A Comparative Analysis of Problem Solving Approaches Between Designers and Engineers

THESIS

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By

William David Taylor

Graduate Program in Design

The Ohio State University

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Master's Examination Committee:

Paul J. Nini, Advisor

Elizabeth B.-N. Sanders, Ph.D.

Philip Smith, Ph.D.
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Abstract

Studying as a designer and working with engineers revealed differences between the disciplines that affect communication. The increasingly complex problems facing society require specialists to manage. Increased specialization can lead to confusion when communicating across disciplines. Designers and engineers both provide vital services to industry and it is important that they be able to work with each other as effectively as possible. With a focus on the two academic disciplines of design and engineering, I have attempted to explore whether collaboration between the two can be positively impacted.

Participants from each field of study were asked to complete a series of evaluations to determine their problem solving tendencies, learning styles, and patterns in thinking. They were then asked to present their problem solving process for approaching a set of complex contemporary issues.

Engineers tend to fall into logical and rational thinking patterns and are more likely to be seen as linear thinkers. Designers differ in their approach to problem solving when there is an opportunity for abstract and innovative thinking. A practical application of this information would require the contributions of both designers and engineers throughout the design and development process. Interaction between disciplines should take place in the form of information exchange, discussions, and informal dialogues. These goals can be achieved through common workspaces, support from management, and strong leadership.
Dedicated to my father.
I would like to thank my advisor, Paul Nini, for his guidance throughout the creation of this thesis. Without his support, encouragement, and most importantly patience, this thesis would not have been possible.

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Vita

1984............................................................... Born – Santiago, Chile

2007............................................................. B.F.A. Studio Arts, Virginia Polytechnic Institute and State University

2010 to 2013 ............................................... Graduate Teaching Associate, Department of Design, The Ohio State University

Fields of Study

Major Field: Design
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Chapter 1: Introduction

1.1: Background

When I graduated with a degree in Studio Art from Virginia Polytechnic Institute & State University in 2007, I was eager to begin my journey toward graduate school in an effort to pursue a newfound interest in sustainable practices in industrial design. It was toward the end of my senior year that I began to explore industrial design as a career path. Through talking with students and researching independently, it was clear I would need to learn more before pursuing a graduate degree. This education came in the form of learning about design methods and practice on my own time as well as working with issues of sustainability as an intern in the Energy Program at Public Citizen in Washington, DC.

Public Citizen is an influential consumer advocacy group and non-profit lobbying organization. It was in their energy policy department that I would begin to learn about sustainable practices on a national scale. My time on Capitol Hill was invaluable for helping me to understand the large-scale issues behind environmental consciousness in not only energy policy, but also in business. Combined with my efforts to understand the field of industrial design, I applied to The Ohio State University in order to pursue research on sustainable practices on a corporate scale.

Soon after arriving at The Ohio State University, I joined the EcoCAR initiative sponsored by the Department of Energy and General Motors in the College of Engineering. It was my intention to invest extra time into an academic cause revolving
around sustainability. To my surprise, it was this experience that would change my academic path considerably.

I soon discovered that the similarities I had conceived of existing between Designers and Engineers were fewer than I imagined. Communication with the Engineers in the program was not overly difficult, but there were certainly differences in the ways that Engineers communicated with each other and with Designers like myself. It is unclear where differences in communication styles were greatest, but effective collaboration between these two disciplines was important enough that, after a year of working with their team, I felt the need to investigate further.

So then why is collaboration between these disciplines of such importance? The world has become smaller and more unified while the problems facing society have become more complex. These increasingly intricate and interconnected systems require authorities from numerous disciplines to manage. The intensification in communication across disciplines can lead to confusion and complications. Organized communication of ideas is required and that organization requires collaboration.

The following document will attempt to examine, diagnose and offer solutions for improving collaborative efforts between Designers and Engineers, for in order to succeed in progressing with sustainability, such an important alliance must first be strengthened.

1.2: Problem Statement

Designers and Engineers both provide vital services to industry. As such, it is important that they be able to work with each other as effectively as possible. As will be discussed, much has been said about collaboration and interdisciplinary cooperation in general; however, one area in which there does not appear to be enough study is how
psychological tendencies in learning affect communication and selection of a path of study. With a focus on the two academic disciplines of Design and Engineering, I will attempt to find a relationship between the thought processes and learning styles of the two groups in an effort to compare and contrast their abilities and to explore whether collaboration between the two can be positively impacted.

1.3: Objective

This study will attempt to discover patterns in thinking within graduate-level Design and Engineering students at The Ohio State University with the intention of applying the findings to improved collaborations between Designers and Engineers. Participants from each field of study will be asked to complete a series of evaluations to determine their problem solving tendencies and patterns. They will then be asked to present their problem solving process for approaching a set of complex contemporary issues. The findings may provide direction for improving interdisciplinary efforts concerning complex problems.

1.4: Scope

Ideally, groups of Designers and Engineers in professional practice as well as academia would be solicited for participation in this study. Even limited to academia, it would be convenient to have graduate-level students from multiple universities participating. As it stands, the most effective and reasonable boundaries of this study were to use the pool of available students at The Ohio State University. In the same respect, psychological evaluations that are readily accessible will be used to provide information that can be applied to determining patterns in thought. It is not necessary to
conduct a longitudinal study at this state in the research, as we are focusing on possible
differences in thinking and not long term changes in thinking processes.

1.5: Overview

This paper will endeavor to begin a conversation this author feels is overdue
about communication across disciplinary bounds between Designers and Engineers.
Much of the conversation concerning this topic is clouded with language that is unclear
and misused often. A chapter discussing pertinent terminology will be included in order
to clear up the fog surrounding many of these terms. This will include thinking styles,
problem types, and general information about both disciplines. Following the
Terminology chapter will be an introduction to the first round of data collection.

The questionnaire chapter will discuss what information is desired from the
disciplines and why that information will be useful. The planning process of selecting
questionnaires will be covered in detail. Participant selection will be an important part of
the process for this study and is discussed as well. The administration of the instruments
and results follow. The information gathered from the surveys will be vital in developing
and administering the next part of the research.

The surveys will have hopefully provided a wealth of valuable material
concerning how Designers and Engineers process information. Using this information
will allow the development of a further study in the format of a workshop. A chapter
discussing the development and administration of the workshop will include specifics
regarding planning and a comparison of results between disciplines. It is hypothesized
that the results from a workshop will continue to build upon patterns uncovered in the
questionnaire, further defining certain traits as belonging to either discipline or both.
The conclusion will discuss the application of data into collaborative efforts but will also address how preconceptions measure up to the realities of the results exposed. It is thought that preconceptions of Engineers as being very different from Designers will be, for the most part, false; however, it is also thought that there will be a number of expectations that hold true. There are clearly fundamental differences between the groups but the similarities may more likely provide the bridge for improved communication. Possible applications of the results will be considered with a focus on how those results might be applied to education or business. An ideal scenario for collaboration will be discussed before finally reflecting on the implications for further research.
Chapter 2: Terminology

Particular key words and phrases will be used throughout this document. In order to ensure clarity, they have been defined here in accordance with how they are to be understood throughout.

2.1: Linear & Lateral Thinking

As problem solving is a leading subject of this document, it makes sense to cover what is behind the action of solving altogether. This means looking into the nature of human thinking.

Thinking is a broad term. It refers to how we use knowledge to analyze situations, make decisions, and solve problems. It is involved in all conscious mental activity whether that involves memory, planning, or learning (Holyoak, 2012). Moreover, thinking involves manipulating mental representations of information in order to draw conclusions. It can then be established that thinking is an active psychological process that is focused towards a goal or conclusion (Hockenbury, 2003).

Simply put, thinking is the act of understanding and making sense of our experiences. This allows for not only comprehension of needs and desires, but planning ahead and, of course, problem solving.

2.1.1: Linear Thinking

Linear thinking has traditionally depended on reasoning and logic to solve structural problems. This type of process is also known as sequential thinking (Bono,
1970). This can be more completely described as a process where thinking moves forward in a step-by-step fashion. The steps involve applying rules, or a set of heuristics, to the problem solving process to direct the process to a final result. The thinking is predominantly left-brained and almost completely linear in direction. This description of a singular pathway is why Linear thinking is often referred to as vertical thinking as well (Hernandez, 2008).

This style of thought rewards a foundation of personal learning based on traditional education, where depth of knowledge in a particular area is compulsory to understanding any given problem and attempting to devise the problem’s solution. Perhaps the educational and, consequently, professional cases that most effectively illustrate evidence for the success in this type of thinking are the sciences. In these fields, possessing capabilities for empirical reasoning and deductive logic are crucial for success and advancement.

2.1.2: Lateral Thinking

The advantage of Lateral thinking is that a depth of knowledge in one area is not as valuable as a breadth of knowledge in multiple areas. This style of thought is based on the concept of creative reasoning as well as an understanding of complexity (Bono, 1970). A key insight into this way of thinking is that it is specifically intended to have no bounds. In this way, it allows for thought that does not have to be logical, predictable, or sequential. The pattern-seeking tendencies of traditional problem solving are replaced by perspective-seeking tendencies, or the desire to see the problem from new and unexpected points of view (Butler, 2010). Perhaps the largest difference between Linear and Lateral thinking is that Lateral thinking does not necessarily have a concrete goal in
mind. Uncertainty, while uncomfortable, can produce otherwise unforeseen results and benefits that are simply not accessible with sequential problem solving processes.

2.1.3: Design Thinking

Design thinking is chiefly a way to describe innovative practices in problem solving techniques. The design-minded professional is uniquely trained to cultivate a broad base of knowledge including the sciences, engineering, arts, history, business, psychology, and so on. This training also introduces a wide array of research methods (Rowe, 1987), which can be applied across any number of issues. Design thinking can also be used to describe a thought process that is just as interested in discovering opportunities as it is in finding solutions.

Design, as both a practice and a field, is widely advancing into many professional arenas as a means of reconsidering pertinent issues from a fresh perspective (Brown, 2008). Although the use of the word “design” can be interpreted as general in many cases, it is treated herein fundamentally as an applied professional practice. Designers are trained to process information in a particular way. This process is referred to as Design thinking.

2.1.4: Summary

Linear thinking and Lateral thinking are two complementary methods of pursuing the solution to a particular problem or set of problems. Linear thinking is based on a logical and sequential thought process that seeks to find order in a given problem. Lateral thinking relies on creative processes that are meant to deconstruct the problem in order to reframe it from a new perspective and consequently reveal previously unidentified interpretations of the issue at hand.
Because issues of increasing complexity are rising at an immeasurable pace within a multitude of industries around the world, the need for innovation is often broadcast. The path to innovation is increasingly being filled with professionals that have experience or education based in non-Linear thinking (Martin, 2009). These are people from numerous backgrounds and industries that understand that there is more than one way to frame a problem. Design thinking and Lateral thinking are desirable as a result.

2.2: Complex Problems vs. Wicked Problems

2.2.1: Complex Problems

Before we can understand the nature of a complex problem we must discuss complexity itself. The concept would seem simple to define; however, reality is not so unassuming. It must be understood first that in order to have complexity, there must be a system to encompass that intricacy. Complexity is often built upon interdependencies between agents of a system that by default are too multifaceted to visualize absolutely. In other words, it cannot be simplified to a model suitable for direct comprehension (Buchanan, 1992). Models of these complex systems are often flawed because they cannot view the issue’s entirety from more than one perspective at any one time.

Problems, like systems, are too intricate to visualize from a single perspective. Just as a complex system is not likely to have a simple explanation, neither is a complex problem likely to have a simple solution. It is therefore important for individuals who manage or interact with complexity to have a way to parse the problem or system in order to be effective. This is why Linear thinking is considered deficient as a standalone method for understanding complex problems (Bono, 1970). Although it would be simple to claim that Lateral thinking is the correct route when Linear thinking is not, it is more
likely that a hybrid of Linear and Lateral thinking methods would be most suitable for approaching complex issues.

2.2.2: Wicked Problems

The Wicked problems approach to design was formulated in the 1960s by a mathematician and Designer named Horst Rittel (Buchanan, 1992). He sought an alternative to the linear model of the design process commonly used at the time. He argued that the majority of problems faced by Designers could be classified as Wicked problems. This entailed a class of social problems that were ill-formulated, confusing, indeterminate, and comprised of conflicting values.

There are a number of characteristics of Wicked problems that have been reworked over the decades, but essentially have remained the same. Wicked problems have no definitive solution, only good or bad approaches. They have no stopping rule. They are unique and they have no alternative solution (Horn, 2007). These rules can seem arbitrary at times but are important for understanding the indeterminate nature of Wicked problems. They are, quite simply, incomprehensible wholes.

2.2.3: Summary

Complex and Wicked problems on the surface contain many of the same characteristics of a system of interconnected parts that are difficult to define or gain a single perspective on. They both require a special skill set to effectively comprehend and begin to deconstruct in order to find a managed solution. Wicked problems differ from Complex problems in that they reference social and cultural problems exclusively. In other words, they engage people as stakeholders at a fundamental level.

2.3: Collaboration
Collaboration is a process where two or more people work together to realize common objectives. The endeavor is often creative in nature and involves the sharing of knowledge across teams and disciplines in order to reach consensus. This process is different from common cooperative ventures in that it involves a deeper level of solidarity and communication. Moreover, the objective and ambitions are shared by all participants.

Collaboration is an important aspect of contemporary communication to be concerned with as the use cases involved affect all. Professionals have continued to become more specialized in their fields of study and, as a result, the language and understanding of these specialists has become more and more segregated from those in other fields. How are individuals supposed to effectively communicate across disciplines if their language has to be reduced to commonplace generalities? How will the problems of our age and those to come be confidently approached if the problem solvers cannot effectively communicate?

A trio of specific categories of collaboration has been selected for further investigation. They include terms often used and misused in relation to collaborative efforts. They will be defined here for clarity.

2.3.1: Interdisciplinarity

One of the terms most often used for collaboration is Interdisciplinarity. This catchall phrase has become ubiquitous as a byword for contemporary innovation in industry and academia alike. Use as a blanket phrase not only nullifies the true nature of the mechanism but also shadows other forms of collaborative efforts available to researchers and problem solvers. Interdisciplinarity concerns the transfer of methods
from one discipline to another (Nicolescu, 2002). It incorporates information, data, techniques, tools, perspectives, concepts, and/or theories to advance understanding or solve problems whose solutions are beyond the scope of a single discipline (*Facilitating Interdisciplinary Research*, 2005).

2.3.2: *Multidisciplinarity*

Multidisciplinarity concerns studying a topic in multiple disciplines at one time (Nicolescu, 2002). It is research in which each specialty makes a contribution while working separately on different aspects of a problem (*Facilitating Interdisciplinary Research*, 2005). A classical painting, for example, can be studied under the disciplines of fine art, history, religion, and so on. The topic in question is enriched by the incorporation of more disciplinary approaches and the end result of knowledge, though broader, is more comprehensive. The use of Multidisciplinarity can be seen as an additive effort to the original discipline.

2.3.3: *Transdisciplinarity*

Transdisciplinarity concerns that which is between the disciplines, across the disciplines, and beyond all discipline. The goal of Transdisciplinarity is to understand the current world and that requires the unity of knowledge (Nicolescu, 2002). This may appear to be a void of disciplinarity that consequently contains nothing of substance to learn from. It is a void, but that of new experience gained by the simultaneous mixing of multiple disciplines into a new approach to knowledge and understanding. It is work done by a team that tries to solve a problem or set of problems that no discipline can approach in isolation. As a result, a new set of tools must be acquired or created for the combined disciplines (Kockelmans, 1979). A key difference between it and other approaches is that
the primary focus is not on any one discipline but on a new generative potential of individuals working together in the context of a specific problem or application (Moore, 2009).

2.3.4: Summary

The importance of collaboration in the modern era is not to be underestimated. Not only are the problems of our time becoming increasingly complex, but the expertise needed to tackle such problems is becoming spread across more and more professional specialties. There is a substantive need for effective collaboration and it is on the rise. This increase in collaborative effort is evidenced in the world of academic research where single-author papers have been on the decline since the end of World War II (Whitfield, 2008).

Transdisciplinarity is radically different from Interdisciplinarity and Multidisciplinarity because its goal is the understanding of the present world, which cannot be understood in the current disciplinary framework (Nicolescu, 2002). The latter two are comfortable within the boundaries of disciplinary research. The three can quite often be confused for each other because they all, at some level, overlap disciplinary boundaries. All of them have their place, including disciplinary research, as ways to understand our world and tackle increasingly complex problems.

2.4: Designers

According to the Design Institute of Australia, “A Designer is a business professional who develops solutions to commercial needs that require the balancing of technical, commercial, human and aesthetic requirements.” Designers can further be seen as a cross between a technician and an artist. The difference between a Designer and an
artist or craftsperson is that a Designer works with and for the benefit of stakeholders. This means that Designers must work within a set of predetermined limitations in order to meet the needs of their employers as well as the needs of the intended users. Designers endeavor to represent a wide range of problem solving abilities from those that are logical and analytical to those that are creative and idiosyncratic.

Design is a big word. It is technically correct to use it when describing any activity of creation that relies on planning instead of chance. The word has, as a result of its ubiquity, been popular for describing many forms of development across business and industry. The word is often a synonym for planning. Although often thought of as a creative endeavor, design can also be used to describe work done by technical professionals such as Engineers in an effort to communicate and resolve project needs. Just as the word has a number of definitions, Designers themselves can be found within a number of specializations. There exist entire fields of Designers that offer technical and creative skills that match the needs of particular industries.

2.4.1: Sub-disciplines

The Designers at The Ohio State University chiefly fall into one of three categories: Visual Communications Designer, Industrial Designer, or Interior Designer. Many other specialties exist that focus on a wide range of fields such as Textiles, Fashion, or Automobiles. Only the disciplines that are relevant to The Ohio State University Department of Design will be described here, as they are most relevant to this research.

Visual Communication Designers develop and prepare visual information for publication or digital distribution with particular emphasis on clarity of communication
and the matching of information styles to audience requirements. They are not only responsible for an in-depth understanding of text and the ways in which people respond to information, but must understand the nature of color, symbols, and pictures as well. Concepts are often displayed as mockups to communicate ideas with clients. The Designer is responsible for all imagery that is associated with the document as well, including illustration and photography. This may result in subcontracting work from other professionals or services. They are responsible for combining all media into a single coherent work that meets the client’s needs. With digital media, this can include user interface and experience. With physical media, the Designer can be responsible for material selection and the production process.

As with other disciplines, the visual communications designer is often a part of a project development team although it is common for them to work alone. In many instances, the Designer will be responsible for image and branding that may appeal to consumers while a marketing specialist will be concerned with the distribution and targeting of markets. More and more, the jobs of visual communication designers are trending into the digital realm. This is largely due to the movement of commercial enterprise to the web and mobile devices. This migration has led to a large number of opportunities for visual communications designers to branch into website design, mobile design, and so on.

Industrial designers predominantly create products for manufacture. They are also known as product designers for this reason. They are particularly concerned with those aspects of products that relate to human usage and behavior, and product appeal. Industrial designers need to be concerned with more than just developing an appealing
product for the consumer, but also one that meets manufacturing and commercial requirements. This may also take into account financial and material limitations in order to reach the optimum design for a product. Finally, the Designer has to incorporate aesthetics and function into their design as well.

Drawing and prototyping are key elements of the industrial design process. These methods are used to communicate and test product ideas in order to facilitate the decision making process. Although iterative design is a key aspect of the product designer’s process, it is not exclusive to this specialization or even Design in general. Industrial designers may have control over any number of aspects of a product’s creation including manufacturing processes, tooling, materials selection, and so on. The reality is that often this is handled by a team of production specialists and the Designer will work alongside others in order to streamline production.

Interior designers plan and detail commercial and residential building interiors for effective use with particular emphasis on space creation, space planning and factors that affect our responses to living and working environments. Interior design is often referred to as a specialization of architecture because these Designers are trained to consider architectural modifications to the spaces they develop. Good design can help people to live more effectively, work better, and be happier. This is the goal of interior design. They deal with space allocation, fixtures, furniture, traffic flow of people through the space, and even surface materials. This is all with the knowledge that the space they are designing will be inhabited by persons that will benefit from their work. Much of their work involves tailoring existing products and services to the space. Similarly to the industrial designer, models and illustrations comprise a large part of the process for
decision-making and communication of ideas to stakeholders. An interior designer is also most likely to be part of a larger team of professionals that may include architects, engineers, suppliers, and materials specialists.

2.5: Engineers

Engineering is a practice that links the discoveries of science with applications to human needs and quality of life. An Engineer is a professional that is concerned with applying knowledge, mathematics, and inventiveness towards developing solutions. Engineers, like Designers, are compelled to work within a set of boundaries dictated to them by stakeholders or simple practicality.

In a similar vein as design, there is great attraction to Engineering based on the huge variety of tasks and environments in which Engineers find themselves working. Whether designing programs for computers, sensitive instrumentation, or working on a major construction projects, there are many possibilities. A large amount of contemporary Engineering is completed with computer-aided design. This can manifest itself in the form of design, testing, systems controls, and analysis. For some time the major disciplines of Engineering were civil, electrical, materials, and mechanical engineering; however, that is no longer the case as numerous sub-disciplines of Engineering have made themselves known and become popular specializations of their forefathers (Frodeman, 2010).

2.5.1: Sub-disciplines

The Engineering disciplines at The Ohio State University far outnumber those of the Department of Design and discussing all of them here will not be necessary. Instead a
focus on the most common Engineering disciplines involved with the EcoCAR projects and consequently this research will be prepared.

Mechanical engineers design, create, and improve systems and machinery that is used for domestic, public, and industrial purposes. This includes the design and manufacture of products ranging from industrial machinery to domestic appliances. Mechanical engineers are responsible for aircraft, ships, engines, and any number of complex mechanized systems like building ventilation. They are often employed in an industrial capacity where they are responsible for design and manufacture of systems and machinery.

Electrical engineers are involved with any number of industries that includes electronics, computer systems, telecommunications, control systems, and power. They are interested in the ways that electricity is produced and consumed on scales from large populations to individual households. Electrical engineers create the systems and devices that generate, transmit, measure, control, and use the electricity needed for everyday living.

Materials engineers are concerned with the ways various materials behave when tested. This may include when they are under pressure, heated, or joined with other materials such as ceramics, metals, rubber, plastics, and wood. They deal with the manufacture, structure, properties, and use of materials including composites. The development of new materials is also an important aspect of materials engineering and this can include the improvement of existing materials. This improvement of existing materials can incorporate reuse and recycling. Areas of work for materials engineers can
be diverse. They often are placed in teams alongside other types of engineers in foundries, plants, and companies involved in alloy research.
Chapter 3: Questionnaires

Prior to my experience learning about design, I had preconceptions of what a Designer was and how they practiced. These preconceptions, although my own, are likely not far off from what many must think of the profession. Creativity and aesthetics took precedence and were key aspects of understanding Designers. I also thought Design to be centered on making things for people; the consumers of a product were chiefly the stakeholders of that experience and so were most important to the Designer while designing. These preconceptions are summarized in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Designers</th>
<th>Engineers</th>
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</thead>
<tbody>
<tr>
<td>Thinking</td>
<td>Lateral</td>
<td>Linear</td>
</tr>
<tr>
<td>Learning</td>
<td>Creative</td>
<td>Logical</td>
</tr>
<tr>
<td>Goal</td>
<td>Form over function</td>
<td>Function over form</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>People</td>
<td>Industry</td>
</tr>
</tbody>
</table>

Table 1. Preconceptions before education
Educating myself followed by formal schooling changed my preconceptions about what a Designer is and how they practice. My preconceptions became expectations. These expectations would become my hypothesized results for Designers as well as Engineers during the study.

Engineers also existed with a set of preconceptions that included logical thinking and practical applications of knowledge. I had not educated myself on Engineering practice and so had not that same experience of reevaluating my self-made preconceptions. It was a stint working with Engineers on the EcoCAR project that would be my instruction in all things Engineer. This time led to a number of experiences that reframed my vision of Engineering significantly. In a way very dissimilar to Design thinking, the EcoCAR Engineers had completely decided the direction with which to take a three-year-long project before the start date had even arrived. From a Design perspective, this may more likely have been an involved process of ideation. I later learned that the Engineering graduate students involved with the project had already spent time figuring out the direction to take the project. It was still a short and very practical process from a design perspective. After nearly a year with the project, my preconceptions faded and a set of expectations arose.

Throughout the rest of this document, tables like Table 1 will describe expectations and results where applicable. The results that remain the same as the expectations will remain unchanged. Different results than expected will be in bold red and inconclusive results will be denoted by a dash mark. In Table 2, it is evident how my preconceptions about both Designers and Engineers changed through time learning and practicing with both disciplines.
Table 2. Expectations following education

<table>
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<td>People</td>
<td><strong>People</strong></td>
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3.1: Planning

In order to understand similarities and differences between Designers and Engineers at a fundamental level, a series of questionnaires would need to be administered. These surveys would need to be detailed enough to provide meaningful information regarding the thought processes of the subjects while also gauging their enthusiasm for further participation. Keeping the number of surveys to a minimum while keeping in mind the time it would take to complete the surveys would be a delicate balance. In an effort to maximize the possible participant count, the number of surveys and time needed to take them would need to be as low as possible. However, enough data would need to be collected to make the effort worthwhile. Initially, however, a number of
tests would have to be selected and piloted. A proper method of distribution would also have to be considered.

Administering these surveys would be difficult if the option to use paper and pen was chosen. Physical tests using paper and pencil can also have a monetary cost. With the rise of and popularity of online personality testing, online was the best route for both administering and making these surveys available in a convenient format for the participants. Online testing, although convenient, is also fraught with unscientific quiz sites designed primarily for entertainment. A selection process that involved searching for educational resources was enacted to find surveys that met two basic requirements. The first of these was accuracy; to make sure that repeat takings of the same test yielded similar results. The second need was authority; evidence that the test in question was from a reputable source and properly cited.

The information that was desired was primarily that which would categorize every participant based on their thinking style and thought process. It was hypothesized that if there were any significant differences between Designers and Engineers that these types of instruments would demonstrate such differences. It would also be possible using these tests to discover any prominent similarities between the disciplines. Understanding these similarities and differences will be crucial to understanding cross-discipline communication for the purposes of collaboration. Therefore, a personality test and a learning style test would be necessary. Given the nature of Linear and Lateral thinking, administering a hemispheric dominance test was seriously considered. However, after further review, the reliability of the science behind such instruments seemed to fall flat (Nielsen, 2013). The search for further exams chiefly included more personality or
learning style surveys until an Empathy Quotient was considered. Finding that there was a version that also tested another component in a Systemizing Quotient made this instrument highly attractive as a third option. Ultimately, the instruments administered would need to follow a questionnaire that would cover a handful of basic questions. Details on these instruments are below.

3.1.1: Questionnaire

Initially, a questionnaire would be administered to collect basic data on the subjects and their relation to Design or Engineering as well as their estimations on their performance on a handful of metrics. As this questionnaire would be customized, a service would need to be utilized in order to administer the questions to the participants via the internet. The popular and reliable surveymonkey.com was selected for convenience for both the administrator and the participants. The service allows customization and design elements for the survey creator as well as ease of distribution and storage of all results.

The questionnaire would ask for basic information to identify each participant such as their name as well as their gender and field of study. Following that, a series of questions would be asked to determine if the person thought that they were creative or an exceptional problem solver. These questions would be rated on a sliding scale. It would also inquire whether they felt confident in their choice of a career path. Ultimately, the goal of these questions would be to cover any loose ends that the rest of the instruments would not cover as well as curiosities desired by the administrator. The questionnaire was only six questions when finished and was distributed digitally, along with the other three surveys, via email. The questionnaire was a prerequisite that needed to be completed first.
as it also contained the consent form requiring the participant’s active agreement before proceeding. Once consent was given and the questionnaire completed, the participant could move on to the next surveys.

3.1.2: Personality Type Indicator

Although a person’s personality is an abstract concept, personality tests are a popular tool for assessing individuals and none is better known than the Myers Briggs Personality Type Indicator (MBTI). The MBTI is an inventory aimed at discovering an individual’s personal traits, strengths, and weaknesses. It is one of the most widely used psychological instruments in the world (Boyle, 1995). The survey was developed by Isabel Myers and Katherine Briggs applying personality theories from psychologist Carl Jung. The test is often used to determine what career options are ideal for a candidate leading to happier lives (Boyle, 1995).

The answers on the MBTI lead the test-taker towards one of 16 possible combinations of personality traits. There is no right or wrong answer on the inventory; it is not a test in that respect. The answers of one participant are not compared against the answers of any others or a norm. The goal is then self-identification and personal improvement. The possible personality types are listed below.

The types are coded via four pairs of metrics where the individual falls somewhere in a spectrum of one of two opposing results. The first of these scales is Extroversion (E) – Introversion (I). This range is intended to expose how people interact with their surrounding environments. Extroversion tends to describe more action-oriented individuals whereas Introversion describes thought-oriented persons. As with all of these metrics, people exhibit behaviors from both sides of a range, but preference for
one side or the other is typical. The second scale is Sensing (S) – Intuition (N). Those that prefer Sensing tend to focus on the reality of a situation to gather information about the world around them. Those that prefer Intuition generally lean towards impressions and pattern-seeking tendencies. They concentrate more on the abstract and theoretical aspects of the world around them. The third metric is Thinking (T) – Feeling (F). This range is self-explanatory in that Thinkers tend to be more logical and fact-based in their processing of information whereas Feelers are more emotion-centric when arriving at conclusions. The final spectrum is Judging (J) – Perceiving (P). This scale focuses on dealing with the outside world. Those that prefer Judging lean towards hard facts and firm decisions. Those that are Perceiving are thought to be more flexible and adaptable.

Types are listed by a four-letter code or acronym, e.g. ESTJ or INFP. According to the Myers Briggs testing group, there is no one type that it is better than any others. All have equal value. There is also the possibility that certain types work best with other types and that, in a collaborative effort, they would produce the best results when placed with particular counterparts. This will not be a focus of this study, but is certainly fodder for future exploration.

It should be noted that there are reliability issues with the MBTI exam. Studies have shown that respondents often receive a different result after completing the inventory a second or third time (McCaulley, 1981). Then again, other studies have found that the test is reliable and that its validity has been thoroughly demonstrated (Carlson, 1985). As a result of this debate, many consider that the MBTI is no longer a viable tool for career selection but still has value as a personality type indicator for personal development (Boyle, 1995).
The popularity of the Inventory is well-known and as such many similar tests have been developed. These tests are not officially licensed by the Myers-Briggs foundation. Instead, they are approximations of the real inventory. The official test must be administered by a licensed professional and includes a follow-up appointment to discuss results. Given the availability and variety of both full-length and abbreviated versions of the exam available online, it seemed unreasonable to give the test in an official capacity. One of these tests that was readily available was the Personality Type Indicator from psychology-tools.com.

The website describes itself as a free-to-use service “dedicated to providing psychology professionals, students, and the general public with transparent access to psychological assessment tools” (“Psychology Tools,” 2014). They go on to say that they strive to provide test questions and answers in the most streamlined possible format, through a simple interface and automatic scoring. The clarity of purpose, clean interface, and ease of use contributed greatly to using the service for this research.

The test describes itself as measuring the four dimensions of the subject’s personality. It reminds takers that there are no right answers but that participants should answer the test the way they are, not the way they would like to be seen by others. The test consists of 70 questions and takes ten minutes to complete. The expectations for this instrument are listed in Table 3.
### Table 3. Expectations of Personality Type Indicator

<table>
<thead>
<tr>
<th>Personality Type Indicator</th>
<th>Designers</th>
<th>Engineers</th>
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<tbody>
<tr>
<td>Extroversion / Introversion</td>
<td>Extroversion</td>
<td>Introversion</td>
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<tr>
<td>Sensing / Intuition</td>
<td>Intuition</td>
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<tr>
<td>Judging / Perceiving</td>
<td>Perceiving</td>
<td>Judging</td>
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#### 3.1.3: Index of Learning Styles Questionnaire

The second test offered to participants was the Index of Learning Styles Questionnaire from North Carolina State University. The Index of Learning Styles (ILS) is an online instrument used to assess preferences on four measurements, much like the MBTI. The spectrums that the questionnaire measures are Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global. They are based off of a learning style model formulated by Richard M. Felder and Linda K. Silverman. The instrument was developed by Richard M. Felder and Barbara A. Soloman of North Carolina State University (“Index of Learning Styles,” 2014).

The first pair of possible learning styles is Active and Reflective. Active learners tend to understand something by doing something with it. An approach that involves immediate activity or discussion is best for active learners. Reflective learners do best
with some time to think before applying what they have learned. Reflective learners are likely to prefer working alone as opposed to with a group. Concerning the second group of learning styles, the Sensing learners prefer facts where Intuitive learners prefer possibilities and relationships. Sensing learners are also like well-established methods and dislike surprise. The counterpart to Sensing is Intuitive. Intuitive learners highly prefer innovation and dislike repetition. Using the creator’s description of the instrument, the Sensing category seems to fit with the description of Linear thinkers and the Intuitive group with Lateral thinkers. The next pairing of learning styles is Visual and Verbal. As with our last instrument, these are the most self-explanatory pair of learning styles. Visual learners remember best what they see whereas Verbal learners get more out of written and spoken word. The final set of styles is Sequential and Global. Sequential learners acquire knowledge in logical progressing steps and follow a similar path when seeking solutions. Global learners pick up information in large jumps and suddenly seem to “get it.” They are also more likely to problem solve creatively but only after they have grasped the big picture. Here again we seem to find a parallel to Linear vs. Lateral thinkers in the ILS Questionnaire.

The website that hosts the ILS claims that there are two important points that users should know. The first is that the results provide an indication of an individual's learning preferences and an even better indication of the preference profile of a group of students. It also warns that those same results should not be over-interpreted. A second point is that a person’s learning style offers an indication of possible educational strengths and weaknesses in a person (“Index of Learning Styles,” 2014). The explanation makes very clear that the test is not to be used as a measure of possible career
aptitude or selection and that classification in that manner can cause more harm than benefit.

The website where the instrument is available states that the ILS may be used at no cost for non-commercial purposes by individuals who wish to determine their own learning style profile and by educators who wish to use it for teaching, advising, or research. The exam consists of 44 questions and takes less than ten minutes to complete. Expectations of the results are shown in Table 4.

<table>
<thead>
<tr>
<th>Index of Learning Styles</th>
<th>Designers</th>
<th>Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active / Reflective</td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td>Sensing / Intuitive</td>
<td>Intuitive</td>
<td>Sensing</td>
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<tr>
<td>Visual / Verbal</td>
<td>Visual</td>
<td>Verbal</td>
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<tr>
<td>Sequential / Global</td>
<td>Global</td>
<td>Sequential</td>
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</table>

Table 4. Expectations of Index of Learning Styles Questionnaire

3.1.4: Empathizing Quotient & Systemizing Quotient

The third and final assessment that was selected for distribution to the Designers and Engineers participating in this study was a combined version of Simon Baron-Cohen's Empathizing Quotient and Systemizing Quotient tests, or EQSQ. The test was
available at personality-testing.info which claims to have been offering a wide selection of psychological tests since 2011. They exist to “educate the public about various personality tests, their uses and meaning, the various theories of personality and also to collect research data” (“Personality Tests,” 2014).

The empathizing-systemizing theory was developed by Simon Baron-Cohen who specialized in autism spectrum disorders (“Empathizing-Systemizing Test,” 2014). The theory proposes that, on a level parallel to personality, there are differences in the way that an individual’s brain may be wired which influences the processing of information into two distinct categories. Those are empathizing and systemizing. This work began while studying autism, during which time Baron-Cohen hypothesized that autism is a severe level of systemizing within the brain. The Empathizing Quotient measures a person’s ability for understanding how other people feel and responding appropriately. The Systemizing Quotient measures a person’s ability for analyzing and exploring a system.

The Systemizing Quotient was developed by Baron-Cohen, Richler, Bisarya, Gurunathan, and Wheelwright in 2003 and the Empathizing Quotient was developed by Baron-Cohen and Wheelwright in 2004 for use in research and to substantiate empathizing-systemizing theory (“Empathizing-Systemizing Test,” 2014). This test consists of 120 questions and can be completed in about 15 minutes. The expectations for this instrument were that Designers would lean Empathizing and Engineers would prefer Systemizing.

3.1.5: Summary
The effort to select and administer surveys that effectively made available data for comparison between Designers and Engineers was a success. These surveys were detailed enough to provide meaningful information regarding the thought processes of the subjects while also gauging their enthusiasm for further participation. If they were willing to invest the half-hour required to take these short exams, then perhaps they would be willing to participate in a workshop as well. The number of surveys and time required seemed to be ideal based on the response from a small pilot study.

3.2: Participants

It was important to choose a relevant sample of participants for the study to ensure results that would provide the most useful set of data. The selection would need to consist of individuals that have received ample education in their respective majors so that they would reflect the knowledge necessary to properly represent their chosen field of study.

It was assumed that selection of Designers for the study would be easier to acquire given my placement within the Department of Design graduate program at The Ohio State University. I would do my best to recruit colleagues as well as upper-level undergraduates, ideally in their senior year, because they would have the most design education as compared to other undergraduates and the need for experienced Designers was imperative to differentiate themselves from similarly experienced Engineers. Personal invitations would be the primary method for enlisting participants. With this said, it was very likely that more participants would be required then could be obtained via personal invitation alone and therefore an alternative route would be compulsory to spread notice. The Department of Design at The Ohio State University had a good record
of assisting design students with their research projects. Often the department would work to help a student find participants within the department if the study they are conducting is relevant to the needs of the department or its students. Through the main office of the Department of Design, an email was distributed to students asking for their participation in this research study. It requested that students be at a senior level or higher in order to participate and that the surveys within would take about half an hour to complete. Unfortunately, this method yielded no participants. As a result, more participants were enlisted by recruiting existing volunteers to invite their design colleagues and classmates.

Being a Designer, though selecting other Designers might prove simple, selecting Engineers outside of my department would certainly be more of a challenge. I was not located within their classrooms or departments, nor did I have connections with many of their instructors outside of this research study. Fortunately, I had been working on a project within the Engineering school and had gained access to upper level and graduate student Engineers. It was through the EcoCAR and EcoCAR2 projects that almost all of my connections within the Engineering school came about. It was also quite fortunate that these projects attract a variety of Engineers. Much like the Department of Design has visual communication designers, industrial designers, interior designers, and so on, the EcoCAR projects attracted Engineers from different sub-disciplines including mechanical, materials, electrical, and more. It should be noted, however, that whereas the Designers recruited had no single project focus as a whole, the Engineers, as evidenced by their participation in the EcoCAR projects, were chiefly interested in entering the automotive field. This was especially true for students at the graduate student level.
The number of participants taking place in the study would ideally be at least 15 from each discipline for a total of 30 research subjects. The minimum number of participants required for this study to have a meaningful data set was ten from each discipline. These 20 total subjects would be responsible for all of the data in the questionnaires.

3.3: Results

Although recruitment was more difficult than initially expected, it was largely a success. At the end of the recruiting cycle, at least ten individuals from each discipline had been successfully recruited. This would have led to meeting the hypothesized minimum requirement for participation in order to develop meaningful results. However, the number of enlisted participants would slightly shrink as data collection went on. It was an unfortunate circumstance that some were unable to complete the requested surveys. Only three of the respondents that agreed to complete the questionnaire failed to do so. This, unfortunately, led to having slightly fewer than the ideal number of participants. In total, nine Designer students (eight graduate, one undergraduate) and seven Engineering students (five graduate, two undergraduate) responded with the requested data. In hindsight, there should have been a plan to recruit notably more than the necessary amount of participants.

Distribution of the surveys was solved by the nature of the instruments already being online. An email was drafted and introduced potential participants to the project and requested their time. Those that agreed were sent a second email with hyperlinks to each instrument necessary to complete the questionnaire portion of this research. The
results of those tests where then emailed back to the administrator where they were assembled in a spreadsheet. The results are discussed below.

3.3.1: Questionnaire Results

The majority of participants from both disciplines were graduate students which are an ideal sample for purposes of testing the minds and methods of people who are solidly within their field of choice. All of the participants minus one Engineer thought themselves to be creative but the Designers decisively considered themselves more creative. This was to be expected of the Designers. Concerning analytical tendencies, the Engineers all felt highly about their abilities whereas the Designers felt confident but only slightly less so in some cases. There was no noticeable difference in personal perception of problem solving ability, preference to work alone, or the idea that all problems can have simple solutions. All Engineers felt confidently about their choice to become an Engineer though whereas some Designers had conflicts about their choice of career path. The Designers were primarily female whilst the Engineers were primarily male. This is not thought to have any bearing on the results, but is worth mentioning.

3.3.2: Personality Type Indicator Results

The results of the Personality Type Indicator are represented in Figure 1.
Concerning the first personality measurement of Extroversion or Introversion, there was a distinct preference in both Designers and Engineers towards Introversion. Sensing and Intuition also provided similar results between the disciplines. Although neither group showed a distinct preference, it could be said that Designers appear to lean towards Intuition and Engineers may be more Sensing. Considering the low number of respondents, it would be impossible to make a conclusion based on these numbers alone. What is not in question is the result that all Engineers were Thinkers when looking at the third metric. Some were more severely leaning than others, but all were on the same side of the spectrum. The Designers were split down the middle with about half being Thinkers and about half being Feelers. So we now can state with some confidence that Engineers tend to be more fact-based and logical in their thinking processes. Observing
the results from the Judging/Perceiving category also showed that all of our Engineers preferred the Judging side of the spectrum. Again, the Designers were split down the middle with half being on each side of the range. Here again we can say with some confidence that Engineers prefer hard facts and firm decision-making in their thought processes.

Although Designers certainly showed some preference for both Introversion and Intuition they remained generally split on every other metric of the Personality Type Indicator. There was also a wide range of severity of type partiality the Designers showed ranging from 19% to 100% across all respondents and all metrics. In fact, four individual measurements from the Designers were below the 50% mark for certainty.

The Engineers showed a distinct partiality towards both Thinking and Judging which is in line with preconceptions of Engineers being Linear and systematic in their thinking. Although this result is interesting, it will need to be paired with other results to be a conclusive finding. None of the measurements from the Engineers were less than 50% certainty.

In Table 5, we see that the expectation of Designers being Extroverted in the first scale was incorrect. They also were inconclusive on the last two metrics of Thinking/Feeling and Judging/Perceiving. This was very unlike the Engineers on these two scales. The Engineers also proved to be Sensing which was against the expectation of Intuitive.
Table 5. Results of Personality Type Indicator

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<td>Judging / Perceiving</td>
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3.3.3: *Index of Learning Styles Questionnaire Results*

The first category of Active/Reflective showed widely varied results within both Designers and Engineers, as shown in Figure 2. As a result, the average for both groups was almost identical. Once again, we see that there is no apparent difference between our respondents.
The second measurement between Sensing and Intuition placed the Designers firmly into the spectrum of Intuition, as shown in Figure 3. This implies that Designers showed a strong preference towards innovative thinking. The Engineers, on the other hand, were slightly into the range of Sensing. Engineers then have a slight preference for facts, well-established methods, and they dislike surprise.
In the Visual and Verbal category both groups undoubtedly stood Visual, shown in Figure 4. It was expected that the Designers would prefer a Visual learning style, but it was surprising to find that Engineers not only prefer Visual learning, but also highly prefer it.
The last metric measured was Sequential/Global. In this category, the Engineers showed no preference either way and remained well balanced, which can be seen in Figure 5. The Designers, however, slightly favored Global thinking. This indicates that they pick up information in “a-ha” moments and tend to problem solve creatively.

Figure 5. Results of Index of Learning Styles Questionnaire: Sequential/Global

In the end, it seems a few preconceptions were true in the case of Engineers leaning towards facts and logic as well as Designers favoring innovative and non-traditional methods. Table 6 outlines where these preconceptions held and where the results differed. There also were surprises in the observations that Engineers just as heavily favored Visual learning, as did Designers.
Table 6. Results of Index of Learning Styles Questionnaire

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3.3.4: Empathizing Quotient & Systemizing Quotient

Although it was the longest test administered, the results for the EQSQ are by far the least complex. They are presented in Figure 6. The Designers and Engineers results mirrored each other. The Designers leaned towards a combined EQ of 40 and SQ of 32. The Engineers had a combined SQ of 40 and EQ of 33. These results show that the Engineers have a higher capacity for analyzing and exploring a system whereas Designers have a higher capacity for understanding how other people feel.
3.4: Summary

A set of instruments was successfully selected with the intention of understanding similarities and differences in thinking styles between Designers and Engineers. The discovery and application of these online surveys was completed following two rules: accuracy and authority. Two tests were from psychological testing websites interested in furtherance of scientific research and knowledge and the other was from a major American university. The science behind each was thoroughly documented at each site and there should be no question that the exams utilized are valid.

The recruitment and distribution method of email, as well as using instruments hosted online, worked flawlessly and received a warm response from the technology-savvy participants. There was, however, a fault in the recruitment plans that did not take
into account that potential participants would be unable to complete their voluntary commitments. It would have been wise to have a greater number of participants than was required for this research or rather to anticipate more falling-out then was initially expected.

The Engineers showed a distinct partiality towards both Thinking and Judging in the Personality Type Indicator, which is consistent with being Linear and systematic in thinking. The Learning Styles Inventory showed Engineers in a position of favoring facts and logic. The Designers, however, favored innovative thinking methods. Both were equally steadfast concerning the Visual learning style. Finally, we saw that Engineers and Designers are opposing each other when it comes to the Empathizing and Systemizing Quotients and that Engineers have a higher capacity for analyzing and exploring a system, whereas Designers have a higher capacity for understanding how other people feel. With this knowledge in hand, there is an ability to gain further understanding about the thought process and problem solving potential of these complimentary disciplines.
Chapter 4: Workshop

The questionnaires had yielded some interesting results about Designers and Engineers. It was revealed that a number of expectations were incorrect. This information was a good start towards understanding the thought processes behind the two disciplines, yet more would be required to come to any concrete conclusions about either group. The mechanism for further study would be a workshop wherein small groups of Designers and Engineers would be asked to solve complex contemporary issues in a short amount of time to see how the disciplines functioned in practice and what, if any, differences were evident.

4.1: Planning

4.1.1: Warm-up Activity

A warm-up activity is often used in focus groups or workshops where research is being done in order to prime the participants for their session. In this instance, an activity that was related to the main activity was selected in order to ready the group. In this way, the activity would be both an appropriate primer for the main activity to come as well as another opportunity to collect valuable data for the purposes of this research.

A good warm-up activity for this research would clear the mind of the participant of any prior tasks or thoughts that may have been at the front of their mind. It would also create an atmosphere of possibility and creativity in order for him or her to be present in the moment and mindful of the task at hand. This meant that a device would be needed to
successfully engage the minds of a group of busy students in the middle of their workday. Although a number of possible activities were considered, the winning tool was a simple set of wooden building blocks.

Figure 7. Sample selection of wooden building blocks

Predictably, students involved in higher education work primarily with computers, text, and spoken word. Hands-on work is often available and even necessary, but is not the primary method of communication with which these students interact. Building blocks then would provide an immediate change to the participant’s normal workday and workflow. The task that would be asked of each person would require him or her to use the blocks provided to describe his or her process when given a problem to solve. They would be instructed to use the blocks to describe that process in any way they saw fit. There would not be a hard time limit for the activity but fifteen minutes seemed longer than necessary and so was selected. After completion of the warm-up activity, a
short break to clean up would be allotted to clean up and prepare materials for the main event.

4.1.2: Group Activity

The main activity would aim to have the participants work in teams to solve complex issues. The simplest way to observe this behavior was to provide the members of the workshop a problem or set of problems to tackle and document how they went about solving them. As a result each group would be provided a series of issues that they would be asked to select from in order to develop an approach to particular problems. This would all be done under watch of video camera and audio recorder. In order not to seed the idea that problem solving was all that mattered, the words “problem” and “solve” would not be used. Instead the terms “issue” and “approach” would be used. A script was written to avoid any confusion and to aid the administrator with this task.

Fourteen issues would be available in total. Two of these issues would be required. The required issues would be provided in order to directly compare how the groups approached a particular issue. The issues were also categorized into four groups: small scale, large scale, experience, and products. These categories would not be known to the workshop participants. The category titles were included for organization and later could be used for interpretation of collected data.
4.2: Participants

The participants for the workshop would be selected from the participants that had already completed the questionnaire portion of the research. Ideally, six participants from each discipline would be selected for the workshop. These six persons would complete the warm-up activity individually but join into two groups of three each for the main activity. It was determined that, given the great distance between the Department of Design and the Center for Automotive Research (the location of the EcoCAR projects) on the campus of The Ohio State University, two separate workshops would allow for maximum convenience for the potential participants. All questionnaire participants were invited to be a part of the workshops. Six Engineers and four Designers responded. Although six Designers were not available, there would still be enough to create two distinct groups for the purposes of collecting data during their workshop.

4.3: Warm-up Activity
4.3.1: **Engineers**

Since the Engineer Workshop occurred first, it will be discussed first. The initial explanation of the activity to the Engineers led to a handful of confused looks. This confusion was short-lived as the Engineers were immediately drawn to the building blocks. Without hesitation, they all dived in and began claiming pieces for their own constructions. The pace was decidedly hectic and even as individuals began to make sense of their builds, fast placement of materials and selection of further blocks was occurring. One Engineer asked for confirmation of the assignment objectives and that seemed to be the only time anyone offered evidence to not being clear on the task. The mood was quiet and studious. Once individuals began to complete their task, the mood in the room lightened and discussion arose until everyone was ready to present their process.

Surprisingly, each construction by the Engineers was unique. The explanations given by the Engineers were all highly similar, however, and usually between one of two possible results. One of these was the explanation that multiple perspectives were necessary in order to fully understand a complex problem and so vigilance in managing the process was required. The other was that a preliminary research stage followed by iterative prototyping was required in order to properly solve a problem. So, although appearing different, the process by most Engineers followed similar paths.
4.3.2: Designers

Announcing to the Designers that building blocks would be involved in their workshop seemed to not be a surprise. Given the nature of Design research methods, especially at The Ohio State University, this is no shock. The explanation of the activity required a few repetitions to become solidified in the minds of the attendants. After everyone was clear on their task, most of the blocks were released from their container although not all of them. The Designers, as opposed to the Engineers, had a much more
reserved approach to the blocks and the atmosphere of the room was thoughtful instead of competitive. This is not to say that certain unique blocks were not desirable and selected quickly, but simply that there seemed to be much less of a rush in selecting pieces. The construction process was quiet and thoughtful.

Unfortunately, one of the Designer participants needed to arrive late to the workshop and was unable to partake in the blocks warm-up fully. The constructions by the remaining three were all unique but all reminiscent of work that had been prepared by the Engineers. Explanations were equally similar when Designers described their process. One Designer visualized project boundaries specifically and was the only of either group to do so.

Figure 11. Sample Designer warm-up construction
4.3.3: *Summary*

Both the Engineers and the Designers said that they highly enjoyed the building blocks exercise. The descriptions of their process were similar between disciplines. Although a few of the Engineer constructions were not as thought through as others, many of the builds would be at home in either workshop.

4.4: Group Activity

4.4.1: *Engineers*

4.4.1.1: *Observations*

Two groups of three Engineers were assembled after completion of the warm-up activity. Each group was provided fourteen issue cards, poster boards, tape, sticky notes, and assorted colors of permanent markers. Workshop instructions were presented to the groups explaining use of materials, time constraints, and what was expected. It was also explained that they would be expected to present their work at the end. One person asked, “What are we doing with the issues?” once selected. It was explained in further detail that we were interested in process, not final product. It was also asked how many they had to
The groups quietly read over their issue cards and after a minute or two began to narrow down their selection. Occasionally a bit of discussion or laughter would arise as they pointed out parts of the cards.

The groups seemed mildly excited to begin. A scribe is appointed for and wrote for each group. There was some difficulty selecting issues. Fortunately, both groups quickly slid into a comfortable place of discussion amongst themselves and starting their thoughts running on how to approach their issue. One group had multiple subjects contributing written words to their poster board. Both teams use only one poster board per issue for this and the remainder of the issues. Now and then some boredom was exhibited while waiting for a team member writing to finish a long or detailed thought that included the tapping of a pen on the table or leaning back and staring around the room.

Either changing topics or the moderator speaking to the room with a time update energized the discussion for a few minutes. The groups were much more comfortable with discussing their ideas and speaking at conversational volume after having completed one issue.

They were almost exclusively creating flow charts with a hint of mind mapping. They were beginning to develop patterns in their problem solving behavior. They are following well-worn paths. Both groups are continuing in the patterns they have developed of discussion followed by creating a flow chart style poster.

Particular words were overheard throughout the activity including “why” and “solutions.” “We’re solving the problem,” was also clearly stated. It was even said by one participant, “I have no interest in this issue.”
Evidence of weariness began to appear. It had been 45 minutes since they began the workshop’s main activity. The groups exchanged banter as they wound down their topics; there was a lot of shuffling of bodies and materials during this process. Restlessness was apparent.

The groups explained their posters and had very similar explanations. For the most part, they simply read what they had written, occasionally interspersing some of the discussed reasoning.

4.4.1.2: Results

The workshop’s main activity concluded with each of the two groups having created five posters upon which they wrote their responses to each issue. Each group had one poster per issue and they appeared to follow similar methods at first glance. Of the materials provided, both groups used only the posters and markers. What seemed important to the groups were legible summaries of their perceived best path of action towards each issue. The style of writing was short and to-the-point. Those points were
placed on each poster in a left-to-right and up-to-down fashion as flow diagrams. This would initially seem to be a linear approach since one step would have to be taken to arrive at the next. In many instances, arrows were drawn across the diagram breaking the linearity of the process. This was almost always for prototyping, testing, and reevaluation purposes. For example, after the process had been followed one time, an arrow would lead back to the first step for repetition of the process after a round of testing.

An analysis of the top five significant words used on the posters were “consider,” “solutions,” “define,” “make,” and “feasible.” Significant words are those that were not key terms used in the issue cards. These words may show a preference for solving a problem rather than looking for new possibilities. What is clearer about these words is an apparent need to understand the issue at hand with as much clarity as possible. The understanding of the problem to be approached is what is most impressive about these Engineers. There was never a moment when they allowed their initial reaction to each issue be their final reaction. A clear practice of clarifying, framing, and comprehending the scope and consequence of each issue was evident. This shows significant forethought on their part. At no point during the exercise were unrealistic options discussed or documented by the groups. This is not a conclusive piece of data that shows Engineers are incapable of such thinking; however, it may be interesting to compare this to the Designers, who had yet to complete their workshop.

It seems that the Engineers are leaning towards logical processes in order to reach an end goal. These well-worn paths seem to serve them well as they have no troubles with any of the issues that either they were assigned or had selected themselves. In most cases, they finished in less than the allotted time provided for each issue. The language
they used was not particularly revealing of any thought processes and reflected the language they spoke during their discussions while approaching the issues.

Finally, an exit interview of the participants was conducted in a group setting. It was asked if the exercise was considered engaging or boring and what might be improved. The only responses given mentioned that, after three issues, the repetition of the assignment began to drag and that by the fifth issue many were bored. The participants reminded the administrator that the building blocks activity was highly enjoyable.

4.4.2: Designers

4.4.2.1: Observations

Two pairs of Designers were assembled into groups after the warm-up activity was cleaned up and put away. The groups were provided the same materials as the Engineers and instructions were presented. In a similar manner to the Engineering group, some clarity was required concerning the purpose of the issue cards and exactly what was expected. It was explained in further detail that we were interested in the process, not a final product. Discussions then continued as issues were eliminated and selected for completion. It was expected that the Designers would be more comfortable with this exercise, and although no discomfort presented, the Designers took more time to select issues.

The Designers were eager to get to work, but cautious about placing anything on their poster board. It seemed as if they felt their work surface was precious and needed to be treated the right way. Perhaps this was an element of perfectionism creeping in on the Designer’s part. Soon, though, an understanding between the group members was
reached and material began to flow onto poster board. That material was almost exclusively sticky notes, which was a material the Engineers never used.

Both groups quickly fell into a comfortable, but separate, conversation on how to approach their issues. Both teams use only one poster board per issue.

Taking more time was not exclusive to the process of issue selection for the Designers. Even though the groups had one fewer member than the Engineers did in their workshop, the time taken for the Designers to finish one issue and move on was significantly longer. Whereas Engineers took 8-10 minutes per issue, Designers were taking on average 15 minutes per issue.

The output of the Designers was different in that they leaned towards mind-mapping more than flow charts. They, like the other workshop, were beginning to develop patterns in their problem solving behavior.

Evidence of weariness came later but was just as pronounced. The longer completion times began to wear on the participants and a pattern of repeating similar problem solving behavior became clear.

The groups explained their posters much in the same way the Engineers did. They read what they had written, occasionally including some of their reasoning. This time the groups had different approaches to their content though. One was very fluid and moved from segment to segment with a clear focused direction and the other was open and unbound by almost any limitations.
4.4.2.2: Results

The first and most obvious difference between the Designers and Engineers is that the Designers used all the materials provided in order to complete their posters. Following in that vein, Designers wrote more on sticky notes than on the poster board itself. This allowed for moving of ideas around quickly and painlessly during the time allotted to approach each issue. Having the ability to move an idea, or step of the process, at any point allowed for a more fluid and less restrictive problem solving process for the Designers. It also worked towards longer time necessary for each issue. The Designers were always over the allotted time for each issue and in many cases took two to three times longer than the Engineers. Although time was a cost, this movement of ideas may indicate a creative-leaning thought process. It certainly seemed natural for everyone present. This fluid rearrangement, however, began to take place within a structure generated by the Designers. The ideas could be moved, but only from one user-created category of the process to another, or simply rearranged within the same one. In this way, the Designers actually showed more structure in their poster boards than the Engineers.
Designers leant towards categories of their process like “observations,” “interviews,” “needs,” and even “opportunities.” This last category was one of the more Lateral thinking elements of any poster from either workshop.

One of the Designer groups wrote very little on their poster boards or sticky notes and as a result of this there were fewer words to analyze than with the Engineers. The group in question, however, spent more time discussing their approaches and reaching consensus than any other group. So a lack of product in the case of words used is not a reflection of a lack of effort. The top five significant words for the Designers were “research,” “current,” “identify,” “evaluate,” and “solutions.” As with the Engineers, the appearance of the word “solutions” is an interesting occurrence as the word was avoided during the workshop and the idea of an end product was discouraged in favor of a focus on the process. Here again there is an interesting similarity to the Engineers as these words lend themselves towards a focus on understanding the issue at hand before an action can be taken.

The Designers tended to lean in a similar direction as the Engineers when concerned with the need to comprehend a problem before solving it. This behavior can likely be explained by the training that both of these groups have received. The process by which the Designers visualized their process however was very different. There were usually some categories of large steps that needed to be taken but with any number of smaller tasks within each header that could be rearranged or approached from different perspectives. In one instance, a category was created specifically to list multiple perspectives.
The workshop stated in their group exit interview that the time started to pass slowly and the repetition of the task became tedious. This group, however, felt the tedium was in having to switch to different issues and not about the time required. One participant said they would have been happy to spend the entire session working on one issue. The blocks exercise was also highly enjoyable.

4.5: Bias Screening Survey

4.5.1: Planning

It is important for any researcher to be aware that results are colored by the metric by which they are measured. In some cases, this can include the bias of the researcher. This research has a chance for bias in association with one group over the other or the proximity to the information collected and design of the tests. In order to come to some solid conclusions about the data gathered in this workshop a further survey would be administered asking non-designers and non-engineers their opinion of whether the creators of the materials involved in the workshop were Linear or Lateral thinkers. All participants in this study will have no prior knowledge of the purpose of this research. This survey will ask a handful of participants to identify a thinking style belonging to each of the building block examples and each group of posters. The building blocks will be analyzed first with no accompanying explanation from the builder and then be reevaluated with the explanations. No identifiers for either Designers or Engineers will be revealed to the participants in the survey. It is thought that this exercise will allow some firm deductions to be made concerning how each discipline thinks.

4.5.2: Participants
The participants for this exercise will not be associated with either discipline in any way. Considering the simple identification tasks required in this survey, no special education is required of the participants in order to receive meaningful results. Participants will be from a random assortment of age 18-35 university graduates by the Co-Investigator.

4.5.3: Results

The building blocks activity was completed by six Engineers. The first round of decisions of whether or not the constructions, based solely on appearance, were linear or lateral was split. After seeing the explanations, one blocks example was changed. This left the overall numbers for the Engineers blocks exercise at four Linear thinkers and two Lateral thinkers. Three Designers completed the blocks activity. The pre-explanation impressions of the participants were almost unanimous in declaring the Designer builds as the work of Lateral thinkers. This result did not change after the explanations were introduced and the participants were asked to confirm or change their answers.

The posters required a bit more consideration according to the participants surveyed. Now there were four groups of posters to analyze. In this instance a judgment of linear or lateral was asked over the entire work of a single group. So five posters would lead to one verdict either way. The posters, like the building blocks, were mixed and without any identifiers. The Engineering groups were split. One was seen as a majority lateral and the other as a majority linear. The Design groups were the same. It is interesting that both groups received a vote for each thinking style. It is more interesting that no group received unanimously linear or lateral votes.

4.6: Summary
A pair of workshops was successfully completed with both Designers and Engineers. The information gathered can be compared and contrasted with that from the Questionnaires in order to gain a more complete picture of the nature of both disciplines in question.

The excitement of both groups to participate in the warm-up activity of building blocks was welcome. The apparent similarities between the groups’ constructions were also intriguing. The explanations that were given seemed to belie the hypothesis that they would be quite different in that arena. The idea that the Designers completed Lateral thinking builds and the Engineers leaned towards Linear thinking builds was initially expected, but then disregarded after seeing the results. It was only when the Bias Screening Survey was given that the idea that differences were present resurfaced. It is still difficult to say how similar or not they may be with such a small sample size.

The main activity was treated with care not to use certain words that may trigger particular responses in the groups. This avoidance seemed not to have any effect on the language used by the participants as they immediately began looking towards solutions. No actual solutions were expressly sought, however an end was certainly in mind while discussing the means. Both disciplines leant towards language that sought to comprehend the issue at hand. Differences arose in style, however, where the Engineers used flow diagrams and bullet points to make their case. Designers preferred a looser sticky-note-based style that allowed a number of alterations over time to be easily made. These differences do lead towards Designers being slightly more lateral in their approach and begin to align with the results from the Questionnaires.
Finally, a Bias Screening Survey was conducted in order to gather more data regarding the leanings of our disciplines and how their results measure up to the definitions of Linear and Lateral thinking set forth in the Terminology section. This survey revealed a number of results that would have been looked over had they not been uncovered by this examination. The idea that the blocks truly showed a noticeable difference in thinking styles was written off after an initial review of the results. The Bias Screening Survey resurrected that hypothesis. This survey also offered the knowledge that the Engineers and the Designers are both capable of producing linear and lateral work even though they may lean towards one direction or the other.

Table 7. Expectations and Results matched
Chapter 5: Conclusion

5.1: Project Summary & Objectives

This study has attempted to uncover patterns in thinking within graduate-level Design and Engineering students at The Ohio State University. Participants from each field of study were asked to complete a series of evaluations to determine their problem solving tendencies and patterns. They were then asked to present their problem solving process for approaching a set of complex contemporary issues. This was all accomplished in order to learn how to facilitate improved communication between the two disciplines.

The world has become smaller and more unified while the problems within it have become larger and more complex. These increasingly intricate and interconnected systems require authorities from numerous disciplines to manage. Designers and Engineers both provide vital services to industry and, as such, it is important that they be able to work with each other as effectively as possible. Collaboration is a popular concept, yet the intricacies of the act are often misunderstood. Understanding the purpose behind multiple styles of communication across disciplines can be an important tool for those seeking to effectively approach complex and wicked problems.

This chapter will attempt to discuss the application of data into collaborative efforts and also will address how preconceptions about Designers and Engineers measure up to the realities as evidenced in the results collected. It was originally predicted that preconceptions of Engineers as being significantly different from Designers would be found to be largely false. It was, however, expected that there would be a number of
presumptions that will hold true. There are clearly fundamental differences between the groups but the similarities shall more likely provide the bridge for improved communication. The applications resultant from this research will be discussed as they apply to each discipline and to collaborative efforts. Finally, the items that would be considered for further and improved study will be discussed.

5.2: Conclusion

At no point during this study was there to be an air of competition between Designers and Engineers. It was important not to let there be the impression that one practice might be superior or more equipped to handle complex problems than the other. Given that this study was conducted from a Design perspective, it was important at all times to remember that reality while participating in the collection and analysis of this data.

The reality of existence is that people are different. These differences can lead people towards a particular career based on their interests. These differences are part of the fundamental nature of a person. It was these fundamental differences that were to be tested by using questionnaires. The questionnaires selected tested for personality type, learning style, empathy, and systemizing. The first of these tests resulted in Engineers showing a distinct preference towards behavior that was linear and systematic. The learning styles test showed that they preferred facts and logic. Designers preferred innovative thinking methods. Both disciplines were highly visual. The Engineers had a higher capacity for analyzing and exploring a system whereas Designers had a higher capacity for understanding how other people feel. These, however, are the only
differences. Overall it would seem that the tests ultimately confirmed that the groups are much more similar than they are different.

With an idea of the fundamental similarities and differences between Designers and Engineers, the issue of problem solving when addressing complex design tasks could be examined. The process of the participants was an important aspect of their abilities and needed to be assessed. The building blocks activity asked our participants to display their process when approaching difficult issues. There were definite similarities in builds across groups; however, the third-party consensus was that Designers are highly likely to be viewed as Lateral thinkers and Engineers are more likely to be seen as Linear thinkers.

The main activity of each workshop focused on the actual process of problem solving and put to the test our participants’ ability to plan an approach to a series of difficult issues in a group setting. There were a number of differences here. The Designers took much more time than the Engineers to discuss and come to conclusions about how to approach the issues. They also chose to write primarily on sticky notes, allowing them to have a fluid and changing approach to their problem solving method. They did this within the framework of a larger step-by-step system, though. The Engineers wrote directly onto their poster board in a flow diagram pattern. In many cases, it appeared like a mind-mapping exercise. It was not difficult to understand, given these explanations, how third parties could not decide which groups were more linear or lateral. Both groups wrote about solutions even though end goals were not expected. There is an interesting similarity as the words each discipline used most lend themselves towards a focus on understanding the issue at hand before an action can be taken.

5.2.1: Summary
Considering the relatively small sample size and scope of this project, it is clear that no definitive statements can be made about the nature of either Designers of Engineers. The results though do point to a number of interesting possibilities. These include that Engineers are much more visually engaged than previously hypothesized. Engineers also tend to fall into a number of logical and rational thinking patterns. They are more likely to be seen as Linear thinkers, but this in no way seems to handicap their ability to approach complex or wicked problems. Designers are surprisingly not that different from their Engineering counterparts in many areas of thinking and learning. They do, however, differ in their approach to problem solving when there is an opportunity for outside-the-box thinking. They are also more likely to be seen as Lateral thinkers and appear to be more empathetic than Engineers.

5.3: Applications

With an improved understanding of the thinking tendencies of our Design and Engineer brethren, there is room to speculate about the ways in which communication across these two disciplines takes place. There has been what appears to be confirmation of preconceptions that Engineers are predominantly Linear thinkers. They also have tendencies towards structure and logical pathways in their problem solving methods. This indicates a need for direct communication with a focus on needs and goals. This style of communication should provide the least resistance when dealing with Engineering types. Though tendencies towards Lateral thinking were present for Designers, they were less sure in their lateral leanings than the Engineers and their preference for linear thought. The key aspect of Design thinking seemed to be a need for open and fluid thought that was undirected at a particular end goal. This would mean that when communicating with
Designers, an acceptance of this need for creative thought is required. The ability to engage Designers on a level of interaction that allows for this freedom of thought is necessary. Interrupting the flow of either Engineers or Designers from their established thought processes may lead to temporary roadblocks in understanding. These roadblocks are inevitable, though. As such, an understanding of the patterns of thinking of the contemporaries with which an individual is working can allow for quicker alleviation of communication difficulties. This will allow for roadblocks to perhaps only become speed bumps.

Applying these similarities and differences between the disciplines into practical examples is a different matter than simply discussing generalities. Sample examples from across the results of the Questionnaire portion of the research will be paired with observations from the Workshop portion of the research in order to arrive at real-world uses for the data.

The first metric on the Personality Type Indicator revealed that both Designers and Engineers showed a preference for Introversion. This means that they are primarily thought-oriented individuals rather than action-oriented individuals. How, then, can the knowledge that both disciplines prefer thought-oriented thinking processes help foster improved collaboration? From an educational point of view, the answer might be to focus part of the curriculum on understanding those professions that are likely to be co-collaborators throughout the student's careers. This knowledge will help different disciplines to be better able to comprehend the background and purpose of other professions. Moreover, this education should focus on the theory behind those professions. Not just what they do and how they do it, but why. For a Designer to
understand the nature of Engineering is not unheard of, but rarer is understanding of the mindset an Engineer is in when problem solving or the purpose behind their actions. An understanding of that methodology would benefit the Designer when working with Engineers on complex projects. This would also be true for the Engineer when needing to understand the Designer. In a business setting, this knowledge may be applied in a more pragmatic way. The drive of Designers and Engineers to prototype their ideas can be put on hold. Small discussion groups can be included at the front end of a project in order to gain a better understanding of the issue at hand. These groups of mixed disciplines can focus on ideation in order to more completely understand a problem. This need to comprehend an issue fully is already innate in both disciplines according to the workshop and so should be a welcomed endeavor.

The Personality Type Indicator also resulted in differences between Designers and Engineers. The most prominent of these was Intuition/Sensing. The Designers preferred Intuition while Sensing was more apparent in the Engineers. This meant that Designers lean towards impressions and focus on the abstract whereas Engineers prefer reality. The Index of Learning Styles had similar results for the scale Intuitive/Sensing which mirrored the Personality Type Indicator. The explanations of those results were also very similar. These differences which lead Designers towards innovation and Engineers towards established paths (according to the Index of Learning Styles) can be applied to practical circumstances as well. In an academic setting, the need for working outside of one’s comfort zone is a necessity if these groups are going to better comprehend each other. The development of activities that stretch these boundaries are sure to be useful. Having the brain trained to contemplate in alternate thinking styles should result in
increased comprehension of those styles. For Designers, this may be an exercise that restricts their ability to work within a wide and unbounded thinking space and requires immediate practical results. For Engineers, this may be working with an issue that has no evident resolution in order to force contemplation about an abstract concept. In a business setting, however, there would need to be different solutions to applying these differences. These individuals are already past school and have been successfully working with other disciplines for some time. The problem with communication for them is not real. This does not mean improvements are not available. Framing the problem in this way should allow for the introduction of new methods of improving communication. The most sensible and perhaps simple method of introducing these improvements is by allowing the individual to process information in the same way that their co-collaborators do. This can be achieved by placing the individual within a team of different disciplines as an observer. This will allow the individual to be exposed to alternate methods of problem solving and communication.

The Index of Learning Styles Questionnaire also revealed the surprising fact that both Designers and Engineers are highly visual learners. This revelation may lead to some interesting ideas about how these disciplines communicate with not only their counterparts, but with their stakeholders. Having a tendency towards visual learning may be applied in more obvious ways that includes visually motivated presentations and aides. This can also be useful as a means of comprehension when one discipline is sharing information with another. However, this can be taken a step further. The Workshop showed how different the style of communication can be between two groups that are both equally visual. With that in mind, how these disciplines are taught to visualize
should be examined. Designers have a far more intricate visualization process innate in their educational practices. Engineers may be able to benefit from sharing in this process. There is also the reality that Design Thinking is a hazier practice than the process used in Engineering. The problem solving space in Engineering is focused and result-driven. In Design, this space is ideally boundless, allowing for any number of thoughts to enter the ideation process. Using a collaborative style like Multidisciplinarity, which allows for the use of multiple disciplinary styles simultaneously, would allow for a shared experience of visualization when problem solving. This concept demonstrated itself when a major American toy manufacturer initiated a new design and development process. Employees from a number of disciplines including Engineering and Design were asked to collaborate on new toy designs away from their usual offices. The groups were exposed to a number of presentations by artists, psychologists, architects, and so on. This led to new outlooks on certain established toy designs and markets which resulted in a building activity set aimed at girls in a market dominated by boys (Jackson, 2002).

The Empathizing Quotient and Systemizing Quotient resulted in disparate results between Designers and Engineers. The higher empathizing range of the Designers showed a higher understanding of emotions. The higher systemizing range of the Engineers exhibited an elevated comprehension of systems. Interdisciplinarity is the transference of methods from one discipline to the other. In an educational setting this may have an impact concerning empathy and systems because these are such polar opposites. If there was a way to have someone not only understand both sides of the equation but take part in it, this would be ideal. Once again, small groups may provide the medium for this understanding. These small groups of students could foster creative
development and understanding through the lens of another discipline’s methods.

Systems are often comprised of people. Designers and Engineers both work with each of these elements. Understanding this, and developing this knowledge between the disciplines, is key to having Designers understand a systemizing viewpoint and Engineers understand an empathizing point of view.

5.3.1: Summary

The ideal scenario for design development in business requires the contributions of both Designers and Engineers. Both groups should be working with each other throughout the development process. Interaction should take place in the form of information exchange, discussions, sharing and informal dialogues. Successful collaboration can be achieved through set goals led by a shared process that relies on a mutual understanding and common vision (Pei, 2007). These goals can be achieved through a number of avenues that a workplace can support including common workspaces, support from management and strong leadership. A focus on a common technical language, such as programs utilized, will also support this adjustment.

Certain Designers and Engineers will be more amenable to these changes in their working methods. Particular characteristics of these individuals are best described by Tim Brown when discussing Design Thinkers (Brown, 2008). The profile of an effective creative thinker will include empathy in order to look at the world through multiple perspectives. These perspectives include clients, colleagues, and end users. Another desirable trait is Integrative Thinking which allows them to see all aspects of a contradictory problem. Optimism ensures that whatever the challenge presented, the option to find an effective solution is always available. Experimentalism allows the
thinker to move in creative directions and not simply incremental changes. Finally, and most importantly, some Designers and Engineers will be more amenable to collaboration. Collaboration means that the best thinkers do not simply work alongside other disciplines, but are fully integrated into other disciplines. This may be as a result of some of the proposed measures here to improve collaboration or because of expertise from the individual in more than one field.

Certain differences will always be in place, and should be expected from two groups differently specialized. The goal is not to homogenize our disciplines and demonize specialization, but to embrace those differences and exploit them.

5.4: Further Study

A number of possible improvements arose as the result of conducting this study. The largest issue faced was that of participant recruitment and retention. Ideally, many more participants would have been tested for the questionnaire portion of the research and a handful more for the group workshop. Recruitment was limited by the selection of chiefly graduate students from two small spaces. These were the Department of Design and the EcoCAR projects. At maximum, approximately double the participants could have been reached that took part. It is unrealistic to believe that recruitment of an entire pool of subjects is possible, however, and so it may be seen as a small success that the number of recruits was effectively enlisted. A solution to this low participant number would be to increase recruitment actions or widen the available participant base.

Another issue that would help with recruitment numbers would be widening the scope of the project. It was stated in the introduction that the most realistic execution of this study would be to focus solely on the pools of students at The Ohio State University
and that remained the right decision for a principal study such as this. In future implementations of this research, a larger pool of subjects could be designated, either from multiple universities, or the professional community.

A further way to increase the effectiveness of this research would be to administer instruments from different sources. The tests given were valuable in gathering information about subjects; however, more tests would only provide more information. There are a number of viable tests that are acceptable including the Big Five personality test which is popular among psychometric testing professionals. Another interesting instrument would be the Need for Cognition scale measures the degree to which cognitive activity is desirable or interesting for an individual. Finally, The Embedded Figures Test measures disembedding, a restructuring skill which, although initially aimed at a person’s ability to deal with unstructured tasks, also has potential for use as a measure for Lateral thinking ability (Butler, 2010).

A larger third-party Bias Screening Survey would further demonstrate the dominance of one thinking style over another among our participants. The handful of participants selected affected the interpretation of the results by challenging preconceived notions about them and restarted a discussion about previously unworkable results. Perhaps even using third parties for confirmation of other areas of further study would be beneficial. It is clear that the use of an outside perspective was a highly valuable tool.

This research concentrated on where the disciplines differentiated themselves from each other. This was inevitable given the nature of the instruments utilized, however, differences are only half of the equation when discussing the practical applications of this data. Similarities comprised about half of the data collected. An
understanding of where these disciplines are similar, rather than their differences, could be the most likely route for successful collaborative improvements. After all, Design and Engineering are both concerned with finding solutions to complex issues and as such are bound to share many of the same values that help in attaining their goals. These shared values are likely central towards effective collaboration.

Finally it should be understood that collaboration is a skill and skills can be taught. The concept of collaboration as a learned skill would be valuable to industries that are looking towards improving collaborative efforts within the ranks of their existing employees. It would also be useful to academic institutions where students are likely to be working with other disciplines in their professional futures. How to teach this skill would be an interesting direction to take further research.
References


McCaulley, Mary H. *Jung's Theory of Psychological Types and the Myers-Briggs Type Indicator*. Gainesville, FL: Center for Applications of Psychological Type, 1981. Print.


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Appendix A: Warm-Up Block Constructions by Designers
Figure 15. Designer warm-up construction

Explanation:

I did a process sort of being that there is a starting point and then that there's a lot of information in all these building blocks and pieces and then there’s a lot of different sorts of paths that you try and build up to, but then maybe they don’t work out, maybe this one doesn’t work out, and finally there is sort of one way that it all fits together that it leads to the final piece. That’s the idea here.
Explanation:

I see that, when we start with a problem, we only have like this view of the problem, so since we start here, we need to define the problem bigger, so that’s what I did. This is what I assume the problem is and then I'll find that that there is actually a lot more things around it. These are like boundaries that would be constraints of the project or constraints of reality or constraints based on my own experience, so things that would scope the project. Then finally I would think that among all of these things, I think this is the thing that interests me, so this is what I frame as the focus of it. Then I move on to this balance to see whether it works or not, and then if it doesn’t, I go back here and I try again, and just keep trying.
Explanation:

It starts here with the problem that you are given, which is a circle with a triangle, but sometimes the idea of problem that you start with isn’t the best solution, and these kind of represent breaking down the problem and what it really means. Reframing it as a collection of a different shape in a different box. As you go you redefine and simplify from a bunch of these opportunities to maybe a solution narrowing it down and changing it evolving as it goes so curved here to a solid form to then a square that’s the same color, and then eventually, that’s my solution.
Appendix B: Warm-Up Block Constructions by Engineers
Explanation:

Usually when you start designing a product you usually have a lot of different crazy ideas which is what all of these are (points) and as you start kind of going through the design process which I symbolized by... (inaudible) ...you kind of weed them out into an idea, that’s what this is (points). That’s kind of the best. Usually, along the way you end up making a bad decision somewhere and you need to restart which is what these are (points to arms). (Continues inaudibly.)
Figure 19. Engineer warm-up construction

Explanation:

I have two explanations because the first thing I built it for wasn’t exactly the question. You were talking about doing a process and for some reason the first step stuck in my mind. I built something that is mostly symmetrical, it’s a little intricate, there’s different layers and different features depending on where you are looking at it.

The first step anytime you are tackling a huge problem is to step really far back and see everything because if you focus in on one part of it you’re never going to get to the right solution. Using this I would look at the whole problem, but then I would take it step by step. So if you look closely you’ll see here (points) and if you step back you’ll see there is more to it than that. That’s where I was going with it.
Figure 20. Engineer warm-up construction

Explanation:

You start down here at the bottom and basically here is the problem (*points to bottom of stairs*) and here is the end goal (*points to top of large block*). As I was building I was looking for all of the staircases to try to build up to the final product. I kept finding ramps and things that would kind of symbolize falling back down and I was trying to build up to it. Eventually I managed to build it out of staircases I found.

*Investigator: So you went through your process while trying to describe your process?*

*Yep.*
Explanations:

I started out by dumping bag of blocks out because I wanted to see what was available. I surveyed the pieces and saw that I could build a house out of them. So I proceeded to build a house. I tried to find all the appropriated blocks to make something that looked like a house, stairs, roof trusses, etc.

He stopped speaking and another Engineer commented about the process part of assignment and yet another Engineer commented on his other building next to the house. “Is that a shed or an outhouse, or a well?”

Um, it’s all three; you might not want to get a well out of it.

Investigator: So as far as process goes?

Once I came up with the idea to make a house then I was just trying to find pieces to match the image that I had in my head.
Figure 22. Engineer warm-up construction

Explanation:

I started with pick whatever your problem is and examine it from as many angles as possible (*points to assembly on the left*) and look at it as many different ways as you can to sort of get all sides of it. And then generate a bunch of ideas everything you can come up with from the mundane to the just completely outrageous and seemingly nonsensical things you could never afford to build, etc. Out of that pile of solutions you narrow it down the one that makes the most sense and try lots of variations and then finally you get the right thing, or at least the thing that’s going to work.
Explanation:

So when you said thought process, my first thing I thought was like how do you develop a product for people? So, I started off with an initial user we are designing the product for. I have a table here for setting down design constraints. Whatever the product needs to be designed to and what constraints are going to be with that. The big picture, what are you trying to meet with this product? Then you split off into different groups, however many you need to do designs for different things. From that you have your different sub teams, so we’re like what EcoCAR is, so you have the team that is responsible for each part of the project and it starts coming together in the different systems, you do a lot of systems testing. That is what this person represents, essentially the engineers or the people testing. Then eventually it comes back together in a prototype and a finished product which goes through more testing and then eventually it gets put out to market. That’s what went through my mind.
Appendix C: Workshop Issues
**Timekeeping Accuracy:** Watches and clocks, whether highly advanced technology or antique mechanisms, can become unsynchronized as individual devices. Keeping these devices synchronized with each other is an ongoing chore.

What approach would you take to this challenge?

**(REQUIRED) Fire Alarm:** Fire alarms in private residences are notoriously neglected by homeowners and tenants. Generally, users are responsible for their placement and maintaining their power supply. According to the National Fire Prevention Association half of the smoke alarms in reported home fires had missing or disconnected batteries.

Nuisance alarms were the leading reason for disconnected smoke alarms.

What approach would you take to this challenge?

*Source: Smoke Alarms in U.S. Home Fires, Marty Ahrens, NFPA Fire Analysis and Research, Quincy, MA, September 2011*

**At-Home Bicycle Maintenance:** While elegant in their simplicity, bicycles do require periodic maintenance to perform as intended, and can require repairs as components wear out and experience damage.

What approach would you take to this challenge?

**Hospital Fabric Cleanliness:** Hospitals must be particularly attentive to the cleanliness of their facilities including reusable gowns, bedding, washcloths, and towels. In-house laundry facilities face the challenge of disinfecting and cleaning fabrics quickly and
efficiently. Disposable materials are not used in some environments to keep costs low and to contribute to a comfortable experience for patients & visitors.

What approach would you take to this challenge?

**Recruiting Designers/Engineers:** You are tasked with developing a plan for selection of potential candidates for your field of study.

What approach would you take to this challenge?

**Hand/Eye Coordination:** Young minds require appropriate stimulation to develop to their full potential. This is true in academics as well as athletics. Effectively cultivating these developmental skill sets are a constant undertaking.

What approach would you take to this challenge?

**Opportunistic Theft:** How often have you witnessed someone leaving his or her personal belongings unattended in a public space? Opportunistic theft cannot be eliminated entirely, but perhaps it can be minimized.

What approach would you take to this challenge?

**Urban Agriculture:** Population growth is taking place primarily in urban settings. More agricultural products are needed to support this population and shipping these products is costly. Gardening in urban environments proves challenging yet has been gaining popularity.

What approach would you take to this challenge?
**Water Purification:** Obtaining clean water is a continuing challenge for a portion of the world’s population. Many products exist to purify water, but none have widespread acceptance or distribution.

What approach would you take to this challenge?

**Automatic Checkout:** The most time consuming part of shopping is often the checkout process. Where human interaction has been reduced significantly by self-checkouts, efficiency has only truly been provided to the store, not the consumer.

What approach would you take to this challenge?

**Drowsy Drivers (Trucks):** Long-distance shipping of goods relies heavily on fleets of truck drivers working around the clock. Although regulations do intend to reduce tiredness by requiring breaks and sleep for drivers, tired drivers will continue to be a problem.

What approach would you take to this challenge?

**National High-Speed Internet:** The United States is falling behind much of the rest of the wired world in Internet connectivity. This is especially evident when comparing speeds. Many countries have Internet speeds over 10 times the national average.

What approach would you take to this challenge?
(REQUIRED) Passenger Air Travel: Travelling by air used to be considered a luxury and a privilege. Now that opportunity is often a miserable experience. The activities of booking, security, delays, and cramped seating are all headaches of modern air travel.

What approach would you take to this challenge?

Password Security 2.0: Computer security has become a top story in the news as major breaches continue to occur in professional and personal settings. Passwords are only useful if they are difficult to obtain. Modern users are becoming aware of the importance of secure and varied passwords and many are forced to comply with password requirements by services and businesses. Complexity, however, leads to users writing their passwords down, defeating the purpose.

What approach would you take to this challenge?
Appendix D: Workshop Posters by Designers (Groups 1 & 2)
Figure 24. Designer Group 1 poster

Figure 25. Designer Group 1 poster
Figure 26. Designer Group 1 poster

Figure 27. Designer Group 1 poster
Figure 28. Designer Group 1 poster

Figure 29. Designer Group 2 poster
Figure 30. Designer Group 2 poster

Figure 31. Designer Group 2 poster
Figure 32. Designer Group 2 poster

Figure 33. Designer Group 2 poster
Appendix E: Workshop Posters by Engineers (Groups 1 & 2)
Figure 34. Engineer Group 1 poster

Figure 35. Engineer Group 1 poster
Figure 36. Engineer Group 1 poster

Figure 37. Engineer Group 1 poster
Figure 38. Engineer Group 1 poster

Figure 39. Engineer Group 2 poster
Figure 40. Engineer Group 2 poster

Figure 41. Engineer Group 2 poster
Figure 42. Engineer Group 2 poster

Figure 43. Engineer Group 2 poster