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Technological Impact on Creativity: Assessing the Impact of Computer Modeling and Rapid Prototyping on Perceived Creativity

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TECHNOLOGICAL IMPACT ON CREATIVITY: ASSESSING THE IMPACT OF
COMPUTER MODELING AND RAPID PROTOTYPING ON PERCEIVED CREATIVITY

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ABSTRACT

This study examined the perceived creativity level of two models, one produced by hand and the other computer generated and produced using rapid prototyping technology, through seven dimensions (Novelty, Aesthetics, Effort, Variation, Deviation, Detail, and Complexity). This study considered potential changes in perceived creativity resulting from the introduction of computer modeling and rapid prototyping. It further studied those dimensions which showed a significant change in creativity, as predictors of how computer modeling software and rapid prototyping increases creative thinking.

This study involved 36 students enrolled in The Florida State University Interior Design Department. Over a three week period in the Fall of 2011, these students completed exercises meant to establish model building techniques and skills, as well as produced the two models listed above (Hand and Computer). Creativity was assessed using an adaptation of the Creative Product Analysis Matrix (CPAM) created by Bessemer and Treffinger (1980). The information obtained from models was compared individually, that is one subject’s hand model to that same subject’s computer model; as well as in whole, that is all subjects’ hand models to all subjects’ computer models.

The findings showed that nearly three times as many subjects produced a model that was perceived as more creative when using computer software and rapid prototyping machinery. It also established that the dimensions termed aesthetics, effort, detail, and complexity all saw a significant increase of creativity in those models produced through rapid prototyping. From this data it can be ascertained that the availability of computer modeling software and rapid prototyping technology provided students with an opportunity for creative growth.
CHAPTER ONE
INTRODUCTION

Introduction

In the design education environment, students are often given extensive training in two-dimensional design techniques, those which give the illusion of three dimensions, both hand generated (sketching, rendering, etc.) and computer generated (AutoCAD, Sketchup, etc.)(Stewart, 2006). However, when it comes to three-dimensional design techniques most programs still teach, refer, and implement strictly hand generated solutions. The problem with relying solely on hand generated solutions is that students of design may be able to visualize the perfect solution, but when it comes to constructing that solution into a model, they tend to lack the knowledge, skills, and time necessary to do so.

When examining grading rubrics for models submitted as a final project in education, it becomes apparent that a majority of the grade is based solely on presentation. Presentation generally includes: craft, how well the model is built; construction, the techniques used to build as well as the sturdiness of the model; material representation, the successful execution of either textural or applied representational materials; and detail, the ability to replicate even the smallest elements that collectively constitute completeness.

This emphasis on presentation ultimately leads students to simplify their design solutions in order to produce a model that will provide them with a good grade. What if these roadblocks were removed? What if the ability to construct a model did not depend on the acquisition of a separate skill set? Could the removal of hand constructed modeling provide students with a platform where creativity is not only enhanced but encouraged? These possibilities foster further inspection into newly available (non-hand) modeling techniques. Recent advances in technology, specifically rapid prototyping technology, which is defined on the next page, provide the ideal opportunity to examine these negative factors. By examining these factors researchers may
consider new teaching strategies to not only remove them, but to provide students with a platform in which creative thinking is fostered.

**Background**

The wide array of synthetic materials and technology now available provides designers with new approaches to the design process (Busch, 1991). Synthetic materials can be defined as a group of materials including metal and plastic polymers used in model making. “The dependence on computer technology is a feature of virtually all industries today; however, CAD (Computer Aided Design) is only one aspect of computerization that has had an impact on the way design is conducted” (Slotkis, 2006, p.166). The Council for Interior Design Accreditation (CIDA) is the governing body which establishes and validates teaching practices in design education environments. For an interior design program to be certified by CIDA it must adhere to a strict set of standards. As of 2011, these standards consisted of four sections and sixteen components (CIDA, 2011). The entire set of standards is provided in Appendix U. This research will focus on standard nine, Space and Form, which states that students must successfully apply the elements and principles of design through two- and three-dimensional solutions. Although CIDA requires two- and three-dimensional solutions, they do not specify that these solutions be constructed solely by hand; they only require that students show a variety of display techniques.

For centuries, three-dimensional models have been proven to be an efficient way of showing layouts and presenting parts as a whole (Slotkis, 2006). Although these models are an effective way to express ideas, for many students the process and creation of a model is very stressful (Taylor, 1971). McMillian referenced model building as an experience in which the likelihood of constructing future models will rely on constructive experiences and, even if the experience is positive, the time associated with model construction usually makes students reluctant to revise, review, and improve their models once they are created (Krathwohl, Benjamin, & Masia, 2001; Sprenger, 1999). Thus, if frustration is experienced, the process of model building will likely be avoided in the future (McMillian, 2001). One way of reducing time, as well as many other negative
aspects associated with three-dimensional design solutions, is through the implementation of rapid prototyping technology.

Rapid prototyping (RP) can be described as a vast array of manufacturing procedures, all of which stem from the creation of a three-dimensional computer generated image (Taylor, 1971). Not only does RP drastically cut down modeling time, but, when properly used, it can accelerate the entire design process (Clay & Smith, 2000). A model which once took a number of days to construct can now be modeled, through the use of such machinery, in a number of hours.

While technology provides many new opportunities to address design issues, some teacher’s attitudes and perceptions of technology prevent them from fully integrating it into their course (Teo, 2008). Boethel & Dimock (1999) proved that when teachers blend technology into constructivist learning situations—environments in which teachers focus on student engagement—the student achievement is positively impacted (Hernandez-Ramos, 2005). Therefore, the goal of this research is twofold. First, this research looks to establish how computer modeling and RP impact creativity through seven dimensions. Second, it examines the impact recorded and examines what aloud for such an impact so that computer modeling and RP technology may be integrated into course curriculum in a way that promotes and enhances creative thinking.

**Purpose**

The purpose of this research was to provide qualitative and quantitative data on the use of computer modeling software and rapid prototyping technology in design education. Prior to 2011, studies conducted on RP technology have focused strictly on aspects of the physical model such as time and craft. Although these studies provide valuable data on the ways in which RP positively influences design, they do not assess the possible impact of RP on creative thinking. Furthermore, there has been no research conducted which compares RP to traditional hand modeling on multiple dimensions of creativity. This research aims at providing statistical data on the dimensions of creativity which are positively impacted through the use of computer modeling software and RP technology.
Guiding Research Questions

The primary question to be answered through this research was: How does the availability of computer modeling, used in conjunction with rapid prototyping technology, impact creativity?

There were many secondary questions to be considered during this study that provided valuable insight into the primary question. They included the following:

1. When judging two models, one constructed by hand and the other computer generated and produced using rapid prototyping machinery, do trends or patterns emerge on an individual or group level?
   a. Is there a defined pattern when comparing changes in individuals tested, that is one subject’s hand model to that own subject’s computer model?
   b. Is there a defined pattern when comparing changes in the subjects as a whole, that is all subjects’ hand models to all subjects’ computer models?
   c. Does a pattern or trend appear when judging students who began at the same levels of creativity?
   d. Does a pattern or trend appear when judging students who exhibit similar traits and/or backgrounds?

2. When judging models, on eight dimensions of creativity, are there apparent trends revealed in the strongest components of hand modeling and the strongest components of computer modeling? These components include:
   1. **Novelty:** The degree to which the design itself is original or striking especially in concept or style.
   2. **Aesthetic Appeal:** The degree to which the design is pleasing in appearance as a whole.
   3. **Effort:** The degree to which the design shows effort, the placement and design seems to have been done to achieve a particular end.
   4. **Variation of Shapes:** The degree to which the design shows a wide usage of various shapes available, how many different shapes were incorporated in the design.
5. **Deviation from Original Plan**: The degree to which the final product deviates from the original plan layout.

6. **Detail**: The small elements that collectively constitute completeness.

7. **Complexity**: The level of intricacy exhibited by the design.

8. **Overall Creativity**: Judge the model on its overall creative appearance using your own personal definition of creativity.

3. Why do certain dimensions of creativity show a significant impact while others do not?
   a. Can an explanation, as to why certain dimensions were significantly impacted by computer modeling and RP technology, be ascertained from data collected?
   b. Can an explanation, as to why certain dimensions were not significantly impacted by computer modeling and RP technology, be ascertained from data collected?

**Objectives**

The objectives of this study are:

1. To understand the opportunities provided to students through the use of computer modeling and rapid prototyping technology.

2. To note how the use of computer modeling, in conjunction with rapid prototyping, affects students’ perceived creativity level.

3. To ascertain which dimensions of creativity judged are significantly impacted by the availability of rapid prototyping technology.

4. To examine the ways in which those dimensions and levels of creativity were impacted by the technology.

5. To establish how rapid prototyping technology can be integrated into learning environments successfully.
Methodology

In order to address the identified research questions, data was gathered through two different methods. First, the researcher distributed a questionnaire. The questionnaire gathered information regarding the subject’s biographical history and current creativity level. Creativity levels were assessed using three different tests, a self-actualization test, a creativity assessment, and an adjective checklist. The data was then compared to the models overall creativity scores, attained from the combination of dimensions 1-7, in order to determine whether correlations could be established between those students who excel in either hand or computer modeling.

Secondly, the researcher had the subjects produce two models, one built by hand and the other computer generated and produced using RP technology. These models were then judged by three industry professionals through an adaptation of the Creative Product Analysis Matrix (CPAM) by Bessemer & Treffinger (1980). The first statistical analysis performed on this data compared each judge’s score to the other judges’ scores in order to establish reliability in the dimensions of creativity judged. Reliability was established through the use of Cronbach’s Alpha. Those dimensions established as reliable were then reanalyzed using the Wilcoxin Signed Rank’s Test (two-tailed), which establishes the exact degree to which each dimensions exhibited change. This degree was used to determine those dimensions which exhibited a significant change as well as those which did not. Finally, the researcher examined why specific dimensions showed a significant change and others did not through an examination of terminology and data associated with that dimension.

Limitations

This study had certain limitations that should be acknowledged. These limitations are introduced here and expanded upon in chapters 3 & 4. Limitations associated with this study include:

1. The truthful completion of the questionnaire by the subjects.
2. The high number of females tested to the limited number of males.
3. Personal and unforeseen biographical traits which may not match those of other students.
4. Personal teaching style of researcher conducting research.
5. Predetermined content of class.
6. Inconsistencies between individual judge’s score of creative dimensions.

It is easy to see the value RP technology provides to designers from all disciplines; however, it is important to note--as Kirton & Lavoie did in their 2005 article titled *Utilizing Rapid Prototyping for Architectural Modeling*--that each of the traditional model building techniques has its own value, and whether hand or computer generated, the main purpose of design is to communicate something effectively (Slotkis, 2006). Moreover, the students of design must still understand the essential elements and principles of manual drawing, because the fundamentals behind composing something on paper or the computer are the same (Slotkis, 2006).

**Conclusion**

This study examined the impact of RP on creative thinking through the judging and comparison of 72 models, 36 created by hand and 36 created using RP. The study explored relationships among subjects’ biographical history, past creative activities, current creativity level, and the two models they created. The availability of RP technology not only allowed students to produce models judged as more creative, but enhanced their perception of model building through the removal of negative aspects associated with model construction (i.e. time, money, etc.). The availability of RP technology provided countless opportunities to the students and faculty of this design education program. Moreover, the inclusion of RP allowed this design education program to fully prepare their graduates in various technological design approaches used throughout the industry today (Flowers & Moniz, 2002).
DEFINITION OF TERMS

**Bauhaus:** The first established school of design, founded in 1919 by Walter Gropius, the school is regarded as the single most influential school of art, architecture, and design.

**Basic Design:** describes the teaching and learning of the design fundamentals commonly referred to as the Principles of Two- and Three-dimensional Design.

**Computer Aided Design (CAD):** involves the use of computer software to assist in the creation, modification, analysis, and optimization of a design. Computer-aided design describes the process of creating drawings through computer software.

**Computer Aided Manufacturing (CAM):** the use of a computer as a tool for the manufacture or assembly of products.

**Computer Graphics:** the graphical representation possibilities of the computer, both on a two-dimensional flat surface and in three-dimensional space.

**Consensual Assessment Technique (CAT):** compares products against one another, through the independent review of each product, and relies highly on domain experts being those who judge.

**Constructivist Teachers:** focuses on student engagement in the learning process; and pattern their instruction after the old Chinese saying: "Tell me and I will forget; show me, and I may remember; involve me and I will understand."

**Constructivist Learning Environments:** an environment where the teacher becomes an advocate rather than a dictator in the learning process

**Creativity:** the production of something which is both novel (i.e. original or unexpected) and appropriate (i.e. useful, or adaptive)

**Creative Product Analysis Matrix (CPAM):** a three-dimensional model aimed at judging the creative level of products. The CPAM evaluates products as being creative through three dimensions, and nine facets. The CPAM is provided in Appendix E

**Elements of Design:** the individual components of a design, the elements act as building blocks of an effective design composition and include Line, Color, Shape, Form, Texture, and Pattern.
**Line:** An extension of a point into space, a line is identified as an edge, although it has no width itself, only length

**Color:** The quality of an object with respect to light reflected by that object, and usually measured by hue, saturation, and brightness

**Shape:** An enclosed space created through the use of other design elements

**Form:** A defining shape that is given the sense of volume

**Texture:** The tactile nature of an object usually exhibited through an actual texture or applied texture.

**Pattern:** Can be described as any decorative arrangement, however, it usually involves the repetition of one or more elements

**Four Creative P’s:** focus on the creative person, creative process, creative product, and creative press (i.e. environment)

**Person:** someone who does creative things with some degree of regularity

**Process:** any thinking process which solves a problem in an original and useful way

**Environment:** the location and stimuli present while creating

**Product:** The end production of something which can be presented as a tangible or intangible indicator of a creative performance

**Creative Product Analysis Matrix (CPAM):** an industry test used to judge the creativity of products

**Model:** any three-dimensional object constructed to serve one of two purposes: either investigative or demonstrative

**Demonstrative Models:** also known as presentation modes, often exhibit a final idea or solution with a high attention to detail. Presentation models convey information such as appearance, use, and structure; in a ways which a graphic representation cannot.

**Investigative Models:** are used for feedback and serve as an essential part of the creative process. Investigative models tend to be constructed quickly with little emphasis on details

**Study Models:** serve as an exploration of form and the relationship of space

**Finished Study Models:** usually show some indication, either in part or whole, as to the material choices that will be used in the final design

**Finished Models:** shows a true scale representation of materials, colors, and details
**Working Models:** show all parts of the structure which have a mechanical component

**Naturalistic Observation:** the observing of individuals in their natural setting

Principles of Design: the rules or guidelines that govern the use of design elements, and include Scale, Proportion, Balance, Symmetry, Rhythm, and Harmony

**Scale:** The relative dimensions of parts to a whole

**Proportion:** The relationship of one part to another or to the whole, in terms of size, amount, or degree

**Balance:** The visual weight of components that creates a sense of equilibrium

**Symmetry:** The perceived sense of proportionality and balance that, for many people, represents a pleasing arrangement

**Rhythm:** A composition technique that offers a sense of coherence through the addition or division of design elements

**Harmony:** The accord between different elements of a design to produce a unity of as a whole

**Qualitative Data:** Describe items in terms of some quality or categorization that in some cases may be informal

**Quantitative Data:** Describes items in terms of quantity and in which a range of numerical values are used without implying that a particular numerical value refers to a particular distinct category

**Rapid Prototyping (RP):** a vast array of manufacturing procedures, all of which stem from the creation of a three-dimensional computer generated image

**Additive RP:** also known as three-dimensional printers, uses one of two layering methods. The first method applies a thin layer of powder and then a liquid binder over and over; the second method uses a molten material that is printed one bead at a time.

**Subtractive RP:** also known as CNC (Computer Numerical Control) machinery it produces models by removing material from a substrate such as wood, foam, or plastic

**Two-Dimensional Design:** the creation of a two-dimensional that replicates a three-dimensional one through a conscious effort of the organization of various elements

**Three-Dimensional Design:** the creation of a three-dimensional object

**Wilcoxon Signed Ranks Test:** presents changes in data through a Z score and p-value
CHAPTER TWO

REVIEW OF LITERATURE

“The dependence on computer technology is a feature of virtually all industries today; however, CAD (Computer Aided Design) is only one aspect of computerization that has had an impact on the way business is conducted” (Slotkis, 2006, p.166). With the wide array of synthetic materials and technology, available today, designers are provided with new approaches to the design process (Busch, 1991). The following review will provide an overview of material pertinent to this research including: design education, elements and principles of design, modeling history, types of models, and rapid prototyping. Lastly, the review will examine creativity, specifically common traits of creative people, the dimensions of creative products, and proven strategies and methods for judging creative products.

Design Education

The history of formal design education can be dated to the establishment of the Bauhaus, which is regarded as the single most influential school of art, architecture, and design (Merriman & Winter (Eds.), 2006). Walter Groupius established the school in 1919, with hopes of furthering the role of the artist in industrial mass production (Keylor (Eds.), 2007). Before the Bauhaus, design was considered a craft; a tradition which was passed on from teacher to apprentice over time (Boucharenc, 2006). By gathering the best designers from each respective discipline at one location, the Bauhaus revolutionized the teaching of such crafts (Merriman & Winter (Eds.), 2006). The school was known to work hand in hand with industrial firms, and its furniture, textile, and lighting fixture designs were all mass produced successfully (Keylor (Eds.), 2007).

In the 2006 article “Research on Basic Design Education: An International Survey” by C.G. Boucharenc, he stated the Bauhaus revolutionized the institutionalization of “basic design”; a term which describes the teaching and learning of design fundamentals that are commonly referred to as the Principles of Two- and Three-dimensional Design (Boucharenc, 2006, p.1). He follows this definition by saying: “the
The pedagogy of Basic Design promotes a holistic, creative, and experimental methodology; in order to develop the learning style and cognitive abilities of students with respect to the fundamental principles of design” (p.1). By providing students with the “basic” fundamentals of design (i.e. an understanding of the elements and principles of design) educators establish building blocks from which the students can grow (Slotkis, 2006).

The Elements and Principles of Design

The field of design is often judged as subjective. However, since the field institutes a set of guidelines which govern its success this perception is not valid (Steffany, 2010). These guidelines, the Elements and Principles of Design, make up the foundation of the discipline. The elements of design can be described as the building blocks which make up designs, while the principles act as a guideline for the proper use of those elements (Nielson & Taylor, 2007). This partnership allows the elements of design to be judged as right or wrong, through an evaluation of the principles of design (Nielson & Taylor, 2007). The elements of design consist of line, color, shape, form, texture, and pattern; a definition of each element if provided on the next page in Table 2.1.

Table 2.1 Elements of Design

<table>
<thead>
<tr>
<th>Element</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>An extension of a point into space, a line is identified as an edge, although it has no width itself, only length</td>
</tr>
<tr>
<td>Color</td>
<td>The quality of an object with respect to light reflected by that object, and usually measured by hue, saturation, and brightness</td>
</tr>
<tr>
<td>Shape</td>
<td>An enclosed space created through the use of other design elements</td>
</tr>
<tr>
<td>Form</td>
<td>A defining shape that is given the sense of volume</td>
</tr>
<tr>
<td>Texture</td>
<td>The tactile nature of an object usually exhibited through an actual texture or applied texture.</td>
</tr>
<tr>
<td>Pattern</td>
<td>Any decorative arrangement, however, it usually involves the repetition of one or more elements</td>
</tr>
</tbody>
</table>

*All definitions obtained from Interior Design: a critical exam (2011) by Clive Edwards*
Nissen, Faulkner, & Faulkner (1994) stated, “these basic elements or tools, along with the principles which guide their application, comprise the visual vocabulary of design” (p. 67). Furthermore, once the elements are understood, the designer may combine and manipulate multiple elements, according to rules set forth by the principles, to create an end product (Steffany, 2010).

The principles of design, are "thought of as more complex, than the elements, and whereas elements are singular components of design, principles are the rules or guidelines that govern the use of those elements" (Slotkis, 2006, p. 32). Establishing a working knowledge of these principles allows designers to communicate both two- and three-dimensional design solutions successfully (Nissen et al., 1994). The principles of design consist of scale, proportion, balance, symmetry, rhythm, and harmony (variety and unity), and are defined in Table 2.2.

Table 2.2 Principles of Design

<table>
<thead>
<tr>
<th>Scale</th>
<th>The relative dimensions of parts to a whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion</td>
<td>The relationship of one part to another or to the whole, in terms of size, amount, or degree</td>
</tr>
<tr>
<td>Balance</td>
<td>The visual weight of components that creates a sense of equilibrium</td>
</tr>
<tr>
<td>Symmetry</td>
<td>The perceived sense of proportionality and balance that, for many people, represents a pleasing arrangement</td>
</tr>
<tr>
<td>Rhythm</td>
<td>A composition technique that offers a sense of coherence through the addition or division of design elements</td>
</tr>
<tr>
<td>Harmony</td>
<td>The accord between different elements of a design to produce a unity of as a whole</td>
</tr>
</tbody>
</table>

*All definitions obtained from Interior Design: a critical exam (2011) by Clive Edwards*
Two- and Three- Dimensional Designs

Two-dimensional design can be defined as “the creation of a two-dimensional world that replicates a three-dimensional one. This is accomplished through a conscious effort of the organization of various elements, while establishing visual harmony or generating visual excitement” (Wong, p. 6, 1977). The design elements used in the composition of a two-dimensional design are classified as line, shape, texture, color, and value (Stewart, 2006). Although three-dimensional designs have the same objective as a two-dimensional design, i.e. establishing visual harmony and generating visual excitement; it does so by adding the design elements of form, mass (Stewart, 2006).

Unlike the observing and processing of information that goes with examining a two-dimensional design, when a client is presented with a three-dimensional design “model,” there is a sense of instant communication and interaction with it (Alley, 1961). Taylor (1971) stated although the model is no more than a three-dimensional representation of a design, by providing the ability to view from all sides and change the perspective as desired, the client feels more connected with it (Taylor, 1971).

The History of Models

Models have been constructed and used as representational objects and figures for centuries (Alley, 1961). Whether the object is a children’s toy or a learning tool, the importance of these models is unassailable. Kings and generals are said to have learned their first military lessons with the aid of toy soldiers. The French inventor, Denis Papin (1647 – 1714), who pioneered the steam engine, conducted all of his experiments by means of models (Payne, 1996). From this it is easy to see why model-making has long been an element of the design process. Models serve as a bridge between ideas and the physical world, especially when ideas are being presented to individuals not trained in the profession of design (Greenhalgh, 2009). They were traditionally built by hand and constructed from various materials such as wood, clay, paper, and foam (Slotkis, 2006). Models range from simple blocked form layouts, used to understand spatial relations and form, all the way to detailed and working prototyped models, used in product development to examine fine parts and details (Taylor, 1971).
As a device that critically influences every aspect of design, the model possesses a value which far exceeds its miniature scale (Busch, 1991). The shipping and aircraft industries produced the first scale models in order to test buoyancy and aerodynamics of proposed designs (Taylor, 1971). While these two industries used scale models, due to size restrictions, the automobile industry has used full-size scale models for decades. By using full scale models, automobile designers are able to manipulate even the finest of details more exactly (Taylor, 1971). One of the most important aspects of a model is scale; since the model is a replica of something else, it needs to have a specific scale to be built (Payne, 1996, p.26). Although models were traditionally used by industrial designers, product designers, and architects to expand concepts and develop prototypes, with the growing responsibilities of interior designers today, models are becoming a valuable tool (Slotkis, 2006).

**Models in Design**

When examining models created in the industry of design, there are many interchangeable terms. Due to this, the following section will examine terminology associated with models, as well as indicate which terms will be used in correlation with future text.

The word *model*, as a broad term, can be described as any three-dimensional object constructed to serve one of two purposes: either investigative or demonstrative (Alley, 1961).

Used primarily for feedback, investigative models, serve as an essential part of the creative process (Starkey, 2006). Investigative models tend to be constructed quickly with little emphasis on details (Greenhalgh, 2009). Demonstrative models, also known as *presentation models*--the term which is used in association with this research--most often exhibit a final idea or solution with a high attention to detail (Slotkis, 2006). Presentation models are used to convey information such as appearance, use, and structure; in a ways which a graphic representation cannot (Frampton & Kobolski, 1981). Within the broad term of investigative and demonstrative models, there are four specific modeling styles: study models, finished study models, finished models, and
working models. A brief description of each specific style and type of model is provided below.

Study models serve as more than a mere three-dimensional representation of a project. They allow for an overall examination of a project through the understanding of relationships within that space (Busch, 1991). A study model generally serves as an exploration of form and the relationship of space (Slotkis, 2006). The overall time and cost associated with the construction of a study model is minimal, since they are usually composed of block forms, and show little representation of colors or textures.

A finished study model takes the previously explained study model and refines it one step further. Finished study models usually show some indication, either in part or whole, as to the materials being used in the final design (Slotkis, 2006). Although these models are viewed as more detailed than study models, they still seem to place little emphasis on intricacy, and instead focus on conveying form and size appropriately (Taylor, 1971).

A finished model takes the previous finished study model and brings it to the next level. Finished models tend to show a true scale representation of materials, colors, and details (Taylor, 1971). Finished models are the final step before presenting the model to a client or class (Busch, 1991).

A working model is meant to show all parts of the structure which have a mechanical component (Busch, 1991). This type of model is said to be a step above finished models since all parts must be represented correctly to gauge whether the action will work or not (Taylor, 1971).

Although models are regarded as a proficient way of portraying ideas, for many students the process and creation of a model is very stressful (Taylor, 1971). McMillian referenced model building as an experience in which the likelihood of constructing future models will rely on constructive experiences, and even if the experience is positive, the time associated with model construction usually makes students reluctant to revise, review, and improve their models once they are created (Krathwohl, Benjamin, & Masia, 2001; Sprenger, 1999). Thus, if frustration is experienced, the process of model building will likely be avoided in the future (McMillian, 2001). It is
important to note, that even though models prove to be an excellent learning and presentation tools, the builder should be clear on the purpose of the model before proceeding with construction. As Susan Slotkis mentioned in her book *Foundations of Interior Design* (2006): “The amount of time, money, and effort expended for a model which goes beyond its scope is wasteful for students, teachers, and industry professionals alike” (p. 165).

Technology has had a significant impacting on design for more than twenty years. In his 1991 book, *The Art of the Architectural Model*, Akiko Busch stated: “As models play and increasingly important role in the design and planning of our environments, the technology of their materials and construction continues to develop” (p. 58). The wide array of synthetic materials and technology available to designers today yield new standards in precision and speed (Busch, 1991). A model which once took a number of days to construct can now be modeled, through the use of rapid prototyping machinery, in a number of hours. Not only does rapid prototyping drastically cut down modeling time, but, when properly used, it can accelerate the entire design process (Clay & Smith, 2000).

**Rapid Prototyping**

Rapid prototyping (RP) can be described as a vast array of manufacturing procedures, all of which stem from the creation of a three-dimensional computer generated image (Taylor, 1971). RP is largely based on Progressive Refinement—“putting a first version of a design into the world’ and then revising that design until all the bugs are worked out” (Collins, Joseph, & Bielaczyc, 2004, p. 18). Revising implies a detailed and systematic process; it is this structured nature that makes rapid prototyping a successful design approach (Jones & Richey, 2000).

Prototyping and model building are integral parts of the design process. They are used to depict and assist in the removal of design errors (Taylor, 1971). However, for prototyping to be successful, there must be an understanding of new and emerging technologies, access to these technologies, available time, and sufficient funds (Greengalgh, 2009). Research has shown that the introduction of rapid prototyping
machinery into educational environments need not be expensive, as long as the environment already employs computer-aided design (Greengalgh, 2009).

There are hundreds of companies manufacturing rapid prototyping machinery. However, despite the manufacturer, the process of RP is conducted only one of two ways: either though the addition of materials or the subtraction of materials (DeBeer, Barnard, & Booysen, 2004).

Additive RP machinery, also known as three-dimensional printers, uses a layering method that builds the model from the ground up in one of two ways (Greengalgh, 2009). The first method applies a thin layer of powder and then a liquid binder over and over again, while the second method uses a molten material, usually plastic that hardens, which is printed one bead at a time (Dimitrov, Schreve, & DeBeer, 2006). These additive rapid prototyping machines allow for the most complex of designs to be modeled, but with their precision comes higher costs associated with the machinery itself as well as the materials for construction (Wohlers, 2011).

The first type of additive rapid prototyping machinery, the stereo lithography, works by using a laser to solidify consecutive layers of a photo curable, liquid polymer; by doing so the machine can produce miniature parts with intricate details (Greengalgh, 2009). The second machine, a fused deposition modeler, distributes a layer of powder and then a layer of binder, over and over again until the model is completed (Greengalgh, 2009). Fused deposition modelers are known to be the most reliable RP machines on the market in 2012, and since they do not use a heating element, they can be left unmonitored while modeling over nights and weekends (Wohlers, 2011). The last additive machine, a solid object printer, sprays small drops of wax (essentially like an inkjet printer) to build up a model (Ryder, Ion, Green, Harrison, & Wood, 2002).

Subtractive RP machinery, also known as CNC (Computer Numerical Control) machinery, produces models by removing material from a block of substrate such as wood, foam, or plastic (Greengalgh, 2009). However, due to size and milling restrictions, some of these machines require that the model be made in parts and then assembled; resulting in more time when compared to additive methods (Ryder, et al, 2002). Although subtractive machines may require the user to do some constructing of
the model, after the machine is done milling; they still have the ability to replicate fine
details in the same way as additive machines do.

Rapid Prototyping (RP) can lend design students a unique opportunity to bring their
ideas to reality (Hogan, 2006). It has been proven through research that design
students not only learn by constructing and manipulating, but they feel empowered and
usually find enjoyment through these activities (Flowers & Moniz, 2002). Although the
hardware is typically expensive, there are low cost options available which can provide
all education facilities the experience of rapid prototyping (Wohlers, 2011).

**Technological Impact on Design**

While technology provides many new opportunities to address design issues, some
teachers’ attitudes and perceptions of technology prevent them from fully integrating it
into their course (Teo, 2008). This leads to technology which is used as a substitute,
rather than a new approach, in the instruction and teaching of elements and principles
of design (Judson, 2006). According to researchers, Muniandy, Mohammad & Fong
(2007) technology use should be embedded within a learning theory to support the
methodology. Presentations used to consist of boards or folders containing hand drawn
sketches and floor plans which took years of practice and hours of dedication to perfect
(Eissen, 1990). However, in the technological society we live in today, presentations are
usually given through computer projections (such as PowerPoint, Prezi, Sliderocket,
etc.) (Judson, 2006). Although the time associated with inputting the data into a
program (such as AutoCAD, Sketchup, 3Dmax, etc.) takes just as long if not longer than
hand rendering, the ability to change views, materials, and elements within the design
right in front of the client is immeasurable (Eissen, 1990). Students of design are given
extensive training in two-dimensional design techniques, those which give the illusion of
three dimensions, both hand generated (sketching, rendering, etc.) and computer
generated (AutoCAD, Sketchup, etc.) (Stewart, 2006). However, when it comes to
three-dimensional designs most programs still teach, refer, and implement strictly hand
produced models.
In a literature review produced by Boethel & Dimock (1999), they prove that when teachers blend technology into constructivist learning situations, student achievement is positively impacted (Hernandez-Ramos, 2005). Furthermore, when used in correlation with a constructivist theory, technology seems to change many aspects of design education (Rakes, Fields & Cox, 2006). Constructivist teachers, who focus on student engagement in the learning process, pattern their instruction after the old Chinese saying: "Tell me and I will forget; show me, and I may remember; involve me and I will understand" (Hernandez-Ramos, 2005, p. 47). In constructivist type learning environments, the teacher becomes an advocate rather than a dictator in the learning process (Elliott, 2010). David Atwood, an instructor at Exeter High School, one of the country’s leading STEM (Science, Technology, Engineering, and Math) education programs, stated: “the student population today does not learn from reading anymore, they learn from watching and doing. In learning the method and process of rapid prototyping, students begin to think more in three-dimensions” (Lacey, 2010, p.18).

There are many studies and reports conducted on the implementation of rapid prototyping in design education. All data collected on rapid prototyping until this point has focused strictly on the machinery itself and relates to justifiable cost, time, and quality. What has not been discussed is how rapid prototyping machinery, in an educational environment, can spur more creativity in those who use it. “It is important to help student’s metacognitively understand the topic of creativity. In turn, this increased understanding of creativity would increase creativity consciousness, demystify creativity, and increase creative ideas and products” (Davis, 1991, p.30). Some publications like, 3D Printing Brings Designs to Life by Gary Lacey, discus how rapid prototyping machinery has affected students, but provides no quantitative data to support their allegations.

**Assessing Creative Performances**

The Evaluation of creativity serves two main purposes—“First, and most important, is to further learning through feedback on the current level of understanding or development in a particular area; Secondly, it establishes the steps necessary to attain the next level” (Boyale & Radocy, 1987, p.9). Creativity has a variety of definitions;
however, they all revolve around the production of something which is “both novel (i.e. original or unexpected) and appropriate (i.e. useful, or adaptive)” (Sternburg & Lubart, 1999, p.3). In 2004, Plucker, Beghetto, & Dow reviewed 90 articles, which were published in peer-reviewed journals and had the word “creativity” in the title. Of these articles, only 38 percent were found to clearly define what creativity was, in relation to their research (Plucker, et. al, 2004). Due to this fact, the term creativity, as relates to this research, will be defined as Plucker et. al proposed in 2004:

Creativity is the interaction among aptitude, process, and environment by which the individual or group produces a perceptible product which is both novel and useful as defined within a social context (p.90)

Creativity has been examined starting with Guilford 1950 and 1977, Mckinnon 1978, and Torrance 1972a, 1972b, 1974, up through current research. There are several tests and assessments aimed at gauging an individual’s creativity level, such as: personality-based creativity tests, biographical inventories, and adjective checklists (Rimm, 1977). However, one major challenge when conducting research that revolves around the assessment of creativity is the general question: How is creativity measured or what is creativity? (Amabile, 1996) Even though a number of studies have been conducted and formal methods of measuring creativity have been created, none can claim to fully capture the many aspects relating to creativity. Thus, according to Puccio & Murdock (1999) “the challenge is not finding an instrument or method for measuring creativity, but selecting the measure that best suits the desired goals” (p.7).

The 4 Creative “P”s

When creativity is being assessed for research, it usually focuses on one or more facets of the four creative P’s (Rhodes, 1961). The four Creative P’s, as they are referred to in literature, focus on the creative person, creative process, creative product, and creative press (i.e. environment).

A creative person can be classified as someone who does creative things (Kaufman, Plucker, & Baer, 2008). Although there is an environment where a person uses a process to create a product; when examining the creative person, research
tends to look into how often that individual produces creative products and the level of creativity associated with each product (Perkins, 1991). An individual may have a creative idea; however, if that is the individual’s only idea, then that individual cannot be classified as a creative person (Kaufman, et. al, 2008). It is like someone saying “I am a skydiver”, but has only gone skydiving once. This person is undoubtedly not a skydiver; however, they have gone skydiving. This analogy translates directly to creativity: someone may have a creative idea, but to be deemed a creative person those ideas must come to fruition with some regularity. As Perkins (1991) said: “a creative person, by definition,…. more or less regularly produces outcomes in one or more fields that appear both original and appropriate” (p.37). Assessments aimed at gauging an individual’s creativity level often look into characteristics possessed by that individual, such as: personality, motivation, intelligence, thinking styles, or knowledge (Sternburg & Lubart, 1995). The assessment will relate to a person’s thinking capacity or knowledge possessed (Perkins, 1991).

The second creative P, the creative process, can be more broadly defined as Fabun (1968) said “the creative process includes any thinking process which solves a problem in an original and useful way” (p.35); this allows the creative process to be studied with greater ease. Torrance (1988, 1995) expanded on this definition and established four steps to the creative process, which are as follows:

1. Sensing difficulties, problems, gaps in information, or missing elements
2. Making guesses or formulating hypothesis about these deficiencies
3. Testing these guesses and possibly revising and retesting them
4. Communicating the results. (p.72)

Donald Treffinger, in his book *Creativity and Giftedness*, talks about the third Creative P, press (i.e. environment), and suggested that there is a correlation between personality prerequisites and the manifestation of creativity. Someone may have all the cognitive prerequisites, but may never exploit creative performances due to an unwillingness to take risks or to an absence of creative environment (Treffinger, 2004). He goes on to say, “[e]ducators need to create an environment in which a child can take risks, challenge instructors, and have time to reflect without punishment. Personality
traits are not immutable: rather, educators can shape the environment to favor various traits” (Treffinger, 2004, p. 151). From this statement, it can be seen that press (the environment) is the only element of the four P’s which can and does affect all the other elements (Fabun, 1968). Treffinger (2004) states that if a person grew up in an environment which did not promote creativity, then that person will more than likely not be creative. Furthermore, if a creative person is trying to solve a problem in an environment which hinders thinking ability, or is unfamiliar, then the solution will more than likely lack creativity (Treffinger, 2004) In other words, if the environment does not promote creativity or creative thinking, then the last of the four P’s, creative products, will more often than not be lacking in creativity as well.

Creative products can be presented as tangible or intangible objects (Amabile, 1983). However, for the purpose of this research, the term “product” will be seen as something which is tangible (i.e. a model). Creative products are used to provide tangible indicators of creativity; therefore, numerous methods have been developed to identify creative products and examine their level of creativity (Puccio & Murdock, 1999).

**Judging Creative Products**

Since creative products are often seen as tangible indicators of creativity, numerous methods have been developed to identify and examine their level of creativity (Puccio & Murdock, 1999). One of these, Amabile’s Consensual Assessment Technique (CAT), has been proven to effectively judge creative products. The Consensual Assessment Technique is grounded in Amabile’s consensual definition of creativity, which states:

A product or response is creative to the extent that appropriate observers independently agree it is creative. Appropriate observers are those familiar with the domain in which the product was created. Thus, creativity can be regarded as the quality of products or responses judged to be creative by appropriate observers, and it can also be regarded as the process by which something so judged is produced (Amabile, 1996, p.33).
She goes on to say that the consensual definition, like most current definitions of creativity, is based on the creative product rather than creative process or person. Developed to solve the challenge of distinguishing the level of creativity a product exhibits; the CAT compares products against one another, through the independent review of each product, and relies highly on domain experts being those who judge. Amabile (1996) states that for a product to be judged using the Consensual Assessment Technique, it must adhere to three requirements.

First, of course, the task must be one that leads to some product or clearly observable response that can be made available to appropriate judges for assessment. Second, the task should be open-ended enough to permit considerable flexibility and novelty in responses. Third, since it is desirable for social psychology research that there not be large individual differences in baseline performance on the task, it should be one that does not depend heavily on certain special skills (p.41).

One obvious difference between Amabile’s Consensual Assessment and standard creativity assessments—where typically a participant would self rate through a paper-and-pencil measure—lies in the use of external judges to rate the creativity of products. To ensure that the researcher is not influencing the judges as to his or her personal view on creativity, Amabile states: “all judges should make assessments independently and should be left alone with little explanation of judging dimensions. However, one instruction that should be given to the judges is that they are not to judge the product against the best work they have ever seen, but to judge as it relates to criteria” (p. 208).

Given the consensual definition of creativity, it is clear that the most important criterion for the results of this assessment procedure rely on the judges ratings be reliable with each other. “By definition, if interjudge reliability in this method is equivalent to construct validity; if appropriate judges independently agree that a given product is highly creative, then it can and must be accepted as such” (p. 208-209).

Although Amabile’s CAT focuses on the creativity of a product, when judged against others in a group, it is still important to deem what components of creativity will be assessed. Due to this, this research study will use the Creative Product Analysis Matrix (CPAM) created by Bessemer and Treffinger (1980) to judge models on independent
variable that collectively constitute creativity. The CPAM focuses on three dimensions of creative products: novelty (original and surprising), resolution (valuable, useful, and solves a need or problem), and elaboration and synthesis (well crafted, attractive, and elegant).

**The Creative Product Analysis Matrix**

The CPAM (Creative Product Analysis Matrix) is an assessment aimed at judging a products perceived creativity level (Bessemer & Treffinger, 1980). The CPAM evaluates products as being creative through three dimensions, and within these three dimensions are nine facets. The first dimension of the CPAM, *Novelty*, includes the facets of originality and surprise: it considers newness in materials, processes, concepts, and methods of making the product (Bessemer & O’Quin, 1999). The second dimension, *Resolution*, assesses how well a product works or functions. Resolution aims at assessing if the product is valuable, logical, useful, and understandable (Bessemer, 2010). The third and final dimension is defined as *Elaboration* and *Synthesis* which looks into the stylistic components of the product through three facets: organic, well-crafted, and elegant (Bessemer & O’Quin, 1999) Provided on the next page in Table 2.3 as well as in Appendix E is a table showing each of the three dimensions along with their respected facets.
Table 2.3 Judging Dimensions Associated with the CPAM

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>Originality</td>
</tr>
<tr>
<td></td>
<td>Surprise</td>
</tr>
<tr>
<td>Resolution</td>
<td>Logical</td>
</tr>
<tr>
<td></td>
<td>Useful</td>
</tr>
<tr>
<td></td>
<td>Valuable</td>
</tr>
<tr>
<td></td>
<td>Understandable</td>
</tr>
<tr>
<td>Style</td>
<td>Organic</td>
</tr>
<tr>
<td></td>
<td>Well-crafted</td>
</tr>
<tr>
<td></td>
<td>Elegant</td>
</tr>
</tbody>
</table>

*Facets and definitions obtained from Bessemer & O’Quin article “Confirming the Three-Factor Creative Product Analysis Matrix Model in an American Sample” (1999).
Conclusion

The Literature reviewed for this study included elements and principles of design, two- and three-dimensional designs, and the production of such designs in the design industry. It then described the production of three-dimensional designs (models) in-depth through the history of modeling, modeling in the design industry, and rapid prototyping along with other new technologies. A number of studies have been conducted, which related toward the application of RP machinery into design education; however, the research to date has not explored how RP can influence creativity. Due to this, more research in the field is needed.
CHAPTER THREE

METHODOLOGY

The purpose of this research study was to assess how computer modeling, used in conjunction with rapid prototyping (RP) machinery, effects creativity. This study was intended to add to the body of knowledge relating to design education, and provide insight into the effective implementation of computer modeling techniques in conjunction with RP machinery. Faculty members of the Florida State University Interior Design program used the data gathered in this study to effectively introduce first year design students to computer modeling techniques.

Description of Research Design

The Principle Investigator (PI) reviewed supporting literature on: the history and uses of computer modeling in conjunction with rapid prototyping machinery, previous research studies involving RP machinery, previous research involving computer modeling, the assessment of creative products, and the four creative P’s (person, process, product, and press). The literature reviewed influenced the foundations behind the creativity assessment tests, final product judging criteria, and a student survey and questionnaire.

This study produced both qualitative and quantitative data related to model building and creativity. Student’s constructed two models; the first model was created by hand while the second model was computer generated, and created with a rapid prototyping machine. These models were judged by trained design educators and assessed for creativity through eight variables, which will be discussed later in the chapter. In an effort to better understand the influence computer modeling and rapid prototyping has on students, the researcher also relied on qualitative data obtained through a questionnaire. The questionnaire aims at establishing the students’ current creativity level. This questionnaire is discussed further in the instruments section of this chapter and can be found in Appendix F.
A naturalistic observation study was conducted in order to learn how students interacted with the newly available technology. Naturalistic observation involves observing individuals in their natural setting (Frankel & Wallen, 2000, p. 536-537). Observational research findings are considered strong in validity because the researcher is able to collect in-depth information about a particular behavior or site. Observational studies can also “reveal descriptions of behaviors in context by stepping outside the group [to] allow qualitative researchers to identify recurring patterns of behavior that participants may be unable to recognize” (The Writing Center at Colorado State University, 1997, para. 3).

It is important to note that the PI does not intend for computer modeling or RP machinery to do away with hand generated modeling, but to allow for more efficient model building options. Hand modeling is essential in learning subjects where the student must physically understand how something is put together and works (Lacey, 2010). Some of the benefits noted by previous research conducted include: the allowance of more time in preliminary stages of design, the ability to revisit a project multiple times, and, most importantly, the ability to create and construct models that the student could not have modeled by hand.

The procedure for research will include 1) reviewing literature, 2) creation of curriculum, judging criteria, and questionnaires, 3) Institutional Review Board approval, 4) data collection via observations, questionnaires, and products produced by students, 5) data analysis, 6) reporting the data, and 7) discussion of the findings and recommendations.

Assumptions and Limitations

In performing this study, the assumption was made that the students’ individual creativity levels were consistent with other students enrolled in design education programs nationwide. It was also assumed that all questionnaires were completed accurately and honestly. In order to meet these assumptions, the students must take the questionnaire seriously (Suskie, 1996). This was addressed by making the students aware that this research may directly affect their future course of study. Moreover, when
conducting research, which may directly affect a participant, the researcher must understand that responses given may be inaccurate if student believes their response is not anonymous. To resolve this problem, the students will be given a disclosure of the data usage in a letter of information prior to participation. The letter of information is provided in Appendix A.

The confidentiality of students was and will be maintained by not releasing students’ names in association with any data. The students were coded to a responding number; that number was used in all data analysis, and the students names were and will not be reported to teachers or departments. This was made clear when the research was introduced and the letter of consent was distributed. The letter of consent is provided in Appendix C.

One factor, associated with research, which is uncontrollable, is the individual students’ biographical history. The experimental population was enrolled in the Florida State University Interior Design Department, and consisted of 4 males and 38 females. Although this population was mostly female; it is assumed that enrollment statistics are congruent with other interior design programs nationwide. However, this information may limit the adaptation of findings to other design disciplines, including engineering or industrial design.

**Institutional Review Board Approval**

The researcher obtained approval from the Institutional Review Board (IRB) at Florida State University prior to any data collection. The questionnaire along with judging criteria were submitted for approval. The IRB application is provided in Appendix H, along with approved student consent letter in Appendix I and approved faculty/judges consent letter in Appendix J.

**Setting**

In 2011, The Florida State University Department of Interior Design completed a major renovation. Part of this renovation included the construction of a full woodworking shop, spray booth, etching machine, and, most importantly, the availability of a rapid
prototyping machine. The RP machinery works through subtractive methods and was obtained from 2BOT. Due to this newly acquired technology, the program is looking into effective ways of introducing rapid prototyping into the curriculum. In traditional studio classes, all models were constructed by hand; however, in an effort to streamline designs, computer modeling and rapid prototyping will be introduced to forty first-year design students. This introduction is meant to allow for more design time, the ability to revisit projects, the ability for more projects in less time, and provide an environment where creativity is not stifled by personal model building ability. All students will be taught in the same studio classroom, providing an identical testing environment. The subjects will also be given an identical instructional video and exercise to prepare them for both hand and computer modeling. Finally, all subjects will be monitored and granted equal access to help.

**Description of Subject**

The subjects involved in this study were all first year students, enrolled in IND1203, Design Fundamentals 1 (DF1), through the Florida State University Interior Design Department. The syllabus for DF1 is provided in Appendix K. All participants were given a questionnaire, biographical assessment, and were judged on two models which they produced. The subjects ranged in age from 18-46 and included 4 males and 38 females. Table 3.1 shows the age distribution of subjects tested. It is important to note that the class consisted of 42 students; however, two students dropped the course and four other students worked in the design field prior to returning to school. Due to this, these students were removed from the research, which left the PI with 36 test subjects.
Table 3.1 Age Distribution of Subjects

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Total Enrolled</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-22</td>
<td>27</td>
</tr>
<tr>
<td>23-27</td>
<td>3</td>
</tr>
<tr>
<td>28-32</td>
<td>3</td>
</tr>
<tr>
<td>33-37</td>
<td>1</td>
</tr>
<tr>
<td>43-47</td>
<td>1</td>
</tr>
</tbody>
</table>

**Description of Instruments**

The researcher obtained qualitative and quantitative data through questionnaires, observation, biographical history, and product judgment. The following section will explain how these elements were executed.

**Questionnaires**

The questionnaire and informed consent letter were administered on site in the classroom. Permission from instructors was granted and part of class time was used for answering the questionnaires. The survey questionnaires were coded to assure anonymity. The cover letter was attached with the questionnaire in order to: introduce the research to the subjects, emphasize the significance of the study, and express gratitude for their participation. For those who were absent, the researcher first asked the instructor to take attendance. From this attendance sheet, a checklist was created to make sure that all subjects had responded to the questionnaire and to avoid any possible duplicate responses.

Upon receiving approval from the Florida State University Institutional Review Board, the researcher distributed a questionnaire to students enrolled in test classes. Once again the questionnaire is provided in Appendix F. These questions provided insight into the students’ biographical history, and focuses on intrinsic factors of each individual. Although biographical assessments help provide insight into the individual; it does not provide quantitative data, which can be used in research. To help fully assess
the students, as well as provide quantitative data, the questionnaire includes three different types of creativity assessments. These assessments included a self-actualization test, a creativity test, and an adjective checklist. These three variables, combined, helped the researcher validity in the tests. The students were not told that this was a creativity assessment, they were only asked to complete the questionnaire as it related to the research.

The questionnaire was distributed in two parts. Part one focused on the student’s biographical history. This included age, gender, year in school, and whether or not the individual had ever simplified a design, in order to construct a model. From this information it can be seen that the majority (91%) of the students participating in the study were female. Participants ranged in age from 18-47; however 76% of those enrolled were 22 or younger. Due to this information, it is not surprising that 50% of the participants are classified as freshman. A breakdown of class levels is presented in Table 3.2.

<table>
<thead>
<tr>
<th>Year in School</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>18</td>
</tr>
<tr>
<td>Sophomore</td>
<td>5</td>
</tr>
<tr>
<td>Junior</td>
<td>5</td>
</tr>
<tr>
<td>First Professionals</td>
<td>7</td>
</tr>
</tbody>
</table>

Since this is a fundamental design class, all incoming students take it, which includes incoming graduate students. This accounts for the fairly even distribution of students classified as sophomores, juniors, and first professionals. The main question to be answered in this section was whether or not the individual had ever been forced to simplify a design, in order to construct a model. By establishing whether or not the subjects had ever simplified a design provides data that can be compared to data attained from models. Table 3.3 shows how the participants responded. It is important to note, that those which were classified as unsure either did not answer the question or replied that they had never constructed a model.
### Table 3.3 Number of Students Who Have Simplified Design

<table>
<thead>
<tr>
<th>Simplify Design</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsure</td>
<td>7</td>
</tr>
<tr>
<td>Yes</td>
<td>14</td>
</tr>
<tr>
<td>No</td>
<td>14</td>
</tr>
</tbody>
</table>

Part two of the questionnaire included a self-actualization test, a creativity assessment, and an activity checklist. These three types of assessments were used in conjunction with one another in an effort to triangulate the creativity level of each student, prior to computer modeling. The first assessment, which can be located in appendix F, is classified as a “Self-Actualization Test”. It asks the subject to indicate the degree to which each statement applies to them, or the degree to which they agree with the statement; by using a scale of 1-5. Once the questionnaires were collected the numbers were added up to reveal each subjects ranking. The results of this assessment are provided in table 3.4 as well as explained below.

### Table 3.4 Distribution of Self-Actualization Scores

<table>
<thead>
<tr>
<th>Self-Actualization Ranges</th>
<th>Classification</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>41-53</td>
<td>Below Average</td>
<td>0</td>
</tr>
<tr>
<td>54-69</td>
<td>Average</td>
<td>2</td>
</tr>
<tr>
<td>70-83</td>
<td>Above Average</td>
<td>17</td>
</tr>
<tr>
<td>84-100</td>
<td>High Self-Actualization</td>
<td>18</td>
</tr>
</tbody>
</table>

The data shows that there is an extremely high amount (94%) of those surveyed who ranked as above average or highly above average in self-actualization. These results were compared to results obtained from this sections creativity assessment and adjective check-list to validity scoring. Both the creativity assessment and adjective checklist can be found in appendix F. Presented in table 3.5 are the results of the creativity assessment. These results show a significant difference from those obtained from the self-actualization test, with only 59% of the participants ranking as above or highly above average. This is attributed to the assessment styles and is why the
researcher setup for a triangulation of data. Individuals are more likely to rate themselves as more creative than they usually are when given the opportunity.

Table 3.5 Distribution of Creativity Scores

<table>
<thead>
<tr>
<th>Creativity Test Ranges</th>
<th>Classification</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>56-79</td>
<td>Below Average</td>
<td>1</td>
</tr>
<tr>
<td>80-102</td>
<td>Average</td>
<td>13</td>
</tr>
<tr>
<td>103-126</td>
<td>Above Average</td>
<td>17</td>
</tr>
<tr>
<td>127-150</td>
<td>Highly Creative</td>
<td>4</td>
</tr>
</tbody>
</table>

The third assessment included an adjective checklist, which asked participants to mark adjectives which applied to them. In this list were positive and negative adjectives which describe creative, as well as, non creative people. A tally of creative adjectives whether positive or negative, was obtained; from this the adjectives that do not describe creativity were subtracted. Table 3.6, located below, shows that once again a significant amount (67%) of participants were ranked as above average or highly above average.

Table 3.6 Distribution of Adjective Scores

<table>
<thead>
<tr>
<th>Adjective check-list</th>
<th>Classification</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-24</td>
<td>Below Average</td>
<td>2</td>
</tr>
<tr>
<td>25-39</td>
<td>Average</td>
<td>9</td>
</tr>
<tr>
<td>40-54</td>
<td>Above Average</td>
<td>21</td>
</tr>
<tr>
<td>55-70</td>
<td>Highly Above Average</td>
<td>3</td>
</tr>
</tbody>
</table>

Observation

The researcher also observed the students over the course of this research study. The purpose of this observation was not to obtain any specific data, but to note any major influences and provide equal help to all students. This observation and constant availability helped ensure that both classes and all students receive the same information, as relates to project parameters.
Product Judging

After receiving both final products, a team of design educators judged each product individually using the Creative Product Analysis Model (CPAM). The judges score sheet is provided in Appendix G. As described in chapter two, the CPAM is an assessment aimed at judging a products perceived creativity level. The CPAM is grouped into three main dimensions that are broken down into nine facets. The first dimension of the CPAM is *Novelty* which includes originality and surprise: it considers newness in materials, processes, concepts, and methods of making the product. The second dimension is *Resolution*, which assesses how well a product works or functions. Resolution aims at assessing if the product is valuable, logical, useful, and understandable. The third dimension, *Elaboration and Synthesis*, looks into the stylistic components of the product through three facets: organic, well-crafted, and elegant. Due to terminology confusion the researcher changed the names of the facets to industry specific terms. This helped ensure that the researcher had as little influence as possible on the judging. Provided on the next page in Table 3.7 as well as in Appendix E is a table showing the relation and definition of each facet, as well as how it relates to the terminology and definitions provided to the judges.
### Table 3.7 Dimensions of CPAM in Relation to Judging Criteria

<table>
<thead>
<tr>
<th>Creative Product Analysis Model</th>
<th>Judges Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Originality</td>
<td>Something New</td>
</tr>
<tr>
<td>Surprise</td>
<td>Can be described two ways: first, through a positive surprise or delight, and secondly through shock or dismay</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Valuable. Logical</td>
<td>How well the product works, functions, or does what it is supposed to do.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Well-crafted</td>
<td>Craftsmanship with an attention to detail</td>
</tr>
<tr>
<td>Organic</td>
<td>The product’s elements come together as a whole</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Elegant</td>
<td>Simplified and refined to its ultimate essence</td>
</tr>
</tbody>
</table>

*It is important to note that the original judging criteria included overall creativity as an aspect. However, since overall creativity is a subjective topic and creativity as a whole is what was being judged the responses to that criterion were excluded.*
Explanation of Procedures

The following research took place over a three week period. Subjects involved in the research were enrolled in IND1203, Design Fundamentals 1 (DF1), through the Interior Design Department at The Florida State University. The DF1 class syllabus is provided in Appendix K. The weeks which research took place are labeled as session 16-20. Week one focused on preparing students for projects through exercises. Week two involved collecting data on hand models and the introduction of SketchUp. Week three focused on collecting data related to computer modeling as well as assisting students with any problems they had with the software. The following section outlines all activities, exercises, and projects supplied to students. Please refer to Table 3.8, which is located at the end of this procedures section, or Appendix L for a summary of the activities which took place each day.

Modeling Handout

The modeling handout focused on specific materials used in model construction, such as: wood, clay, Styrofoam, cardboard, as well as others. It described how each material can be used and successful implementation of each. After introduction, the students were shown techniques used in model construction, as well as demonstrations on how each material can be manipulated to achieve the effect desired. Some techniques included: how to cut materials, how to make straight edges, how to cut clean edges, and how to make a straight material bend. Once the introduction was given the students completed two exercises. Both exercises were meant to allow students to use the skills they had just learned as well as provide feedback on ways in which the model could be more successful. These exercises are outlined in the following section.
Exercise 1-

Exercise 1 presented the students with two copies of a church façade. It asked the students to use one as a base and the other for embellishment. They were asked to cut away from the base and either build up or take away to make the façade appear three dimensional. It was apparent from observations that many students only built the façade up; they do not think to subtract from it. Out of the 36 students involved in this research only one student subtracted from and added to the base, all of the other students only built up from the base. This student’s model was used as the example of what was expected. This is important to point out so the students understand exactly what they did that was good and what could be done to improve designs. After feedback was provided the students moved on to exercise 2, which is outlined in the following passage. Exercise 1 is provided in Appendix M.
Exercise 2

Exercise 2 presented students with a church floor plan. It asked the students to build up from the base using the skills and experience received from exercise 1. There were two main differences between exercise 1 and 2. First, in exercise 2 the students are asked to only build up from the base, unlike exercise 1 where the students could build up or remove from the base. Second, the students were asked to design the build up as if you were looking at the model from a specific view, and to make that view dynamic. The students were told that this may be accomplished through a variation of shapes and plane changes. This exercise is meant to force the students to think in unconventional ways. Just because something appears on a floor plan as a square, circle, or triangle; it does not need to take that shape when extended from the base. An awning in a floor plan may look like a 10 x 20 rectangle, but that rectangle may be eight
feet off the ground. Underneath the rectangle there may only be two four by four posts; so although it appears as if the space is taken up, it may not be. These models were not supposed to be based in reality since the removal of reality may allow the students to think in more whimsical and unconventional ways. Exercise 2 is provided in Appendix N.

**Hand Modeling Project**

![Figure 3.3 Hand Model Layout](image)

The hand modeling project asked students to build up from the base, by hand, and make as many changes as possible. Just as in exercise two the students were encouraged to manipulate the floor plan to appear in plan view as the same, but when looked at from any other view; the model should be intricate and deviate from the generic shapes that appear on the base. The hand modeling projects handouts are provided in Appendix P. As can be seen on the next page in Figures 3.4 and 3.5 the students were beginning to think in unconventional ways, however, the models submitted seemed to lack a high level of variation and/or deviation from the original plan layout. Furthermore, the biggest issue with the majority of hand models was a lack of attention and detail when cutting and constructing the model. As referenced in Chapter
2, the ability to construct a model that will be viewed as successful depends not only on the ability to construct, but the ability to replicate fine details successfully (i.e. craft & detail). Moreover, as can be seen in Figure 3.4 the models that showed a higher level of variation and/or deviation tended to show a lower level of craft and/or detail. Whereas, those models which showed a higher level of craft/or detail tended to show a lower level of variation and/or deviation as seen in Figure 3.5.

![Figure 3.4 Hand Model 1](image1)

![Figure 3.5 Hand Model 2](image2)

**Introduction to SketchUp**

Following the completion of the hand model students were given an introduction to Google SketchUp. SketchUp is a very user friendly three-dimensional computer modeling program. The students were provided with a list of keyboard shortcuts and given instruction on how to use the program. The list of keyboard shortcuts is provided in Appendix O. The students were given instruction into creating a straight line, a curved line, a box, as well as how to manipulating a figure in three dimensions.
Computer Modeling Project

The computer modeling project also involves the students constructing a model that is built up from a base. However, this model was conceptualized through the use of Google SketchUp. The models created in SketchUp were then constructed using a 2BOT rapid prototyping machine. The computer modeling project handouts are provided in Appendix Q.
Table 3.8 Summary of Daily Activities

<table>
<thead>
<tr>
<th>Session</th>
<th>Activities</th>
</tr>
</thead>
</table>
| Session 15 | • Handout on materials used in model making  
            • Handout on how to manipulate materials  
            • Exercise 1                                    |
| Session 16 | • Exercise 2                                          
            • Introduce project 8a                          |
| Session 17 | • Introduce Sketchup                                  
            • Handout on SketchUp                             
            • Help with questions related to 8a               |
| Session 18 | • Project 8a due                                      
            • Introduce project 8b                          |
| Session 19 | • Classroom exercise: serial planes (this does not apply to research  
            • Help with questions related to 8b               |
| Session 20 | • Turn in project 8b                                  |

Summary

As described above, this study was conducted to map changes in the perceived creativity level of two models. The research design for this study was discussed and included: questionnaires, observations, and judging criteria were conducted to collect pertinent data. Thirty-six students enrolled in the Florida State University Department of Interior Design formed the sample of the study. Descriptive analyses were used to analyze the collected data.

This research study is intended to add to the body of knowledge relating to design education and provide insight into the use of rapid prototyping in such settings. Moreover, the researcher hopes that this study will spark further research into rapid prototyping and the introduction of such technology into design curricula. Finally, the current study, along with potential future studies, will hopefully enable the introduction of RP machinery in a way that promotes creative performances.
CHAPTER FOUR

RESULTS

Introduction

This chapter will present the findings obtained from this research study. It will summarize the data as well as provide tables and figures in order to clearly present the information. The goal of this research was to examine the perceived creativity level of two models constructed by first year design students; one modeled by hand the other computer generated and modeled with RP machinery. Furthermore, the research examines the creativity level of each student, prior to any model construction; in order to assess whether associations can be made between students who excel in one modeling type but not the other, and vice versa. These findings were obtained through the judging of two models, one produced by hand and the other computer generated and produced via RP machine.

Establishing Validity of Dimensions Judged

First, this study must establish that the scores obtained from models judged are similar to one another, and, most importantly, are deemed reliable. This question examined each variable judged and whether the scores produced by each judge were consistent with the scores of the other judges.

- When examining the score given by three independent judges on each of the 10 variables of creative products how often are the judges in agreement?

The judging criteria, adapted from the creative product analysis matrix (CPAM) (Besemer & Treffinger, 1980), originally consisted of the 10 variables: Novelty, Aesthetic Appeal, Organization, Effort, Balance, Variation of Shapes, Deviation from Original Plan, Detail, Complexity, and Overall Creativity. Since there were multiple judges, the researcher used Cronbach’s Alpha to assess interrater reliability. As noted in Table 4.1 the reliability level must exceed a rating of .7 or 70%; due to this, the variables Organization and Balance were deemed unreliable. Even though it was proven reliable, through testing, the researcher also removed the variable Overall Creativity; since the
individual variables of creativity should be compiled to determine a model's overall creativity level. A table showing the relationship between the variables of the CPAM and the 10 variables used in this research study can be found in Appendix E.

Table 4.1 Interrater Reliability Analysis

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Hand Model</th>
<th>Computer Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>.867*</td>
<td>.827*</td>
</tr>
<tr>
<td>Aesthetic Appeal</td>
<td>.828*</td>
<td>.804*</td>
</tr>
<tr>
<td>Organization</td>
<td>.855*</td>
<td>.614</td>
</tr>
<tr>
<td>Effort</td>
<td>.883*</td>
<td>.811*</td>
</tr>
<tr>
<td>Balance</td>
<td>.786*</td>
<td>.624</td>
</tr>
<tr>
<td>Variation of Shapes</td>
<td>.871*</td>
<td>.766*</td>
</tr>
<tr>
<td>Deviation from Original Plan</td>
<td>.901*</td>
<td>.825*</td>
</tr>
<tr>
<td>Detail</td>
<td>.903*</td>
<td>.751*</td>
</tr>
<tr>
<td>Complexity</td>
<td>.903*</td>
<td>.866*</td>
</tr>
<tr>
<td>Overall Creativity</td>
<td>.903*</td>
<td>.808*</td>
</tr>
</tbody>
</table>

*Above 0.70 agreement

This data shows that 8 out of the 10 variables judged were established as reliable through interrater reliability analysis. Those variables, which were established to be reliable include: Novelty, Aesthetic Appeal, Effort, Variation of Shapes, Deviation from Original Plan, Detail, Complexity, and Overall Creativity. Establishing reliability between the judge’s scores provides the researcher with statistical data that affirms which variables should, and can, be analyzed further. In retrospect, since one’s perception of organization and balance is subjective, it makes sense that these variables would not be agreed upon between individual judges. For example, an individual may prefer either symmetrically or asymmetrically balanced designs. In turn, their preference of either type of balance will influence their decision as to whether or not a design evokes organization. This can be seen in the data obtained from judges. Table 4.2 presents each judge’s individual rating of balance and organization in relation to the other judges.

From this data, it is apparent that even though the judges were not in agreement as to whether or not a model evoked organization or balance, they did show a correlation between their own ratings of the two dimensions. When comparing one judge’s score of organization to that same judge’s score of balance, they were only in disagreement 3 out of the 210 times tested (.01%). Moreover, the judges scored the dimensions
identically the same 97 out of the 210 times (46.1%). Agreement was established as the comparison of organization and balance which deviates by only one number, positive or negative, on the scale judged. When looking at this data the associations outlined earlier become more apparent. Subject number one’s hand model is the perfect example of this disagreement between judges. When looking at judge one and two’s rating of subject one’s hand model, not only do the judges agree between their own ratings, but with each other. However, judge three scored the model completely different than judge one or two. This can only be due to personal preferences which affect the judge’s perception of what constitutes organization and balance.
Table 4.2 Examining Correlations between Organization and Balance

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</table>
Assessing Changes in Creativity on Eight Variables

Next, this study was interested with assessing whether the perceived creativity level of students models was higher when judging models produced by hand or models produced via computer. This question examined the difference seen in the two models, through the eight variables previously established as reliable.

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*Red shows scores which were identical, Green shows major disagreements.

*J1O = Judge 1 Organization, J1B = Judge 1 Balance, J2O = Judge 2 Organization...and so on.*
When judging two final products, one model constructed by hand and the other computer generated and produced using a rapid prototyping machine, do those which are computer generated score as being more creative?

The data from all judging sheets were collapsed for analysis; this data can be located in Appendix S as well as on the next page in Tables 4.3 and 4.4. First, a table was created which included each individual variable and the three judge’s scores. The scores for each variable were then calculated to produce a mean value, which ranged from 0 to 6. Although there were no drastic across the board changes seen from hand to computer models, it is important to note that the overall number of models who evoked lower creativity levels was cut in half. When examining models through each dimension judged there are 252 occurrences where a model could be judged as low, average, or high in creativity. In the hand models there were 34 high, 113 average, and 105 low. The computer models on the other hand had 51 high, 146 average, and 55 low. Although the number of dimensions judged as highly creative only rose by 17, the number of dimensions judged as average rose by 32, and the number of dimensions judged as low dropped by 50. Tables 4.3 shows this distribution.
Table 4.3 Mean Value of Hand Model

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Once the mean value of each variable was obtained, the mean value of each model created by hand was subtracted from the mean value of each model created via computer. This produced a number ranging from -6 to 6. From this number, it could be ascertained that if the final sum remained positive, then the student’s computer model was judged as being more creative. Adversely, if the sum became negative, then the student’s hand model was judged as more creative. The data in Table 4.5 presents the number of positive sums (Computer > Hand), negative sums (Computer < Hand), as well as those which saw no change (Computer = Hand).

From this analysis, it can be observed that a majority of the students embraced the newly available technology and subsequently saw an increase in perceived creativity level when comparing hand and computer modeling. The lowest number of models judged, in each variable, as more creative when using the computer was 18, or 51%. This can be misleading if it is the only number looked at, because although it is barely over 50%, there is not one but two other categories (Computer < Hand & Computer = Hand) that still factor into the equation. When analyzing the two other categories, it can be seen that although the lowest number of models representing no change is 3, a mere 8.5%, the highest number in any variable rated as better through hand modeling was only 10, which represents only 28.5% of models produced.

To get a better idea of the overall change each category saw, the columns were added up and divided to attain their mean value. When this was done, it became evident that models produced via the computer were judged as much more creative, with a mean value of 21.125 or 60.5%. The mean value of models produced by hand was a mere 8.125 or 23.1%, and those models which saw no change had a mean value of 5.75 or 16.4%. Although these values do not show the exact degree to which each student’s model was more or less creative, it is still shows that a majority of those tested saw an increase in perceived creativity when modeling thru the computer.
Table 4.4 Comparison of Hand vs. Computer Modeling

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Hand &gt; Computer</th>
<th>Hand &lt; Computer</th>
<th>Hand = Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>10</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>8</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>Effort</td>
<td>6</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>Variation</td>
<td>10</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Deviation</td>
<td>10</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Detail</td>
<td>7</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Complexity</td>
<td>6</td>
<td>21</td>
<td>8</td>
</tr>
<tr>
<td>Overall Creativity</td>
<td>8</td>
<td>20</td>
<td>7</td>
</tr>
</tbody>
</table>

These comparisons show that the perceived creativity level of individual models is higher in models produced via computer. Also, when comparing hand and computer models, on the eight variables deemed reliable, the variables termed aesthetic, effort, variation, and detail were significantly better in models produced using the computer. Establishing which variables report a significant change in perceived creativity helps the researcher answer the main question associated with this study. This information was used in the remainder of data analysis to further understand why some variables show significant change while others show little to none.

Analyzing the Degree of Change

Next, the study was interested in seeing whether the differences in perceived creativity levels of the two models were significant or not. This question measured the degree to which creativity changed and whether or not the change was deemed significant.

- When judging products on eight independent variables, are there apparent trends seen between strong components of hand modeling versus the strongest components of computer modeling?

To help answer this question the data collected from the judges was analyzed using a non-parametric t test, the Wilcoxon signed ranks test. The Wilcoxon signed ranks test presents changes through a Z score and p-value. A significant change is classified as
any value which falls within p<.05. Presented in Table 4.6 are the Z score and p-value for each component of the creativity judgment.

Table 4.5 Comparison of Creativity

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Computer Model</th>
<th>Hand Model</th>
<th>Wilcoxin Signed Ranks Test (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>14.39</td>
<td>14.70</td>
<td>Z = -1.307, p = .191</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>16.57</td>
<td>14.38</td>
<td>Z = -2.642, p = .008*</td>
</tr>
<tr>
<td>Effort</td>
<td>13.59</td>
<td>20.42</td>
<td>Z = -2.097, p = .036*</td>
</tr>
<tr>
<td>Variation</td>
<td>15.95</td>
<td>17.70</td>
<td>Z = -1.666, p = .092</td>
</tr>
<tr>
<td>Deviation</td>
<td>13.64</td>
<td>16.05</td>
<td>Z = -0.958, p = .325</td>
</tr>
<tr>
<td>Detail</td>
<td>15.42</td>
<td>18.00</td>
<td>Z = -2.437, p = .015*</td>
</tr>
<tr>
<td>Complexity</td>
<td>13.21</td>
<td>16.75</td>
<td>Z = -2.161, p = .031*</td>
</tr>
<tr>
<td>Overall Creativity</td>
<td>13.88</td>
<td>16.06</td>
<td>Z = -1.720, p = .085</td>
</tr>
</tbody>
</table>

*p<.05

These comparisons show that the perceived creativity level was significantly impacted, in four of the eight variables tested, when transitioning from hand to computer modeling. Further, when students are transitioned from hand modeling to computer modeling, their perceived creativity level is judged higher in the variables Aesthetics, Effort, Detail, and Complexity. Establishing a significant change in the perceived creativity level of each model produced allows this data to be studied further to explain why the change occurred.

**Relationship between Questionnaire and Models**

Finally, this study was interested in seeing if there was a relationship between scores obtained from the questionnaire, and the perceived creativity level of the student’s model.

- Can a trend be seen in students who have similar backgrounds or creativity scores and those who excel in either hand or computer modeling?

This question compared data obtained from the questionnaire to creativity levels associated with each student’s model. Items from the questionnaire to be compared included: whether or not the student had ever simplified a design, whether the individual
preferred Mac or PC operating system, information from the biographical assessment; as well as, scores obtained from the self-actualization test, the creativity assessment, and the adjective checklist. These components were compared to the students overall mean model value, whether it was positive or negative, as well as each component of creativity judged. This data was then analyzed using the linear regression statistical test. The linear regression test attempts to model the relationship between variables and determine if one variable is a predictor of another (Cohen, J., Cohen, P., West, & Aiken, 2003). However, after running multiple tests, no correlations could be established between data obtained from the questionnaire and data obtained from model judging. When examining the assessments and tests associated with the questionnaire it can be seen that the majority of the subjects tested were rated as highly creative. Due to this, it was difficult to establish correlations between independent data across the board.

**Conclusion**

The research questions for this study were answered using statistical data analysis techniques. This study produced reliable data, establishing consistency in the judge’s responses, through interrater reliability. The study then compared each models perceived creativity level, through the mean value of each variable judged, to the test class as a whole. This showed that 60.5 % of students produced a model that was judged as more creative when computer generated. The percentage of those who produced a better model by hand was a mere 23.1%, while those who saw no change between the two models seemed high at 16.4%. The data was also analyzed using the Wilcoxon sign rank test to provide the degree to which each variable saw significant change. From this, it was established that the variables termed Aesthetics, Effort, Detail and Complexity were significantly higher when the models were produced and generated using a computer.
CHAPTER FIVE
DISCUSSION

Introduction

The purpose of this research study was to assess how computer modeling, used in conjunction with rapid prototyping (RP) machinery, effects creativity. This study was intended to add to the body of knowledge relating to design education and provide insight into the effective implementation of computer modeling techniques and RP technology. This chapter provides an overview and analysis of the data presented in Chapter 4. The results obtained from conducting this study will be discussed and key findings will be noted, including interrater reliability, dimensions of creativity, those dimensions deemed reliable, and the analysis of data through statistical tests (i.e. Cronbach’s Alpha and the Wilcoxin Signed Ranks Test). This chapter will conclude by naming the limitations associated with this study as well as making recommendations for future research opportunities associated with the use of RP technology in classroom environments.

Key Findings

Assessing Reliability of Judging Dimensions

Any study involving multiple judges must establish that the judges’ scores are congruent with one another. Establishing reliability between the judges’ scores provides the researcher with statistical data that affirms which variables should, and can, be analyzed further. Due to this, the researcher used Cronbach’s Alpha to establish interrater reliability between the dimensions judged (Novelty, Aesthetics, Organization, Effort, Balance, Variation, Deviation, Detail, and Complexity). Cronbach’s Alpha revealed that the dimensions organization and balance were not agreed upon by the judges as a whole. As stated in Chapter 4 and presented in Table 4.2, since one’s perception of organization and balance is subjective, it makes sense that these variables would not be agreed upon between individual judges. For example, an individual may prefer either symmetrically or asymmetrically balanced designs. In turn,
their preference of either type of balance will influence their decision as to whether or not a design evokes organization. This is repeatedly seen in the data obtained from models judged.

The data shows that although the judges were not in agreement as to whether or not the model evoked organization or balance when examining their own ratings of the two dimensions they did agree. When comparing one judge’s score of organization to that same judge’s score of balance, they were only in disagreement 3 out of the 210 times tested. Moreover, the judges scored the dimensions identically the same 97 out of the 210 times. Agreement was established as the comparison of organization and balance which deviates by only one number, positive or negative, on the scale judged. It is important to note this finding since most creativity assessment aimed at judging a products perceived creativity level include these two dimensions.

**Assessing Changes in Creativity**

As presented in Chapter 4, 60.5% of subjects tested were judged as having a more creative model when built using computer modeling software and RP machinery. While this may not seem like the majority, when compared to the other two categories -- those who produced a more creative hand model and those who saw no change between models -- its impact is quickly revealed. When comparing the number of subjects whose hand models were judged as more creative, a mere 23.1%, to the percentage whose computer models were perceived as more creative, 60.5%, it becomes evident that when the model was created via computer and produced using RP machinery the students perceived creativity levels were positively impacted. Although this does not measure the exact degree to which models are judged as more or less creative, it provides valuable insight into the expected number of students who would benefit from the availability of RP machinery.

**Significant Changes in Perceived Creativity**

Although the last section examined changes in perceived creativity level, it did so through the comparison of one subject’s hand model to that same subject’s computer model. This section, on the other hand, examines the changes in perceived creativity level, but does so by combing all the scores attained from the judged models. This
collapsed data was then analyzed using the Wilcoxin Signed Ranks Test in order to assess changes present in the test class as a whole, rather than individually. Table 5.1 shows the relationship between the definition of those dimensions which saw significant change, aesthetics, effort, detail, and complexity, and the aspects of the machine which provided for such a change. When looking at the definitions of each dimension, it becomes apparent why these specific dimensions stood out. As described in Chapter 2, RP machinery provides students with support in many different areas associated with model construction. Some of the things already established as supportive include, but are not limited to, a faster production time associated with the construction of the model, an ability to replicate even the finest of details, and the ability to construct things which could not be constructed through traditional hand modeling techniques.

Table 5.1 Positive Aspects of RP Machinery

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Definition</th>
<th>How RP Influences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>The degree to which a design is pleasing as a whole.</td>
<td>RP machinery allows the designer to work out all aspects of design before producing the model. This results in what appears as a high level of effort and ultimately an aesthetically pleasing model.</td>
</tr>
<tr>
<td>Effort</td>
<td>The degree to which a design shows effort. The placement and design seems to have been done to achieve a particular end.</td>
<td></td>
</tr>
<tr>
<td>Detail</td>
<td>Small elements that collectively constitute neatness.</td>
<td>RP machinery can produce models from exact dimensions down to a 1/16th of an inch.</td>
</tr>
<tr>
<td>Complexity</td>
<td>The overall intricacy of design.</td>
<td>RP machinery allows designers to produce models that exhibit a high level of detail and attention.</td>
</tr>
</tbody>
</table>
Dimensions of Creativity

Through an examination of the data collected from this research it immediately becomes apparent that technology, computer modeling software and RP machinery, assisted students in producing models that were perceived as more creative than previously constructed hand models. When examining the dimensions affected by such technology it is interesting that those dimensions which showed some change, novelty, variation, and deviation, can be attributed to the introduction of computer modeling software, whereas, those dimensions which showed a significant change, aesthetics, effort, detail, and complexity, can all be attributed to the introduction of RP machinery. The following section will review how each specific technology aloud for such a change through an examination of each dimension. It will also present images of models produced by subjects tested to further demonstrate the changes viewed through research.

Change Attributed to Computer Modeling

When defining those dimensions which showed some change; novelty, variation, and deviation; it becomes evident that the introduction of computer modeling software helped assist in such change. It is easy to see how these dimensions were positively influenced through an examination of positive and negative aspects associated with computer modeling software. Since the RP machine available to students only removes material on one axis, the judges were provided with PDF images of the students' design. When looking at these images, it is easy to see how computer modeling assisted students in the three previously mentioned dimensions.

Novelty

By allowing students to make real time changes to a model, the software provides a platform where new ideas flourish. Furthermore, by allowing designers to rotate the model and view it from every perspective computer modeling software promotes new and/or novel ideas, which previously could not be envisioned. As one student said: “I used to have trouble drawing and visualizing my final design, but when modeling on the computer, I can see the entire design from every angle. It really helped me see things in
a new way.” Figures 5.1 shows the hand model submitted by subject 6 and Figure 5.2 shows the computer model submitted by subject 6. When looking at the two models it is easy to see how novelty was increased in the computer design.

Figure 5. 1  Hand Model Produced by Subject 6

Figure 5. 2  Computer Model Produced by Subject 6
Although, Figure 5.1 shows a novel idea it lacks variation and deviation. Figure 5.2, on the other hand, not only shows a novel idea, but also a high level of variation and deviation. Presented below in Figure 5.3 is the hand model which judged highest in novelty. Although, this is a highly novel idea it seems to have the same down falls as Figure 5.1 in that it lacks a high level of variation and deviation.

![Figure 5.3 Most novel hand model submitted](image)

**Variation and Deviation**

When looking at the dimensions termed variation, the degree to which the design shows a wide usage of various shapes available; and deviation, the degree to which the final product deviates from the original plan layout, it is surprising that they were not significantly impacted. Even though these two dimensions related directly to the project, it is the researchers’ opinion that since the subjects tested were first year students their design vocabulary is low. Design vocabulary relates to the knowledge one has in a specific area. Those with a low design vocabulary think in elementary shapes and
figures, such as squares, circles, rectangle, etc. Those with a high design vocabulary think in compound and complex figures, such as, octagons, arches, cantilevers, etc. So instead of thinking in multiple planes and levels, complex figures, these students think about only one change. For example, those with a low design vocabulary might take a square and taper or slant it in one direction, they do not think to taper and slant the object. However, when given access to computer modeling the students were prone to think in complex figures through the ability to make changes in real time. By making real time changes designers are no longer limited to thinking of something and transferring that thought to paper. Only after that thought is transferred to paper does the designer begin to see the changes they can make. With computer modeling, once that thought is in the program, it can be copied and pasted multiple times in order to edit, revise, and make changes as necessary. Figure 5.4 presents the hand model submitted by subject 16. In this model there is a heightened level of variation and deviation, however, the craft and construction of the model takes away from the overall design. On the other hand, Figure 5.5 shows the computer model produced by subject 16. This model is not all that much different in relation to variation and deviation, but since the RP machine shows a fine attention to detail the overall model appears as more successfully.
Figure 5.4 Hand Model Produced by Subject 16

Figure 5.5 Computer and RP Model Produced by Subject 16
Changes Attributed to RP Machinery

When examining those dimensions which showed a significant change; aesthetics, effort, detail, and complexity; it becomes apparent that the introduction of RP machinery influenced this change. By examining the positive aspects of RP, which were outlined in Table 5.1, it is apparent that the very purpose of RP machinery is to remove these dimensions in order to alleviate stress associated with model construction. It is important to note that these four dimensions somewhat feed off of one another. For example, if either detail or complexity are present then a model will also show effort and, if a model shows two of these dimensions, it will more than likely also be viewed as aesthetically pleasing. On the other hand, if a model does not show some level of detail or complexity then it will most often be viewed as showing little effort and, if a model shows little effort, it is unlikely that it will be aesthetically pleasing.

While there are a vast number of positive aspects associated with RP, when looking at negative aspects there seem to only be three. The first two aspects relate to the cost associated with acquiring the machinery and the cost associated with materials used by machine. The third aspect, learning and understanding software associated with machinery, seems to relate more to computer modeling software rather than RP itself. Although previous studies have noted an increased cost associated with the use and inclusion of RP machinery, this begins to not be the case.

As noted earlier, table top RP machinery can now be obtained from a number of reputable manufactures for a very reasonable price. Moreover, the foam which our university uses costs $35 per sheet and nine models are cut from one sheet. That is less than $6 per student. As a student and instructor of furniture design, I have seen students spend much more than this on materials associated with construction. Furthermore, students cannot assume that they will construct the model perfectly the first time so there is usually unnecessary wasting of materials from alterations or changes. Moreover, since costs associated with machinery have dropped drastically over the past few years and The Florida State University Interior Design Department already requires students to obtain a personal computer as well as computer modeling
software, the introduction of this machinery is not only inexpensive but very viable to this type of institution.

**Aesthetics**

When looking at aesthetics, the degree to which a design is pleasing as a whole, it is easy to see why models built using RP machinery would be significantly higher than those built by hand. Two reasons for this are, first, since the machine cuts the model from one material, the design will obviously appear as one cohesive unit and second, since the model is designed in three-dimensions prior to construction, the student is able to view it as such. As mentioned earlier, when designing by hand, the student may lack the perspective drawing skills needed to produce a drawing that actually represents the end model. However, when preliminary designs are done on the computer, the student has the ability to make changes in real-time and rotate the model to see it from all possible perspectives. Figure 5.6 and 5.7 provide good examples of how complex designs read as a whole entity when produced through RP machinery. Figure 5.6 shows the hand models produced by subject 12 and 14. In these models, the students are beginning to think in more creative ways, however, as mentioned earlier those hand models which evoked a high level of variation, detail, or complexity tended to lack an attention to craft and detail. Figure 5.7 shows how subjects 12 and 14 were able to develop their designs further when they did not have to think about craft or construction.
Figure 5.6 Hand Models Produced by Subject 12 and 14

Figure 5.7 Computer Models Produced by Subject 12 and 14
Effort

When looking at the dimension termed effort, the degree to which a design shows effort, the placement and design seems to have been composed to achieve a particular end. It is also apparent that RP machinery assists in this area. As previously mentioned, when models are produced using RP machinery, the user simply enters their data into the machine’s software, clicks make, and the machinery takes it from there. Since the machinery is very precise, the model will undoubtedly evoke a high level of effort. As mentioned multiple times the hand models that showed a high level of effort tended to lack a high level of variation, deviation, or complexity within their design. Figure 5.8 presents two hand models produced by subject 21 and 23 that show a high level of effort, but seem to lack any sort of variation, deviation, or complexity. Figure 5.9 then presents those same subjects computer models in order to show how creativity is enhanced when the amount of effort dedicated to construction is reduced.

Figure 5.8 Hand Models Produced by Subject 21 and 23
Figure 5.9 Computer Models Produced by Subject 21 and 23

Detail and Complexity

Detail, the small elements that collectively constitute neatness, and complexity, the overall intricacy of a design, will obviously be perceived higher in models constructed through RP. Looking back to Table 5.1, it is apparent that one of the major positive aspects attributed to RP, is the ability to produce models from exact details down to a 1/16th of an inch. This ability to produce models with exacting details is why models produced through RP machinery are much more complex as well. As previously mentioned as well as presented, in Figures 5.4 and 5.5, the subjects tested were, for the most part, unable to construct models by hand that showed a high level of detail and complexity. However, Figures 5.10 and 5.11 show just how detailed and complex models can be when using RP. Figure 5.10 shows a high level of complexity through intersecting figures while Figure 5.11 exhibits a high level of detail in the pillar as well as the wall. It is not to say that these models could not be constructed by hand, but the time and skill associated with executing such a high level of detail and complexity is rare.
This study was conducted on a relatively small number of students when compared to the vast number of students enrolled in associated programs worldwide. As stated in Chapter 3, the experimental population, enrolled in The Florida State University Interior Design Department, consisted of 4 males and 38 females. Although this population is...
mostly female, it is assumed that enrollment statistics are congruent with other interior design programs nationwide. However, it is important to note that the information obtained from this research may be limited in its adaptation to other design disciplines; such as, architecture, engineering, industrial design, etc.

Additionally, the PI does not intend for computer modeling or RP machinery to do away with hand generated modeling, but to allow for more efficient model building options. Hand modeling is essential in learning subjects where the student must physically understand how something is put together and works (Lacey, 2010). Moreover, the students of design must still understand the essential elements and principles of manual drawing, because the fundamentals behind composing something on paper or the computer are the same. Because, whether hand or computer generated, the main purpose of the design is to communicate something effectively (Slotkis, 2006).

**Reconsiderations**

**Questionnaire**

Although the questionnaire produced valuable information, by reformatting it, the researcher believes it could provide better insight into the subjects’ past. The original questionnaire was composed of a biographical assessment, a creativity assessment, a self-actualization test, and an adjective checklist. The biographical assessment provided the most informative data, such as age, gender, and year in school. However, the three other assessments, which were meant to provide a triangulation of the individual subject’s creativity level pre model construction, did not provide any useful data. The one assessment that showed some relevant data was the adjective checklist. Due to this, the researcher suggests the composition of a questionnaire that not only includes some sort of biographical assessment, but an inventory test as well. One such test, the Creative Behavior Inventory (Hocevar, 1979, 1980), examines the frequency in which previously conducted creative activities are completed. The implementation of such test would provide more substantial quantitative data on the subject’s past. By attaining such
data the researcher could then make better conclusions as to why certain individuals excel while others do not. The creative behavior inventory is provided in Appendix T.

Judging Criteria

As discussed earlier in this chapter, the dimensions termed organization and balance were deemed unreliable. Due to this, the dimensions need not be included in future research studies. Although the researcher did not include the dimension of overall creativity in data analysis, it was still interesting to see the judges’ rating in relation to the subject’s overall score.

Sequence of Models

One thing that may also have influenced the increase in perceived creativity of computer models is that the computer models were created second. In order to reduce the impact of constructing the first model on overall model building techniques the students were not given feedback on their first, hand model, until after the second, computer model, was submitted. Still it would be interesting to change the sequence of model building to include the computer model first. However, if this was done it would remove the ability to judge changes seen from the introduction of technology and would only relate to specific model building techniques, since the students would have already been introduced to computer modeling.

Recommendations for Future Research

This research study uncovered new and valuable information related to the impact RP technology has on creative thinking. The study also validated previous research conducted on RP technology, which was outlined in Chapter two. The following section discusses changes this researcher would make to the questionnaire and judging criteria, in order to produce a higher quality and volume of data.

In an effort to reveal significant past traits that may influence whether the subject will excel in hand or computer modeling, the researcher suggests revising the questionnaire. This revision, as described in detail above, would include replacing the three creativity assessment with an inventory of past creative activities. By making
these changes the researcher will not only minimize time associated with completing the questionnaire, but allow for a higher volume of quantitative data to be collected. It would also be beneficial to expand this study to include a larger population of students once revisions to the questionnaire have been made. With a larger population size, it may be easier to denote traits which affect whether or not a student may excel when using RP technology. If this study were to be repeated or revisited, it would also be beneficial to conduct an exit survey with the students. This survey would focus on positive and negative aspects that the students experienced while using the technology.

Conclusion

The purpose of this research study was to assess how computer modeling, used in conjunction with rapid prototyping (RP) machinery, effects creativity. This study looked to establish traits which could lead to predictions as to whether or not an individual would benefit from RP machinery. Specifically, traits associated with past experiences. This research also examined the creativity level of each student, prior to any model construction; in order to assess whether associations can be made between students who excel in one modeling type but not the other, and vice versa. This study found that nearly three times as many subjects were perceived as producing a more creative design when using RP technology versus hand modeling techniques. It also established that the dimensions of creativity, termed aesthetics, effort, detail, and complexity, were all significantly more creative when using RP. This data supports the theory that RP promotes creative thinking by proving that the inclusion of RP technology not only influences aspects of model building, such as time and cost, but provides students with a platform which promotes creative thinking.

In conclusion, the data obtained from this research study revealed interesting information relating to the subjects tested as well as the technology it examined. Future research into RP technology and how it impacts creativity will provide for the seamless introduction of RP technology into classrooms worldwide. It is the researcher’s opinion that RP technology provides designers, who do not have model building skills, the opportunity to produce a model which truly exhibits their idea.
APPENDIX A

LETTER OF INFORMATION (STUDENT)

Dear Students:

I am conducting a study to assess the effect, positive or negative, that rapid prototyping has on individual students’ creativity levels. This research aims at assessing current levels of creativity throughout first year interior design students, the effect of rapid prototyping on these students, and whether or not the introduction of rapid prototyping allows students to be more creative. By participating in this study you will help provide valuable insight into effective introduction of rapid prototyping machinery and assist in determining whether it will allow for students to think more creatively.

Please read the consent form information on the following pages. There are no risks or benefits associated with this research, and all information is anonymous. By signing the following consent form you are agreeing to participate in this study.

Thank you for your participation,

Anthony Conetta
APPENDIX B

LETTER OF INFORMATION (FACULTY)

Dear Faculty:

I am conducting a study to assess the effect, positive or negative, that rapid prototyping has on individual students’ creativity levels. This research aims at assessing current levels of creativity throughout first year interior design students, the effect of rapid prototyping on these students, and whether or not the introduction of rapid prototyping allows students to be more creative. By participating in this study you will help provide valuable insight into effective introduction of rapid prototyping machinery and assist in determining whether it will allow for students to think more creatively.

Please read the consent form information on the following pages. There are no risks or benefits associated with this research, and all information is anonymous. By signing the following consent form you are agreeing to participate in this study.

Thank you for your participation,

Anthony Conetta
APPENDIX C

LETTER OF INFORMATION AND CONSENT (STUDENTS)

FSU Behavioral Consent Form

Rapid Prototyping (RP): Gauging levels of Creativity.
You are invited to be in a research study that will evaluate the effect of rapid prototyping on individual students’ creativity level. You were selected as a possible participant because you are in enrolled in Design Fundamentals 1 (DF1) during the Fall semester of 2011. Please read this form and ask any questions you may have before agreeing to be in the study. This study is being conducted by Anthony Conetta, Graduate Student, Department of Interior Design, Florida State University.

Background Information:
The purpose of this research study is to evaluate the effect, positive or negative, of rapid prototyping on students enrolled in design education programs; specifically the effect rapid prototyping has on individual students’ creativity levels.

Procedures:
If you agree to be in this study, you will be asked to do the following things: complete a brief questionnaire prior to study that is meant to establish a creativity level pre exposure; create both hand and computer generated models, to be judged; and lastly complete an exit survey gauging creativity level post exposure and obtaining participants’ feedback on rapid prototyping machinery. This study will take place during regularly scheduled DF1 class times.

Risks and benefits of being in the Study:
There are minimal risks associated with this study.
The benefits to participation are to help assess the most efficient way of implementing rapid prototyping in preliminary studio classes.

Compensation:
There is no compensation associated with the study. However, all who participate will have their model created using the rapid prototyping machine.

Confidentiality:
The records of this study will be kept private and confidential to the extent permitted by law. All students who participate will be designated a number to ensure anonymity. In any sort of report I might publish, I will not include any information that will make it possible to identify subjects. Research records will be stored securely in a locked cabinet and only the researcher and committee will have access to these records.

**Voluntary nature of the Study:**
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University or with the Interior Design Department. If you decide to participate, you are free to not answer any questions or withdraw at anytime without affecting those relationships.

**Contacts and Questions:**
The researcher conducting this study is Anthony Conetta. You may ask any questions you have now. If you have questions later, you are encouraged to contact him at ***-***-****

You may also contact the committee chairman Marlo Ransdell at ************, with any additional questions.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the FSU IRB at 2010 levy street, Research building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644-8633, or by email at humansubjects@magnet.fsu.edu.

You will be given a copy of this information to keep for your records.

**Statement of Consent:**
I have read the above information. I have asked questions and received answers. I consent to participate in the study.

___________________                __________________
Signature                                                  Date

___________________                __________________
Signature of Investigator                           Date
APPENDIX D

LETTER OF INFORMATION AND CONSENT (FACULTY)

FSU Behavioral Consent Form

Rapid Prototyping (RP): Gauging levels of Creativity.
You are invited to be in a research study that will evaluate the effect of rapid prototyping on individual students’ creativity level. You were selected as a possible participant because you are in enrolled in Design Fundamentals 1 (DF1) during the Fall semester of 2011. Please read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Anthony Conetta, Graduate Student, Department of Interior Design, Florida State University.

Background Information:
The purpose of this research study is to evaluate the effect, positive or negative, of rapid prototyping on students enrolled in design education programs; specifically the effect rapid prototyping has on individual students’ creativity levels.

Procedures:
If you agree to be in this study, you will be asked to do the following things: complete a training session outlining how to judge products created by students, review the judging sheet, participate in practice judging sessions to ensure there is sound judging across the board, and finally judge products created by students.

Risks and benefits of being in the Study:
There are minimal risks associated with this study. The benefits to participation are to help assess the most efficient way of implementing rapid prototyping in preliminary studio classes.

Compensation:
There is no compensation associated with the study.

Confidentiality:
The records of this study will be kept private and confidential to the extent permitted by law. All students who participate will be designated a number to ensure anonymity. In any sort of report I might publish, I will not include any information that will make it
possible to identify subjects. Research records will be stored securely in a locked cabinet and only the researcher and committee will have access to these records.

**Voluntary nature of the Study:**
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University or with the Interior Design Department. If you decide to participate, you are free to not answer any questions or withdraw at anytime without affecting those relationships.

**Contacts and Questions:**
The researcher conducting this study is Anthony Conetta. You may ask any questions you have now. If you have questions later, you are encouraged to contact him at ****-****

You may also contact the committee chairman Marlo Ransdell at *********, with any additional questions.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the FSU IRB at 2010 levy street, Research building B, Suite 276, Tallahassee, Fl 32306-2742, or 850-644-8633, or by email at humansubjects@magnet.fsu.edu.

You will be given a copy of this information to keep for your records.

**Statement of Consent:**
I have read the above information. I have asked questions and received answers. I consent to participate in the study.

___________________                __________________
Signature                                                  Date

___________________                __________________
Signature of Investigator                           Date
### APPENDIX E

**CREATIVE PRODUCT ANALYSIS MATRIX**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Novelty</td>
<td>Originality</td>
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<td>Surprise</td>
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<td>Resolution</td>
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<td>Style</td>
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<td>Well-crafted</td>
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<td></td>
<td>Elegant</td>
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APPENDIX F

QUESTIONNAIRE

Name ____________________________________________________________

Rate yourself on the degree to which each statement applies to you, or the degree to
which you agree with the statement. Use the following scale
1 = Never
2 = Rarely
3 = Occasionally
4 = Often
5 = Always

Self-Actualization Test

___ 1. I enjoy some unknowns in life.
___ 2. Most people are basically good.
___ 3. I am a spontaneous person.
___ 4. There is a philosophy behind life.
___ 5. I accept myself, and like who I am.
___ 6. I feel I have a mission in life—a vision about what I am and who I will become.
___ 7. I am independent and self-sufficient.
___ 8. I can concentrate very intensely on my work.
___ 9. I am unprejudiced when it comes to open discussions.
___10. I have a strong enthusiasm for life.
___11. I am creative.
___12. I can appreciate again and again the simple and commonplace experiences.
___13. I handle stress well.
___14. I have marvelous moments of intense enjoyment.
___15. I form strong bonds with people.
___16. I am a kind, considerate, and charitable person.
___17. I enjoy working toward a goal.
18. I define right and wrong according to my own standards more than society's conventions.
19. I am working to become what I am capable of becoming.
20. I feel I am high in self-actualization
Self-actualization is defined as: The motivation to realize one's own maximum potential and possibilities. It is considered to be the master motive or the only real motive, all other motives being its various forms.

Creativity Assessment

21. I am unconventional in many ways.
22. I am very artistic.
23. I am quite absent minded
24. I try to use metaphors and analogies in my writing.
25. I am a very active and energetic person.
26. I enjoy thinking a new and better ways of doing things.
27. I am very curious.
28. I am quite original and inventive.
29. Some of my past or current hobbies would be considered “unusual”.
30. I like the nonsense forms and bright colors of modern art.
31. My ideas are often considered impractical or even “wild”.
32. I would rate myself as having high “intuition” and “insight”.
33. I like some body smells.
34. I am able to work intensely on a project for many hours.
35. I like trying new ideas and approaches to a problem.
36. I often become totally engrossed in a new idea.
37. Most of my friends are unconventional.
38. The word “quick” describes me.
39. I could be a spontaneous person.
40. I have engaged in a lot of creative activities.
41. I would rate myself high in self confidence.
42. I am always open to new ideas and activities.
43. Sometimes I become so involved in a new idea I neglect what I should be doing.
44. I am often inventive and ingenious.
45. I enjoy trying new approaches to problems.
46. I have taken thing apart just to see how they work.
47. I have participated in theatrical productions.
48. I have a great sense of humor.
49. My stories of mysterious, physical happenings are true.
50. When I was young I was always building and playing with things.

Check boxes next to statements which you have said or would say:

☐ We’ve already tried that before.
☐ It can’t be done.
☐ See? It didn’t work!
☐ It won’t work.
☐ No way.
☐ Are you nuts?
☐ It’s a waste of time.
☐ I’m telling you it won’t work.
☐ I just know it won’t work.
☐ It’s too modern
☐ It’s to old-fashioned
☐ Not that way
☐ This is the last try.
☐ You’ve got to be kidding me.
☐ Let’s not bother.
☐ We’re not ready for it yet.
☐ Walk, don’t run.
☐ Be practical
☐ It’s been the same for twenty years so it must be good.
☐ Let’s use proven methods.
Don’t rock the boat.
We have to be practical.
It’ll mean more work.
That’s not our responsibility.
That’s not our job.
What’s the use?
Why bother?
You can’t teach an old dog new tricks.

Assessment of Past Activities and Adjective Check-list

Look at the list of activities below and check those which you have done or would enjoy doing.

☐ Wrote a poem
☐ Produced a puppet show
☐ Acted in, directed, organized, or designed stage settings for a play or skit
☐ Made up a song
☐ Explored a cave
☐ Read a science magazine
☐ Developed photographs
☐ Made or worked on a motor/engine
☐ Planted a garden
☐ Collected something (insects, stamps, antiques, flowers,…)
☐ Kept a daily log or journal
☐ Organized or helped to organize a club
☐ Figured out a way of improving something which you or others do
☐ Investigated something that interests you (out of School) government, health, fitness,…)
☐ Made a poster for a club, school, or other event
☐ Organized or helped organize a rummage, yard, or garage sale
☐ Sketched a landscape
☐ Designed jewelry or clothing
☐ Draw for funny, fantasy
☐ Drew construction plans or documents
☐ Made or altered a recipe
☐ Go above and beyond when creating something which you enjoy
☐ Obsession with a particular topic or area of study
☐ Sought out as an expert in some area
☐ Have extracurricular activities which are more important than regular school work
☐ Known as the class clown
☐ Absentminded
☐ Feel a compulsion to begin work on lots of projects
☐ Use existing knowledge as a basis for new ideas
☐ Building new structures instead of using existing ones
☐ Looks at big picture, seeing “forest” instead of “trees”
☐ Avoid perceptual sets and entrenched ways of thinking
☐ Questions the norms and assumptions
☐ Finds problems
☐ Thinks logically
☐ Flexible thinking
☐ Metaphorical thinking
☐ Uses skill and flexibility in decision making
☐ Makes independent judgments
☐ Novel
☐ Finds order in chaos
☐ Uses non verbal communication
☐ I have a good sense of humor
☐ I believe I am creative
☐ I tend to become childishly involved in simple things
☐ I am very curious
☐ I have had many hobbies
I am a risk taker
I am not bothered by mess or disorder
I enjoy things which are mysterious
I am full of energy
I enjoy being independent
I engage in odd habits or rituals
I can get lost in a problem
I enjoy complicated ideas
I ask a lot of questions
I act childish or silly at times
I am a self starter
I am self confident
I see beauty in things others may not
I am sometimes stubborn
I can be persistent
Sometimes I am sloppy
I sometimes act without planning
I question authority and rules
I am open-minded
I enjoy taking things apart
I stick with a project until it is completed
I am not afraid of being thought of as different

Mark adjectives which apply

☐ Capable
☐ Clever
☐ Confident
☐ Egotistical
☐ Humorous
☐ Individualistic
☐ Informal
☐ Insightful
Intelligent  
Interests wide  
Inventive  
Original  
Reflective  
Resourceful  
Self-confident  
Sexy  
Snobbish  
Unconventional  
Affected  
Cautious  
Commonplace  
Conservative  
Conventional  
Dissatisfied  
Honest  
Interest narrow  
Mannerly  
Sincere  
Submissive  
Suspicious

All questions on this survey are obtained from Creativity is Forever 5th edition (Davis), and have been validated through previous studies.
Biographical Assessment

Name_________________________________________________________________
Age    ________________________________________________________________
Sex   _________________________________________________________________
Year in school__________________________________________________________
Highest degree attained__________________________________________________

1. Computer Literacy, please mark those programs which you have explored.
   Microsoft Word  ☐  Microsoft Excel  ☐  Microsoft PowerPoint  ☐  Google Sketchup  ☐
   CAD  ☐  Adobe Photoshop  ☐  Adobe InDesign  ☐  Adobe Illustrator  ☐

2. Please list any other programs you use on a regular basis.
   ______________________________________________________________________

3. What computer platform are you most comfortable with, Mac ☐ or PC ☐.

4. What would you describe as your personal design style?
   ______________________________________________________________________
   ______________________________________________________________________

5. What attracted you to the interior design program? _______________________
   ______________________________________________________________________

6. If you could design one thing what would it be? _________________________

7. How many hours are you enrolled right now? _____________________________

8. How many individuals reside at your dwelling?

9. What type of dwelling do you reside in; house, apt, dorm….

10. What area of design do you wish to work?

11. When creating designs do you focus on the big picture, or do you find yourself focusing on details.

12. Have you ever had to simplify a design so that you could construct a model?

13. Please list Job History and include your title and duties,
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

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APPENDIX G

JUDGE’S SCORE SHEET

Judge: ____________________________     Product Number:___________________

Please Rate following categories on a scale of 1-6; 1 being the lowest, little to no effort shown, and 6 being the highest, above and beyond what is expected.

Dimensions of Judging

**Novelty:** The degree to which the design itself is original or striking especially in concept or style.

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**Overall Aesthetic Appeal:** In general, the degree to which the design is pleasing in appearance as a whole.

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**Overall Organization:** The degree to which the design shows a coherent unity or functioning whole, illustrates overall organization.

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**Evident Effort:** The degree to which the design shows effort, the placement and design seems to have been done to achieve a particular end

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**Balance:** The degree to which the design shows good balance, symmetrical or asymmetrical.

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**Variation of shapes:** The degree to which the design shows a wide usage of various shapes available, how many different shapes were incorporated in the design.

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**Deviation from original plan:** The degree to which the final product deviates from the original plan layout.

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**Detail:** The small elements that collectively constitute completeness, the amount of detail in the design.

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**Complexity:** The level of complexity or how intricate the overall design appears.

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**Overall Creativity:** Using your own subjective definition of creativity, the degree to which the design is creative.

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APPENDIX H

IRB APPLICATION AND APPROVAL MEMORANDUM

Online Human Subjects Application

Human Subjects Application For Full IRB and Expedited Exempt Review

1. Project Title and Identification
1.1 Project Title
Rapid Prototyping (RP): Gauging levels of Creativity.
Project is: Thesis

1.2 Principal Investigator (PI)

<table>
<thead>
<tr>
<th>Name (Last name, First name MI)</th>
<th>Highest Earned Degree</th>
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<tbody>
<tr>
<td>Conetta, Anthony Louis</td>
<td>Bachelor's Degree</td>
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<th>University Department:</th>
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<td>INTERIOR DESIGN</td>
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The training and education completed in the protection of human subjects or human subjects records: None

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<th>Occupational Position:</th>
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<tr>
<td>Student</td>
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</table>

1.3 Co-Investigators/Research Staff

1.4 Faculty Advisor/Department Chair/Dean Information

<table>
<thead>
<tr>
<th>Name (Last name, First name MI)</th>
<th>Highest Earned Degree</th>
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<tr>
<td>Randsell, Marlo</td>
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</table>

Mailing Address: 1231

<table>
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<tr>
<th>Phone Number: 850-644-1436</th>
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Fax: 850-644-1436

<table>
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<tr>
<th>University Department:</th>
<th>Email: <a href="mailto:mrandeck@fsu.edu">mrandeck@fsu.edu</a></th>
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<tbody>
<tr>
<td>INTERIOR DESIGN</td>
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The training and education completed in the protection of human subjects or human subjects records: None

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<th>Occupational Position:</th>
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2. Funding

2.1 Is this research funded by an internal (FSU) or external agency? No

How costs of research will be covered?

There will be minimal costs associated with this study. The materials used to complete study will be provided from department materials fee. All other costs associated will be taken care of.
3. Institutional Oversight

3.1 Is this research proposal being reviewed by any other institution or peer review committee?

No

4. Conflict of Interest

Federal guidelines encourage institutions to assure there are no conflicts of interest in research projects that could adversely affect the rights and welfare of human subjects. If this proposed research study involves a potential conflict of interest, additional information will need to be provided to the IRB. Examples of potential conflicts of interest may include: any sort of compensation, in cash or other form, for services to an individual and his or her immediate family, the value of which exceeds $10,000 in a one-year period or an equity interest which exceeds $10,000 or which exceeds a five percent ownership interest.

4.1 Do any of the investigators or personnel listed on this research have a potential conflict of interest associated with this study?

No

5. Payment or Other Compensation for Research Subjects

5.1 Will you give subjects gifts, payments, compensation, reimbursement, services without charge or extra credit/class credit?

No

6. Protocol Description and Other Details

6.1 Describe the objective(s) of the proposed research including purpose, research question, hypothesis, method, data analysis, research design and relevant background information etc.

Purpose: The purpose of this research study is to evaluate the effect, positive or negative, of rapid prototyping on students enrolled in design education programs; specifically the effect rapid prototyping has on student’s creativity levels. This study is intended to add to the body of knowledge relating to design education along with providing insight into the effective implementation of rapid prototyping machinery in design education programs. The data gathered in this study will then be used by faculty members of the Florida State University Interior Design program to effectively incorporate machinery into their curricula.

Research Question: The primary question to be answered through this research is: Does the introduction of rapid prototyping machinery, in early stages of design education, allow students to produce more creative products?

Method: The researcher will first review supporting literature on: the history and uses of rapid prototyping machinery, previous research studies involving rapid prototyping machinery, the four creative Ps (person, process, product, and press) and how they affect the end product, along with effective teaching techniques in design education. The literature reviewed will then influence the creation of pre and post creativity assessment tests, final product judging criteria, and a student survey and questionnaire.

The study will also produce qualitative and quantitative data. Students will turn in two final models “Products”, one created by hand, the other computer generated and created with a rapid prototyping machine. These products will be judged by trained design educators and assessed for creativity level-the level of novelty and appropriateness- of the final product. This is where all quantitative data will be obtained. In an effort to better understand the influence of rapid prototyping on students, the research will also rely on qualitative data which will be
obtained through questionnaires, surveys, and observation. The preliminary questionnaires will also include questions aimed at establishing the students' current creativity level. The post questionnaire will include similar questions to see if the students are unconsciously more creative than when they started.

Data Analysis: The data analysis that will be used for this study will include statistical analysis of survey data, pre and post exposure. The PI will also employ faculty members as trained judges to analyze creative products produced by student. This data will be analyzed to obtain whether creative products are more or less creative when comparing hand and computer generated models.

Research Design: The research design of this study will be conducted in two phases. Phase one will include wide distribution of surveys and questionnaires, to obtain students creativity level pre exposure. Phase two will include the judging of creative products produced by students, to assess creative level of hand generated product vs. computer generated product. The study will combine qualitative and quantitative techniques and data.

Background Information: Design education programs have always placed an importance on the construction of a final model. Although models are an efficient way to express Ideas, the drawbacks to model building far outweigh the positives for most students. If the model does not portray the idea successfully it is almost always going to have a negative effect on the students’ grade. Just as one builds skills in visual and media arts overtime, the same must be assumed for model building. The student may be able to visualize the perfect solution, but when it comes to constructing that solution into a physical product- they may lack the knowledge and skills necessary to do so.

6.2 Following categories will apply for the evaluation of the project:
- Questionnaires or Surveys to be administered
- Subjects studied at FSU
- Students as Subjects

6.3 Survey Techniques: the only involvement of human subjects will be in the following categories:
- Research on normal educational practices in commonly accepted educational settings
- Research involving educational tests (cognitive, diagnostic, aptitude, achievement)
- Research involving survey or interview procedures

Research involving survey or interview procedures:
1. Responses will be recorded in such a manner that human subjects cannot be identified, by persons other than the researcher, either directly or through identifiers linked to the subjects. Yes

2. Would subjects’ responses, if they became known outside the research, reasonable place the subject at risk of criminal or civil liability or be damaging to the subjects’ financial standing or employability. No

3. The research deals with sensitive aspects of the subject’s own behavior, such as illegal conduct, drug use, sexual behavior, or use of alcohol. No

6.4 This study will include following methods:
- Experimental/Control Design
- Qualitative
- Quantitative

6.5 Describe the tasks subjects will be asked to perform.
Upload surveys, instruments, interview questions, focus group questions etc. Describe the frequency and duration of procedures, psychological tests, educational tests, and experiments; including screening, intervention, follow-up etc. (If you intend to pilot a process before recruiting for the main study please explain.)

The survey that will be distributed will focus on the students’ biographical history, and current...
level of creativity. The survey will be distributed during normal class time, and take approximately 20 minutes. After completing the study the students’ will be asked to reflect on positive and negative aspects while using the rapid prototyping machinery. This study will take place during the Fall 2011 semester.

6.6 How many months do you anticipate this research study will last from the time final approval is granted?

2

7. Participant (Subject) Population

7.1 Expected number of participants
   Number of male: 4  Number of female: 32
   Expected number of participants: 36

7.2 Expected Age Range
   - 18-65

7.3 Inclusion/Exclusion of Children in this Research
   Exclusion
   If this study would exclude children, NIH guidelines advise that the exclusion be justified, so that potential for benefit is not unduly denied. Indicate whether there is potential for direct benefit to subjects in this study and if so, provide justification for excluding children. Note that if inclusion of children is justified, but children are not seen in the PI’s practice, the sponsor must address plans to include children in the future or at other institutions.
   - No direct benefit established (exclusion of children permissible)
   Provide justification for exclusion of children:

   Any subject involved in this study will be enrolled at Florida State University. Therefore, none of the subjects will be under the age of 18.

7.4 Other Protected Populations to be Included in this Research
   - Gender Imbalance - all or more of one gender

7.5 Inclusion and Exclusion of Subjects in this Research Study
   Describe criteria for inclusion and exclusion of subjects in this study

   Inclusion Criteria:
   All students enrolled in Design Fundamentals 1 (IND1203) will be asked to participate.

   Exclusion Criteria:
   Only those students enrolled in IND 1203, will be asked to participate. All others will be excluded.

7.6 Location of subjects during research activity or location of records to be accessed for research
   - Florida State University

7.7 Describe the rationale for using each location checked above
   Upload copies of IRB approvals or letters of cooperation from other agencies or sites, if it has been granted or
Data will be collected during class time, therefore all research will be conducted on Campus.

8. Recruitment of Participants (Subjects)

8.1 Describe the recruitment process to be used for each group of subjects

There is no recruitment process. Those enrolled in INDI203 will be asked to participate, but will not be forced to participate.

8.2 Explain who will approach potential subjects to take part in the research study and what will be done to protect individuals' privacy if required in this process

The PI, Anthony Conetta

8.3 Are subjects chosen from records?

No

8.4 FSU policy prohibits researchers from accepting gifts for research activities. Is the study sponsor offering any incentive connected with subject enrollment or completion of the research study (i.e. finders fees, recruitment bonus, etc.) that would be paid directly to the research staff?

No

9. Risks and Benefits

9.1 The research may involve following possible risks or harms to subjects:

9.2 Does the Research Involve Greater Than Minimal Risk to Human Subjects?

"Minimal Risk" means that the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

No

9.3 Explain what steps will be taken to minimize risks or harms and to protect subjects' welfare. If the research will include protected populations (see question 7.4) please identify each group and answer this question for each group.

All data collected will be coded and stored on the PI's Computer or in locked storage.

9.4 Describe the anticipated benefits of this research for individual subjects in each subject group. If none, state "None".

None

9.5 Describe the anticipated benefits of this research for society, and explain how the benefits outweigh the risks.

The benefits to participation are to help assess the most efficient way of implementing rapid prototyping in preliminary studio classes.
10. Confidentiality of Data

10.1 Will you record any direct identifiers, names, social security numbers, addresses, telephone numbers, email addresses, cookies etc.?  

Yes  
Explain why it is necessary to record findings using these identifiers and describe the coding system you will use to protect against disclosure of these identifiers:  
Students names will be taken at the beginning of study. After this moment all students will be referred to as a coded number.

10.2 Will you retain a link between study code numbers and direct identifiers after the data collection is complete?  
No

10.3 Will you provide the link or identifier to anyone outside the research team?  
No

10.4 Where, how long, and in what format (such as paper, digital or electronic media, video, audio, or photographic) will data be kept? In addition, describe what security provisions will be taken to protect this data (password protection, encryption, etc.)  

All data will be retained until the study is completed. Electronic data will be stored on the PI's computer. Paper responses will be kept in a locked cabinet with access only given to PI and committee.

10.5 Will you place a copy of the consent form or other research study information in the subjects' record such as medical, personal or educational record?  
No

10.6 If the data collected contains information about illegal behavior, please refer to the NIH Certificate of Confidentiality Kiosk for information about obtaining a Federal Certificate of Confidentiality.

11. Use of Protected Health Information (PHI): HIPAA Requirements

In the course of conducting research, researchers may desire to obtain, create, use, and/or disclose individually identifiable health information. Under the HIPAA Privacy Rule, covered entities (healthcare providers, health plans, employer or healthcare clearinghouses) are permitted to use and disclose protected health information for research with individual authorization, or without individual authorization under limited circumstances set forth in the Privacy Rule.

11.1 As part of this study, will you be accessing PHI from a covered entity for research purposes?  
No

12. Informed Consent Process

12.1 Recognizing that consent itself is a process of communication, please expand on your responses to questions 8.1 and 8.2 and describe what will be said to the subjects to introduce the research.  

Subjects will be given a brief explanation of the study and asked to read the consent form. After this subjects will be fully informed on all parts of research.

12.2 In relation to the actual data gathering, when will consent be discussed and documentation obtained?
10. Confidentiality of Data

10.1 Will you record any direct identifiers, names, social security numbers, addresses, telephone numbers, email addresses, cookies etc.?

Yes

Explain why it is necessary to record findings using these identifiers and describe the coding system you will use to protect against disclosure of these identifiers:

Students names will be taken at the beginning of study. After this moment all students will be referred to as a coded number.

10.2 Will you retain a link between study code numbers and direct identifiers after the data collection is complete?

No

10.3 Will you provide the link or identifier to anyone outside the research team?

No

10.4 Where, how long, and in what format (such as paper, digital or electronic media, video, audio, or photographic) will data be kept? In addition, describe what security provisions will be taken to protect this data (password protection, encryption, etc.)

All data will be retained until the study is completed. Electronic data will be stored on the PI's computer. Paper responses will be kept in a locked cabinet with access only given to PI and committee.

10.5 Will you place a copy of the consent form or other research study information in the subjects' record such as medical, personal or educational record?

No

10.6 If the data collected contains information about illegal behavior, please refer to the NIH Certificates of Confidentiality Kiosk for information about obtaining a Federal Certificate of Confidentiality.

11. Use of Protected Health Information (PHI): HIPAA Requirements

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11.1 As part of this study, will you be accessing PHI from a covered entity for research purposes?

No

12. Informed Consent Process

12.1 Recognizing that consent itself is a process of communication, please expand on your responses to questions 8.1 and 8.2 and describe what will be said to the subjects to introduce the research.

Subjects will be given a brief explanation of the study and asked to read the consent form. After this subjects will be fully informed on all parts of research.

12.2 In relation to the actual data gathering, when will consent be discussed and documentation obtained?
12.3 Please name the specific individuals who will obtain informed consent and include their job
title/credentials and a brief description of your plans to train these individuals to obtain informed consent
and answer subject's questions:

The PI, Anthony Conetta. No one else will be obtaining consent.

12.4 What questions will you ask to assess the subjects' understanding of the risks and benefits of
participation?

After subjects read the consent form time will be allotted for any questions they may have.

12.5 Informed Consent Waivers

☐ Request waiver of documentation of consent.

☐ The only record linking the subject and the research would be the consent form and the principle risk of the
research would be the potential harm from a breach of confidentiality (if checked, explain below):

☐ The research involves minimal risk and includes no procedures for which written consent is normally required
outside the research context.

☐ Request waiver of some or all elements of consent.

☐ The research involves no more than minimal risk to the subjects.

☐ A waiver will not adversely affect the rights and welfare of the subjects.

☐ The research could not practically be carried out without waiver or alteration.

☐ Where appropriate, the subjects will be provided with additional pertinent information after participation (if
checked, explain below):
APPROVAL MEMORANDUM
Date: 9/30/2011
To: Anthony Conetta
Dept.: INTERIOR DESIGN
From: Thomas L. Jacobson, Chair
Re: Use of Human Subjects in Research
Rapid Prototyping (RP): Gauging levels of Creativity.

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 9/26/2012 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.
Cc: Marlo Ransdell, Advisor
HSC No. 2011.7038
APPENDIX I

APPROVED LETTER OF CONSENT (STUDENTS)

FSU Behavioral Consent Form

Rapid Prototyping (RP): Gauging levels of Creativity.

You are invited to be in a research study that will evaluate the effect of rapid prototyping on individual students’ creativity level. You were selected as a possible participant because you are in enrolled in Design Fundamentals 1 (DF1) during the Fall semester of 2011. Please read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Anthony Conetta, Graduate Student, Department of Interior Design, Florida State University.

Background Information:

The purpose of this research study is to evaluate the effect, positive or negative, of rapid prototyping on students enrolled in design education programs; specifically the effect rapid prototyping has on individual students’ creativity levels.

Procedures:

If you agree to be in this study, you will be asked to do the following things: complete a brief questionnaire prior to study that is meant to establish a creativity level pre exposure; create both hand and computer generated models, to be judged; and lastly complete an exit survey gauging creativity level post exposure as well as obtaining participants’ feedback on rapid prototyping machinery. This study will take place during regularly scheduled DF1 class times.

Risks and benefits of being in the Study:

There are minimal risks associated with this study.

The benefits to participation are to help assess the most efficient way of implementing rapid prototyping in preliminary studio classes.

Compensation:

There is no compensation associated with the study.

Confidentiality:

The records of this study will be kept private and confidential to the extent permitted by law. All students who participate will be designated a number to ensure anonymity. In any sort of report I might publish, I will not include any information that will make it possible to identify subjects. Research records will be stored securely in a locked cabinet and only the researcher and committee will have access to these records.

Voluntary nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University or with the Interior Design Department. It is important to note that all aspects of the course will be the same whether you decide to participate or not, and that non participation will not affect your grade in any way. If you decide to participate, you are free to not answer any questions or withdraw at anytime without affecting those relationships.

Contacts and Questions:

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the FSU IRB at 2010 levy street, Research building B, Suite 276, Tallahassee, Fl 32306-2742, or 850-644-8633, or by email at humansubjects@magnet.fsu.edu.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and received answers. I consent to participate in the study.

________________________  __________________________
Signature                  Date

________________________  __________________________
Signature of Investigator Date

APPENDIX J

APPROVED LETTER OF CONSENT (FACULTY)

FSU Behavioral Consent Form

Rapid Prototyping (RP): Gauging levels of Creativity.

You are invited to be in a research study that will evaluate the effect of rapid prototyping on individual students' creativity level. You were selected as a possible participant because you are a faculty member of The Florida State University's Department of Interior Design. Please read this form and ask any questions you may have before agreeing to be in the study.

This study is being conducted by Anthony Conetta, Graduate Student, Department of Interior Design, Florida State University.

Background Information:

The purpose of this research study is to evaluate the effect, positive or negative, of rapid prototyping on students enrolled in design education programs; specifically the effect rapid prototyping has on individual students' creativity levels.

Procedures:

If you agree to be in this study, you will be asked to do the following things: complete a training session outlining how to judge products created by students, review the judging sheet, participate in practice judging sessions to ensure there is sound judging across the board, and finally judge products created by students.

Risks and benefits of being in the Study:

There are minimal risks associated with this study.

The benefits to participation are to help assess the most efficient way of implementing rapid prototyping in preliminary studio classes.

Compensation:

There is no compensation associated with the study.

Confidentiality:

The records of this study will be kept private and confidential to the extent permitted by law. All students who participate will be designated a number to ensure anonymity. In any sort of report I might publish, I will not include any information that will make it possible to identify subjects. Research records will be stored securely in a locked cabinet and only the researcher and committee will have access to these records.

Voluntary nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University or with the Interior Design Department. If you decide to participate, you are free to not answer any questions or withdraw at anytime without affecting those relationships.

Contacts and Questions:

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, you are encouraged to contact the FSU IRB at 2010 levy avenue, Research building B, Suite 276-C, Tallahassee, Fl 32306-2742, or 850-644-7900, or by email at humansubjects@magnet.fsu.edu.

You will be given a copy of this information to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and received answers. I consent to participate in the study.

_________________________    ______________
Signature                        Date

_________________________    ______________
Signature of Investigator          Date

## APPENDIX K

### DF1 (IND 1203) SYLLABUS

#### DESIGN FUNDAMENTALS I      IND 1203      Fall 2011

<table>
<thead>
<tr>
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<th>Date</th>
<th>Subject</th>
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<td>1</td>
<td>M Aug 29</td>
<td>Welcome; Classroom Exercise: Diagramming; Creativity</td>
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<td>due: Project 1, Diagram of a Journey (5%)</td>
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<td>Classroom Exercise: Composition; organizational elements</td>
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<td>Introduce Composition Analysis</td>
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<td>3</td>
<td>M Sep 5</td>
<td>LABOR DAY HOLIDAY</td>
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<tr>
<td>4</td>
<td>W Sep 7</td>
<td>Classroom Exercise: Composition; rhythm, emphasis</td>
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<td>M Sep 12</td>
<td>due: Project 2, Composition Analysis (5%)</td>
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<td>Introduce Line Composition</td>
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<td>Classroom Exercise: Line</td>
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<td>6</td>
<td>W Sep 14</td>
<td>Classroom Exercise: Line</td>
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<td>due: Project 3, Line Composition (5%)</td>
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<td>Introduce Black and White Study</td>
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<td>Classroom Exercise: Negative/positive space</td>
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<td>Classroom Exercise: Negative/positive space</td>
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<td>9</td>
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Introduce **Value Scales**
Classroom Exercise: Value

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<td>due: <strong>Project 6, Negative/Positive Space</strong> (10%)</td>
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<td>Classroom Exercise: Planes 1</td>
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<td>Classroom Exercise: Planes 2</td>
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<td>Introduce <strong>Projected Line Composition (hand), Project 8a</strong></td>
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<td>17 M</td>
<td>Oct 24</td>
<td>Computer Lab: introduce SketchUp software</td>
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<td>18 W</td>
<td>Oct 26</td>
<td>due: <strong>Project 8a, Projected Line Composition</strong> (hand) (5%)</td>
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<tr>
<td></td>
<td></td>
<td>Introduce <strong>Projected Line Composition(digital), Project 8b</strong></td>
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19 M Oct 31 Classroom Exercise: Linear Elements
(Experience wheelchair)

20 W Nov 2 due: Project 8b, Projected Line Composition (digital) (5%)
Introduce Linear Elements
Classroom Exercise: Linear Elements

21 M Nov 7 Classroom Exercise: Linear Elements

22 W Nov 9 due: Project 9, Linear Elements Project (5%)
Introduce Serial Planes
Classroom Exercise: end, edge, side treatments

F Nov 11 VETERAN'S DAY HOLIDAY

23 M Nov 14 Classroom Exercise: Serial Planes

24 W Nov 16 due: Project 10, Serial Planes Project (10%)
Introduce Form and Function
Classroom Exercise: Form and Function

25 M Nov 21 Classroom Exercise: Form and Function

W/R/F Nov 23-25 THANKSGIVING HOLIDAY

27 M Nov 28 Classroom Exercise: Form and Function

28 W Nov 30 Classroom Exercise: Form and Function

29 M Dec 5 Journals due

30 W Dec 7 LAST DAY OF CLASS.
due: Project 11, Form and Function Proj. (clock) (15%)
## APPENDIX L

### SUMMARY OF DAILY ACTIVITIES

| Session 15 | • Handout on materials used in model making  
|            | • Handout on how to manipulate materials  
|            | • Exercise 1  

| Session 16 | • Exercise 2  
|            | • Introduce project 8a  

| Session 17 | • Introduce Sketchup  
|            | • Handout on SketchUp  
|            | • Help with questions related to 8a  

| Session 18 | • Project 8a due  
|            | • Introduce project 8b  

| Session 19 | • Classroom exercise: serial planes (this does not apply to research)  
|            | • Help with questions related to 8b  

| Session 20 | • Turn in project 8b  |
APPENDIX M

EXERCISE 1

Moving into the third dimension
APPENDIX N

EXERCISE 2
APPENDIX O

INTRODUCTION TO SKETCHUP

Shift + Scroll Bar = Pan
Scroll Bar = Orbit
Scroll in/out = Zoom in/out
Space Bar = Select
R = Rectangle
M = Move
Q = Rotate
S = Scale
L = Line
A = Arch
F = Offset
E = Eraser
P = Push/Pull
B = Paint Bucket
T = Tape Measure
G = Make Component
Shift + Z = Zoom Extents
Ctrl + Z = Undo
Esc = Exit out of any command
SketchUp works in three dimensions.

Remember:
X, Y, & Z axis – Green, Red, and Blue.
To match a point hover over that point for 2 seconds and then it will lock.
For an object to be pushed or pulled it must be a closed loop.
Making Components/Groups is essential when building complex objects.
APPENDIX P

HAND MODELING PROJECT

DF1: Project 8a (Hand Model) - PROJECTED LINE COMPOSITION

Project Description, Part a:
Using the black and white composition provided in the syllabus, evolve the lines into planes of various lengths and values. Plane thickness should correspond to thickness of lines in the original composition.

Project Requirements:
With a piece of cardboard 8 ½” x 11” acting we had talked about making the requirement and equal square, to make everything more standard for judging. 12”x12” or 6”x6” as the "base" of the composition, use the given composition as a “plan view” of 2 possible design configurations of plane relationships. Both designs shall be mounted on the same base (each composition oriented in the same direction for comparison purposes.) Use value to heighten the form/shape differences between the two compositions. On the base, include your name and PROJECTED LINE.

Project Duration: 1 week. Project Value: 5%
APPENDIX Q

COMPUTER MODELING PROJECT

DF1: Project 8b (Computer Model) - PROJECTED LINE COMPOSITION

Project Description, Part b:
Using the same back and white composition provided in the syllabus, evolve the lines into planes of various lengths and values. Plane thickness should correspond to thickness of lines in the original composition. Create a different solution from your hand crafted model.

Project Requirements:
You will be given instruction in the use of SketchUp software, and time in class (in the CAD Lab) to work on a tutorial. You are to develop the whole project digitally. As in Part a, use the given composition as a “plan view” of 2 possible design configurations of plane relationships. Use value to heighten the form/shape differences between the two compositions. Part b will be submitted in a printed (8 ½ x 11”) format. Provide at least 4 views of the dual compositions (always seen together!) Make sure your name is on each sheet.

BONUS: You will be given directions to download your SketchUp file and a 3-D model will be created of your project with the Program’s new laser router!

Project Duration: 1 week. Project Value: 5%

Critiques for both projects will be done on the same day (Session 20).
APPENDIX R
DATA FROM QUESTIONNAIRE

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</table>
APPENDIX T

CREATIVE BEHAVIOR’S INVENTORY

Creative Behavior Inventory (Hocevar, 1979, 1980)


This is an inventory, not a test. The inventory is simply a list of activities and accomplishments that are commonly considered to be creative. For each item, circle the answer that best describes the frequency of the behavior in your adolescent and adult life. Be sure to answer every question, and don’t worry about duplicate or similar items.

<table>
<thead>
<tr>
<th></th>
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<th>3-4</th>
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<th>5-6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Never</td>
<td>Once</td>
<td>Twice times</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Received an award for acting.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>2.</td>
<td>Worked as an editor for a school or university literary publication.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>3.</td>
<td>Worked as an editor for a newspaper or similar organization.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>4.</td>
<td>Constructed something that required scientific knowledge such as a radio, telescope, scientific apparatus, etc. (excluding school or university course work).</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
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<tr>
<td>5.</td>
<td>Painted an original picture.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>6.</td>
<td>Designed and made your own greeting card.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>7.</td>
<td>Gave a recital.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>8.</td>
<td>Presented an original mathematics paper to a professional or special interest group.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>9.</td>
<td>Founded a literary magazine or similar publication.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>10.</td>
<td>Made a craft out of metal (excluding school or university work).</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>11.</td>
<td>Made candles.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>12.</td>
<td>Knitted or crocheted something (excluding school or university work).</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>13.</td>
<td>Put on a puppet show.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>14.</td>
<td>Made your own holiday decorations.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3-4</td>
<td>5-6</td>
</tr>
<tr>
<td>15.</td>
<td>Built a hanging mobile (excluding school or university work).</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<td>5-6</td>
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<tr>
<td>16.</td>
<td>Received an award for performance in modern dance or ballet.</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<td>5-6</td>
</tr>
<tr>
<td>17.</td>
<td>Received an award for performance in popular dance.</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<td>5-6</td>
</tr>
</tbody>
</table>

19. Made a sculpture (excluding school or university work).

20. Had an original music published or publicly performed.

21. Had a piece of literature (poem/short stories, etc.) published in
    a school or university publication.

22. Developed an experimental design (excluding school or university work).

23. Wrote poems (excluding school or university work).

24. Entered a project into a science contest.

25. Received an award for an artistic accomplishment.

26. Received an award for making a craft.

27. Made a craft out of plastic, Plexiglas, stained glass or a similar material.

28. Made cartoons.

29. Made a leather craft.

30. Made a ceramic craft.

31. Wrote music for one instrument.

32. Wrote music for several instruments.

33. Designed and made a piece of clothing

34. Cooked an original dish.

35. Prepared an original floral arrangement.

36. Applied math in an original way to solve a practical problem
    (excluding school or university work).

37. Wrote an original computer program (excluding school
    or university work).

38. Drew a picture for aesthetic reasons.

39. Wrote the lyrics to a song.

40. Choreographed a dance.

41. Wrote a short story (excluding school or university work).

42. Wrote something humorous such as jokes, limericks, satire, etc.

43. Made jewelry.

44. Recorded a music record or CD.

45. Put on a radio show.

46. Had a piece of literature (poem, short story, etc.) published
    (not in a school or university-related publication).

47. Took and developed your own photographs.

48. Performed ballet or modern dance in a show or contest.

49. Had art work or craft work publicly exhibited.

50. Won an award for musical accomplishments.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
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<th>2</th>
<th>3-4</th>
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<tr>
<td>51</td>
<td>Wrote clever or humorous letters.</td>
<td></td>
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<tr>
<td>52</td>
<td>Won an award for a scientific project or paper.</td>
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<tr>
<td>53</td>
<td>Assisted in the design of a set for a musical or dramatic production.</td>
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<tr>
<td>54</td>
<td>Had art work published in a school or university publication.</td>
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<tr>
<td>55</td>
<td>Had a role in a dramatic production.</td>
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<tr>
<td>56</td>
<td>Had art work published.</td>
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<tr>
<td>57</td>
<td>Started but did not finish a novel.</td>
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<td>58</td>
<td>Wrote and completed a novel.</td>
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<td>59</td>
<td>Made or helped make a film or video tape.</td>
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<td>60</td>
<td>Won an award for some achievement in literature.</td>
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<td>Entered a mathematical paper or project into a contest.</td>
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<td>62</td>
<td>Had a scientific paper published.</td>
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<tr>
<td>63</td>
<td>Planned and kept a garden.</td>
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<td>64</td>
<td>Kept a sketch book.</td>
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<td>65</td>
<td>Was a participating member of a symphony orchestra.</td>
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<td>66</td>
<td>Entered a contest as a singer.</td>
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<td>67</td>
<td>Entered a contest as a musician.</td>
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<td>68</td>
<td>Directed or managed a dramatic production.</td>
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<td>69</td>
<td>Designed and made a costume.</td>
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<tr>
<td>70</td>
<td>Played an instrument (percussion, including piano) with a reasonable degree of proficiency.</td>
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<tr>
<td>71</td>
<td>Played an instrument (string) with a reasonable degree of proficiency.</td>
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<td>Played an instrument (brass) with a reasonable degree of proficiency.</td>
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<td>73</td>
<td>Played an instrument (wind) with a reasonable degree of proficiency.</td>
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<td>Participated in a drama workshop, club, or similar organization.</td>
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<td>75</td>
<td>Participated in a craft workshop, club, or similar organization.</td>
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<td>Participated in a writers’ workshop, club, or similar organization.</td>
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<td>Participated in a dance workshop, club, or similar organization.</td>
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Carlson, S. (2005). The next generation goes to college. The chronicles of higher education; information technology, Retrieved from chronicle.com/free/v52/i07/07a03401.htm


Instructional Technology & Association for Educational Communications and Technology. Available From http://reusability.org/read/chapters/wiley.doc.

BIOGRAFICAL SKETCH

Education

Florida State University

August 2010 – Present:
- Obtaining Master's of Fine Arts in Interior Design
- Composing Research Thesis: The Technological Impact on Creativity: assessing the impact of computer modeling and rapid prototyping on perceived creativity.
- Current GPA 3.4/4.0

May 2008 – August 2010:
- Bachelor's of Science in Interior Design
- Graduated with Honors/Deans list 3.2/4.0

State College of Florida Manatee-Sarasota

August 2004 – December 2007:
- Associates in Arts Degree
- Graduated with Honors/Deans List 3.4/4.0

Skills and Awards

August 2009 – Present:
- Founder and President of the Florida State USGBC Students Organization

August 2010 – Present:
- Created TC Designs: Focused on custom design, and fabrication printing through screen and spray techniques, Also focus on custom pieces of furniture created from recycled furniture.

January 2011 – Present:
- Teaching assistant in Furniture Design as well as technology assistant for the Florida State University.

Software Proficiency:
- AutoCad
- Revit
- 3DS Max
- Cap
- Google Sketchup

Microsoft Office
- Word
- Excel
- Power Point

Adobe Creative Suite
- Photoshop
- Illustrator
- InDesign

Internet Based Programs
- Jing-Screen capture
- Animoto
- Prezi
- Officezilla

Computer Skills:
- Audio and Video editing & mixing
- Graphic Design
- Logo Design
- Tattoo Design