	0.26	0.10
	people	0.14	0.14	0.11	0.08	−0.40	−0.20	0.01	0.11	−0.18	0.19	0.17	−0.01	−0.22
	hour	0.11	0.37	0.07	0.03	−0.20	−0.08	0.07	0.18	−0.12	0.09	0.27	0.07	−0.15
stage 4	**count**	0.26	0.31	0.35	0.26	−0.28	0.26	0.26	0.40	0.31	0.26	0.33	0.35	0.35
	people	0.26	0.31	0.35	0.26	−0.28	0.26	0.26	0.40	0.31	0.26	0.33	0.35	0.35
	hour	0.26	0.31	0.35	0.26	−0.28	0.26	0.26	0.40	0.31	0.26	0.33	0.35	0.35
stage 5	**count**	0.10	0.41	0.37	0.30	−0.41	0.12	0.30	**0.48**	0.07	0.15	0.35	0.32	0.21
	people	0.10	0.41	0.37	0.30	−0.41	0.12	0.30	**0.48**	0.07	0.15	0.35	0.32	0.21
	hour	0.09	0.41	0.36	0.29	−0.41	0.10	0.29	**0.48**	0.05	0.14	0.34	0.31	0.19
stage 6	**count**	−0.02	0.10	−0.09	0.05	0.24	0.03	0.22	−0.19	0.14	0.07	0.24	−0.03	0.00
	people	0.01	0.11	−0.06	0.07	0.26	0.06	0.24	−0.17	0.14	0.10	0.25	−0.01	0.02
	hour	−0.04	0.10	−0.11	0.03	0.22	0.01	0.21	−0.20	0.13	0.04	0.23	−0.06	−0.02
total	**count**	0.08	0.30	0.24	0.19	0.04	0.14	−0.10	0.33	0.14	0.28	0.20	0.23	0.17
	people	0.10	0.03	−0.10	0.04	**−0.51**	−0.11	−0.24	−0.10	−0.17	0.18	−0.03	−0.06	−0.32
	hour	0.02	0.27	−0.06	0.17	0.06	0.13	−0.16	0.13	0.26	0.18	0.15	0.17	0.15
interaction type	**interv.**	0.02	0.30	0.22	0.14	0.10	0.11	−0.12	0.31	0.11	0.21	0.16	0.21	0.16
	b. storm	−0.26	−0.09	−0.05	−0.33	0.31	−0.07	−0.19	0.14	0.00	−0.16	−0.19	−0.12	0.21
	observ.	0.11	0.00	−0.11	0.32	−0.16	−0.02	−0.03	0.22	0.09	0.24	0.11	0.03	0.09
	survey	0.41	0.03	−0.02	0.28	−0.30	0.17	0.06	0.12	0.14	0.44	0.20	0.15	0.11
	prototype	0.12	0.30	0.29	0.33	0.06	0.17	0.35	0.23	−0.05	0.22	0.33	0.26	0.11

Figure 4-11: Correlation between user interaction and reviewer ratings

the correlations are negative (though generally not significantly so), which suggests that more interaction with users tends to correlate with poorer ratings. This may suggest that quality rather than quantity of the interaction is important. Interaction with users appears to play some role, but not a dominating one. Deeper understanding of the data requires a closer look at the details of these interactions.

4.5.3 User Interaction and Team Effectiveness

Figure 4-12 shows the Spearman correlations between interactions with users and each of the team effectiveness questions. In Stage 5, there is a significant negative correlations between *flexibility in decision-making* and user interactions. This stage is concurrent with selecting a concept to pursue, and may reflect overall team anxiety about making a choice. In stage 6, there is significant positive correlation with *being committed* to the team and project. This occurs after the concept is selected, and may indicate that teams have committed to their choices. It is also observed that in this table and in the previous that significant correlations tended to occur in the middle- to late-stages, rather than the earliest stages, of design. This suggests that user interaction at the beginning of a project plays less of a role than user interaction later on. At the start of a project, user interaction tends to focus on gathering needs and defining requirements, but at the end of the project the emphasis shifts to user testing and evaluation of concepts. The implication is that the user testing aspect of user-centered design is critical.

4.5.4 Team Effectiveness and Reviewer Ratings

Finally, Figure 4-13 considers yet another aspect of a team's performance, namely, its overall effectiveness. The table shows that several measures of team effectiveness have statistically significant correlations with the *implementation* of the product, but only one, *provides feedback*, is correlated with generating good quality concepts (*idea*). This dichotomy between *idea* and *implementation* might be explained by tension that

		TEAM EFFECTIVENESS														
		Adapts goals	Resources usage	Resolves conflicts	Shares leadership	Understand tasks	Provides feedback	Flex. dec. making	Provides help	Thinks creatively	Self-aware	Committed	Respect	Well organized	Commun. profess.	Self-assess. effect.
S. 1, TR 1	count	**−0.50**	−0.02	−0.27	−0.26	0.01	−0.32	0.09	−0.22	−0.24	−0.41	−0.12	0.09	−0.29	0.09	−0.29
	people	**−0.48**	0.08	−0.01	0.01	0.02	−0.18	−0.10	−0.25	**−0.50**	−0.27	−0.15	0.00	−0.34	0.09	−0.11
	hour	−0.24	0.16	−0.02	−0.17	0.18	−0.22	0.19	−0.06	0.03	−0.23	0.10	0.31	−0.16	0.08	−0.25
S. 3, TR 2	count	−0.41	−0.13	−0.18	−0.19	−0.30	0.26	−0.30	−0.40	−0.20	−0.18	−0.25	−0.34	−0.06	−0.44	−0.28
	people	**−0.52**	−0.20	−0.29	−0.30	−0.41	0.02	−0.34	**−0.49**	−0.32	−0.35	−0.34	**−0.51**	−0.24	**−0.61**	−0.41
	hour	−0.45	0.10	−0.22	−0.25	−0.12	0.21	−0.19	−0.11	−0.19	−0.08	−0.15	−0.21	0.04	−0.25	−0.19
S. 4, TR 2	count	−0.19	−0.21	0.12	0.17	0.00	0.19	−0.31	−0.21	−0.30	0.10	0.00	−0.26	−0.02	−0.24	0.07
	people	−0.19	−0.21	0.12	0.17	0.00	0.19	−0.31	−0.21	−0.30	0.10	0.00	−0.26	−0.02	−0.24	0.07
	hour	−0.19	−0.21	0.12	0.17	0.00	0.19	−0.31	−0.21	−0.30	0.10	0.00	−0.26	−0.02	−0.24	0.07
S. 5, TR 2	count	−0.43	−0.39	−0.06	0.03	−0.24	0.13	**−0.51**	−0.41	**−0.51**	−0.07	−0.21	−0.28	−0.13	−0.34	−0.12
	people	−0.43	−0.39	−0.06	0.03	−0.24	0.13	**−0.51**	−0.41	**−0.51**	−0.07	−0.21	−0.28	−0.13	−0.34	−0.12
	hour	0.43	0.40	0.07	0.02	0.26	0.12	**−0.51**	0.42	**−0.51**	0.09	0.22	0.28	0.14	0.34	0.14
S. 6, TR 3	count	0.29	0.40	0.09	0.23	0.47	0.24	0.29	0.36	0.16	0.18	**0.48**	0.34	0.33	0.33	0.29
	people	0.30	0.41	0.08	−0.23	**0.47**	0.24	0.30	0.36	0.17	−0.18	**0.48**	0.33	0.34	0.33	0.30
	hour	0.28	0.40	0.09	−0.22	0.46	0.24	0.28	0.37	0.14	−0.18	**0.48**	0.36	0.32	0.32	0.28
Total, ATR	count	−0.13	−0.26	−0.35	−0.07	−0.11	−0.06	0.03	0.14	−0.23	−0.28	−0.06	−0.04	−0.09	−0.22	−0.13
	people	−0.33	−0.36	−0.19	−0.15	−0.38	−0.39	−0.39	−0.09	**−0.47**	**−0.49**	−0.22	−0.36	−0.33	−0.43	−0.39
	hour	−0.11	−0.23	−0.11	0.03	−0.16	−0.28	0.06	0.19	−0.22	−0.21	0.07	0.20	−0.01	−0.11	−0.13
Interact. type, ATR	interv.	−0.10	−0.25	−0.32	−0.09	−0.11	−0.06	0.06	0.17	−0.21	−0.28	−0.05	0.00	−0.07	−0.17	−0.11
	b.storm	0.16	0.12	0.40	0.40	0.35	−0.16	0.12	0.30	−0.02	0.16	0.35	0.40	0.33	0.35	0.30
	observ.	−0.03	−0.35	−0.07	−0.05	−0.35	−0.19	−0.14	−0.35	−0.04	−0.20	−0.29	−0.04	−0.18	−0.33	−0.32
	survey	−0.05	−0.11	0.00	0.08	−0.03	0.00	−0.22	−0.08	−0.25	−0.12	0.00	−0.13	−0.01	−0.18	−0.02
	prototy.	−0.03	−0.06	−0.14	−0.31	0.00	0.06	−0.03	−0.03	−0.10	−0.12	−0.06	−0.19	0.00	−0.03	0.00

Note: S. = Stage, TR = Team Review, ATR = Average Team Review

Figure 4-12: Correlation between user interaction and team cohesion

	Reviewer Ratings												
	Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*	*Q8*	*Q9*	*Q10*	*Q11*	*idea*	*impl.*
Adapts goals	0.13	0.29	0.27	0.24	**0.56**	0.33	0.14	0.07	**0.48**	0.23	0.16	0.30	0.44
Resources usage	0.10	0.26	0.19	0.02	0.34	0.15	0.24	−0.21	0.22	0.11	0.13	0.15	0.09
Resolves conflicts	0.28	0.39	0.02	0.20	0.38	0.42	0.04	0.11	0.46	0.19	0.20	0.36	0.40
Shares leadership	0.29	**0.51**	0.20	0.31	0.26	0.38	0.02	0.23	**0.60**	0.32	0.25	0.44	**0.51**
Underst. tasks	0.27	0.39	0.20	0.19	**0.57**	0.42	0.16	0.19	**0.54**	0.23	0.24	0.37	**0.52**
Provides feedback	0.43	**0.56**	**0.47**	0.36	0.45	0.44	0.31	0.45	0.45	0.34	0.45	**0.53**	**0.54**
Flexible dec. mak.	0.19	0.30	0.30	0.15	**0.69**	0.36	0.33	0.14	0.41	0.26	0.45	0.33	0.44
Provides help	0.22	0.19	−0.13	0.04	**0.62**	0.26	−0.22	0.07	0.37	0.14	0.00	0.16	0.32
Thinks creatively	−0.13	−0.04	0.20	−0.10	0.45	−0.09	0.24	−0.15	0.06	−0.06	0.06	−0.08	0.06
Self-aware	0.28	0.46	0.12	0.29	0.44	0.42	0.18	0.19	**0.59**	0.20	0.28	0.40	**0.50**
Committed	0.23	0.21	−0.13	0.09	**0.55**	0.32	−0.07	0.15	**0.47**	0.12	0.08	0.21	0.44
Respect	0.11	0.24	−0.03	0.14	**0.68**	0.37	0.04	0.21	**0.65**	0.14	0.24	0.26	**0.63**
Well organize	0.31	0.26	0.00	0.24	**0.61**	0.39	−0.07	0.15	**0.47**	0.32	0.06	0.31	0.46
Commun. well	0.08	0.12	0.00	−0.06	**0.70**	0.28	0.08	−0.09	0.39	0.04	0.03	0.12	0.34
Self-assess. effectively	0.17	0.23	0.12	0.03	**0.61**	0.28	0.09	0.17	0.37	0.13	0.08	0.22	0.43

Figure 4-13: Correlation between team cohesion and reviewer ratings

often occurs in the construction of a product. In the early stages, it is important to spend adequate time scoping the problem. Designers must, however, at some point start creating the artifacts in order to meet deadlines. Fabrication of a concept can be a more challenging task than anticipated and require a great deal of integration of physical components. Furthermore, how well a team integrates itself and functions together is important. The "idea vs. implementation" distinction is shown in the final presentation review form, Figure 4-4.

There is a significant correlation between how reviewers perceived *usability*, "Can a user easily figure out how to user it?" and many of the team effectiveness categories. Since the building skills and expertise were varied across all the teams, the final prototypes were at different levels of fidelity. A prototype which is more developed is more likely to be perceived as usable. Those teams which were able to reach a critical stage in the development of their prototype perhaps had more team cohesion, as represented by the higher values from the team reviews.

Only teams who work together well will be able to execute well. Note that teams which provide feedback and share leadership tends to understand market better, suggesting the importance of collaborative teamwork.

4.6 Moving forward

Conducting user-centered design methods is not merely following a simple sequence of steps to cleanly acquire the needs from users. While there is no "magic bullet" method for figuring out what products to make and manufacture, it is clear that a designer must carefully conduct this process. Instead of treating users only as people from which to gather needs, designers need to strive towards a sense of empathy with those who they encounter. Resources in a company are always limited, so it may not be practical to go as deep as one would want. Perhaps *user-centered design* should be thought of as ***people**-centered design* so that those who interact with relevant stakeholders will be in the right mindset beyond only the "use" experience [57].

To conclude, the original questions posed in the Introduction will be addressed in light of the data. Second, limitations of this research will be articulated. Third, specific recommendations will be made for design pedagogy and education. Finally, in Future Work, suggestions will be made for the next steps of research that will further our understanding of user-needs analysis.

1. *What are the characteristics of a design that are important to reviewers?*
   The results of this work suggest a product's desirability, and to a lesser extent, an understanding of how they fit in with their competitors, tend to be predictors of ratings on other criteria. This result suggests that reviewers may talk about the importance of "usefulness" and "does it fill a compelling, unmet need," but in fact their visceral reaction to a product ("I want this!") is more critical.

2. *Is there a link between the quantity and nature of interactions with users and reviewer ratings?*

Results of this study show that more interaction with users is not as important as one might think, though quality of interaction might be more important. Findings also suggest that later stage interaction with users may be critical, in particular getting feedback on specific concepts from the same user over a period of time.

3. *Is there a link between the quantity and nature of interactions with users and team effectiveness?*
   Interaction with users is linked to flexibility in decision-making and commitment to the team only in the middle stages of design. This may be due the anxiety of selecting a concept and renewed team commitment that occurs after a selection has been made.

4. *What is the nature of the relationship between team effectiveness and reviewer ratings?*
   Findings suggest that aspects of team effectiveness are linked to the implementation of a concept. This may be because of the way the building of prototypes forces the integration of components and, by extension, the team members who construct those components.

4.6.1 Limitations

This study has several potential limitations that may affect results. First, all surveys and questionnaires given to design teams relied on self-reporting and assumes that individuals were able to give accurate responses, although in reality people may under or over estimate. Second, every effort was made to encourage teams to engage with users in a thoughtful manner in order to benefit their projects. The risk is that teams would submit user interaction reports simply to fulfill a requirement although qualitative review of the user interaction reports suggest this is not the case. Finally, many of the relationships between datasets were found through correlation, and it is important to recall that this is not the same as causation.

4.6.2 Recommendations for Design Education and Pedagogy

This study has brought to light many concerns and suggestions for how best to teach user-centered design methods in product design and development courses.

Requirements vs. Real Interest

There is a danger to both "novice" and "expert" students of user-centered methods when they encounter these procedures in the classroom. Students may view the use of the methods as "just another assignment" and feel that as long as they fulfill the requirements, e.g. *talk to 10 different users*, their outcome will be successful. Students may also care only about their grade and not believe that these methods can be useful. Educators should try to structure the product design courses such that students will want to try methods on their own. If there is no insistence from the instructors, however, then the students will not be urged to try something new.

There is No Magic Bullet

Teaching these methods may say to students that there is a "right" and "wrong" way to approach designing products and systems for people. While at a very high and abstract level, this may be true, there are almost an infinite number of situations in which one may need to design a product. In showing data from studies such as this, students can see that you cannot just blindly follow instructions put forth in class. Methods and procedures can provide a solid first step to the process. They can also see the variety of products and instances in which certain methods will and will not work. The students, however, must be in tune with what they learn along each step of the process and be prepared to adapt. Which information is pertinent? What if users express different needs?

Documenting and Quantifying the Process

Although the very documentation of the design process, such as the user interaction forms that were assigned to students in this study, may impede progress on the project itself, it is beneficial to have a record of the design activities and decisions. Good record keeping can help teams manage all the information they gathered. Students and researchers alike can look back on the processes and perhaps see where things may have "broken down". What if a team had a good concept early on but ended choosing a different idea to follow? What if there was something in the *implementation* of the concept which prevented the prototype from being successful?

Constant Dialogue Throughout the Process

Often it is not practical to go back to every user and keep a dialogue with him or her throughout the duration of the process. There is something to be said, however, when designers return to the same users later on in the process. If a team has formulated a problem from a specific need of a particular user, doesn't it make sense to see what that user thinks of the concepts the team has started to develop? In the study, it was shown that the team that went back to a user multiple times did really well. Thinking about a relationship with users over a longer time scale will increase the likelihood of forming empathy with those for whom you are designing. As with all the methods, this will not guarantee success. One will, however, be more grounded and confident of the design decisions made.

"I thought field studies would be easy!"

Students will have preconceived notions of what user-centered methods are like. Only after they have to implement a method first hand, do they realize how difficult it might be. Educators may consider giving students a taste of what fieldwork is like through short exercises in class before they go out "into the wild."

4.6.3 Future work

Richer data through intercollegiate studies

A number of institutions teach user-centered design methods in engineering and design courses. It would be of great value to compare and contrast data regarding types of design methods, quality and quantity of user interaction, team effectiveness, and design outcome measurement with some of these universities to form a more comprehensive view of how to best teach the material.

Assessing qualitative aspects of user-centered design

The conclusions in this paper were drawn largely from measurable data, such as ratings, gathered from teams and reviewers. Clearly, the quality of user-centered design practice must play a key role as well. The challenge is gathering such data on a suitable scale while still remaining tractable to analyze. Future work should consider how to thoughtfully assess the qualitative aspects of user-centered design.

Partnership with industry

Literature in user-centered design tend to emphasize individual cases in which methods are applied. Future work should formulate a strategy for assessing user-centered methods on a larger, more quantitative scale within the context of industry. Do the experiences in the classroom prepare students at all for what they may encounter in actual practice? What can we do as educators to improve that preparation?

Table 4.1: Team effectiveness survey

Adapts goals	The team is able to think critically about its goals and adapt those goals accordingly
Uses resources well	The team takes advantage of all resources available, and looks for opportunities to improve efficiency.
Resolves conflicts	The team makes sure conflicts are clearly resolved.
Shares leadership	The team allows different people to control activities where they excel.
Understands tasks	All team members know what is going on and what they should be doing.
Makes decisions flexibly	The team realizes that different problems may require different approaches.
Provides help when needed	Team members are willing help out by doing whatever needs to be done.
Thinks creatively	The team is open-minded and willing to consider new ideas or change plans as needed.
Is self-aware	Team members are aware of how their actions affect the team.
Is committed	Team members are strongly committed to doing a good job.
Is built on respect	Team members feel listened to and respected, and also listen to and respect others.
Is well organized	The team's effort and meetings are efficient.
Communicates professionally	Team communication is good, focused on the project, and not driven by personal agendas.
Provides feedback	Team members receive appropriate feedback on how they are doing.
Self-assessed effectiveness	Each team member considers her/his self to be effective in a team.

Table 4.2: User methods presented in class

Interviews	Talking with a user using a set of prepared questions.
Surveys	Giving a questionnaire to a large number of people to gather data quickly.
Wants and Needs Analysis	Brainstorming with a group of users to distill wants versus needs.
Card Sorting	Having the user sort cards with attributes of product in order to develop mental model.
Group Task Analysis	Working with a group of users to analyze the use of the product.
Focus Groups	Meeting with a group of potential users to discuss concerns with the product or concept.
Field Studies	Observing users "in the wild" as they use the product in the real environment.
User Feedback Testing	Bringing prototypes of various fidelities to the user to elicit feedback.
Bug List	Enumerating challenges a user group faces in their daily activities. Not a software bug.

Chapter 5

Summary and Conclusions

5.1 Introduction

This research took preliminary steps to answer various questions. The two broad areas of focus were in *user needs* and *design creativity.* This chapter returns to the original questions, provides some answers and suggestions and describes steps for the future.

Two new frameworks were developed to help novices develop a reflective practice in how they approach users and in thinking critically about which user-centered methods to use.

5.1.1 User needs

Based on the studies of ESD.40 - Product Design and Development, conclusions and suggestions were made to address the questions:

> *How might design action with respect to user interaction relate to product outcome?*

- Novices need to be taught a more nuanced view of user-centered methods that go beyond merely acquiring design requirements.

- No correlation was found between quantity of user interaction and project outcome.

- Teams that went back to the same users for additional feedback later in the process tended to do better.

  How do we teach students to figure out why, when, and how to engage with users and customers in the product design and development process?

- While resources are precious when real deadlines exist, taking the time to cultivate a reflective culture can be helpful in the long run.

- Novices should think about the usage of user-centered methods beyond the actual meeting with customers. What happens before? What happens after? These actions should be thoughtful.

- User-centered design may be better framed as **people**-centered design, especially to novices who may be tempted to just go through the motions.

5.1.2 Design creativity

Based on the studies of 2.97 - Design-a-palooza, conclusions and suggestions were made to address the questions:

How do we provide unfamiliar situations in design for novices to promote creativity?

- Current engineering curricula may not provide sufficient opportunities to develop creativity.

- Measures of creativity are difficult to obtain as individuals are all unique and conditions under which measures are taken are different. Holistic, case-based methods should be developed to create a tool-kit of ways to help foster creativity. There is no magic pill to improve one's creativity.

- Giving students many new, unfamiliar design situations can tap hidden potential in various design and communication skills.

- Students value the environment where it is okay to fail. Why can't that be done in a typical classroom setting? Should that be done?

5.1.3 Real life

Given all this, there are still many factors in the design process that are hard to account or predict for. This graphic sums up the experiences of many novices, where the idea at the beginning may be good, but for whatever reason, the implementation does not go as well as expected.

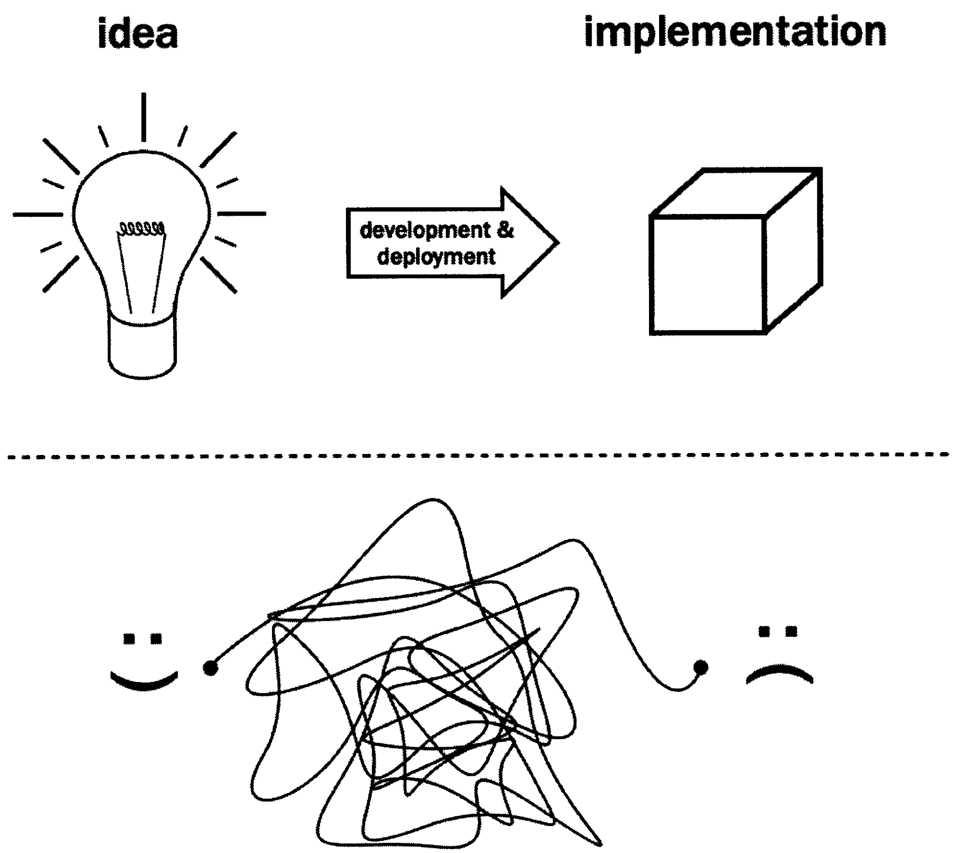

Figure 5-1: Ideally, idea to implementation is straightforward. In reality, that is not the case.

5.2 Moving Forward

I hope this thesis has provided new understanding and perspectives in how novices design products for people and thus, how one should go about training novices. Within these studies, there is still much data that has not been analyzed. Through the past two years of research, I have been able to take a first complete pass at the analysis and come up with findings. Here are specific points of future work:

- For the product development classes, take an in-depth look at each team's journey and where there might have been a "breakdown" or a "wrong" decision made.
- Find data at other universities with product design and development classes to see how the teams' design processes differ.
- Create ways to assess the communication skills of designers. Student stated the desire to develop and utilize the importance skill set of conveying your message to an audience.
- Further develop conceptual frameworks and models to account for different factors and work in different scenarios. Compare these models with what practitioners actually do in industry.

Appendix A

Extra Figures

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User Interaction Form A - Problem Formulation | Market Opportunity

The purpose of this form is to document the interaction with users and customers as you determine market opportunities for the term project. For **each** interaction with a potential user, please answer the following questions as completely as possible. We suggest that you complete each form as soon as possible after interacting with your user, while thoughts are still fresh in your mind. Please attach any supplemental materials you think will be helpful, and then upload to Stellar. Documentation of each interaction will aid you in formulation your team presentations by helping to explain how user interaction affected your design process.

Note: This form (User Interaction Form A) is meant to be used until March 19. After March 19, you should use User Interaction Form B.

Team: ______________________________

Date: ______________________________

Preparation

- Why did you decide to meet this person or group of people?
- How did you get connected with them?
- How much time and what did you do to prepare for this interaction?

Interaction

- Who did you meet?
- Where did you meet?
- When did you meet?
- How long was the meeting?
- What was the nature of the meeting? Include supplemental materials as needed.

Response

- What is the takeaway message from this interaction?
- Are you planning to meet with them again? Explain.
- Were there any unexpected findings from this interaction?
- How does this affect the decision making process for your team?

Figure A-1: User interaction report form

Reviewer name:______________________________

Team number: ________ **Project:** ____________________________________

Please explain your ratings as necessary.

1. USER/MARKET NEED (20%)
A. What user need does the project address?____________________________

B. Is this user need compelling, unmet, and clearly defined? — not really 1 2 3 4 5 absolutely

C. Is there an understanding of where the product fits in with its competitors? — not really 1 2 3 4 5 absolutely

D. Is there a viable market for this product? — not really 1 2 3 4 5 absolutely

2. PRODUCT CONCEPT (20%)
A. Usefulness – Has thought been put into the functionality of the product with respect to the user's goals? *Do I need it?* — not really 1 2 3 4 5 absolutely

B. Usability – Has thought been put into how the user(s) will interact with the product? *Can I easily figure out how to use it?* — not really 1 2 3 4 5 absolutely

C. Desirability – Has thought been put into creating a desire among users to own it? *Do I want it?* — not really 1 2 3 4 5 absolutely

3. BUSINESS ASSESSMENT (15%)
Is the business case for the product plausible? — not really 1 2 3 4 5 absolutely

4. PROTOTYPE (20%)
Does the prototype communicate the product concept convincingly? — not really 1 2 3 4 5 absolutely

Do users respond positively to the product? — not really 1 2 3 4 5 absolutely

5. PRESENTATION (10%)
Was the presentation well structured and delivered? — not really 1 2 3 4 5 absolutely

6. Do you believe this project could become a successful product? (15%) — not really 1 2 3 4 5 absolutely

7. Any other comments? (please use reverse side, if needed)

ESD.40 Final Presentation Review Form 1

Figure A-2: Reviewer rating form for final presentation

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