Imagination + Imagery: A Model for Design Pedagogy

by

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ABSTRACT

The Imagination + Imagery model for design pedagogy is presented. Two studies were conducted to develop the model: (a) the visual imagery assessment of design students; and (b) a historical research on the concept of imagination. Results suggest the following implications as the components of strong imagination for design thinkers: (a) the ability to shape vivid images of objects in mind; (b) the ability to mentally transform the spatial representations of images; (c) to consider the ethical consequences of imagined situation; (d) to use imagination for resolving design wicked problems; and (e) to actively imagine for mental and emotional health.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter starts with the problem statement explaining the background and motivations of the current study. Then, the significance and primary objectives of the research will be described. Next, the scope and limitations of the study will be presented. Finally, the chapter ends with definitions and abbreviations that are important to this research study.

1.1.1 Demand for a New Pedagogical Model

Given the obsession with user-centered and technical approaches in the design process, the designers themselves are being overlooked. Human-centered design has had an undeniable impact on the innovative culture of the 21st century. However, this process has overlooked the human in the designers themselves and has limited their potential growth. In 1998, Hugues Boekraad and Joost Smiers expressed their concerns about the degeneration of designers into specialists who serve product engineering and marketing campaigns rather than social reform (Boekraad & Smiers, 1998). They wrote: “Design is in danger of becoming a branch of product development, marketing communication, and technological fetishism”. Currently, most design schools provide curriculums which are influenced by the modern demand for better customer experience, while the designer experience is being neglected. However, design initially emerged from the Bauhaus model with considerable attention to the inner states of the artists and designers. Walter Gropius, the founder of the Bauhaus school inscribed in his manifesto: “We perceive every form as the embodiment of an idea, every piece of work as a manifestation of our innermost

selves. Only work which is the product of inner compulsion can have spiritual meaning" (Gropius, 1923, para.1).

Gropius believed that the lifeless production of objects will enslave the individuals and disorder society. He suggested that the key for this problem is in the hands of designers: "...The solution depends on a change in the individual's attitude toward his work, not on the betterment of his outward circumstances, and the acceptance of this new principle is of decisive importance for new creative work" (Gropius, 1923, p. 1).

Boekraad and Smiers (1998) claimed that returning to the Bauhaus manifesto does not provide a solution for "the disturbing effect of product engineering and marketing on design and the visual arts". However, Gropius philosophy could be somehow adapted into the modern design education by the help of new discoveries in cognitive science and psychology. For example, researchers and instructors can utilize the empirical studies of the mind (Oxman, 2001), creativity (Kowaltowski, Bianchi, & De Paiva, 2010), and imagination (Lin, Hsu, & Liang, 2014) to develop new design curriculums.

This study seeks to address this need for a new educational strategy, by proposing a model which is focused on the design students and their cognitive abilities rather than artifacts and their qualities. This model is developed to explain the potential of intentionally integrating historical and modern understandings of imagination into the design education process. The findings of two studies are utilized to outline the Imagination + Imagery (I+I) model: (a) the assessment of cognitive spatial and object visual abilities of design students; (b) a historical research on the concept of imagination from Aristotelian phantasma to the quasi-pictorial theory of visual imagery. More details about both studies and their objectives can be found in the following sections.

1.1.2 Visual Imagery Profile

Two critical aspects of a designer's experience are visual perception and cognition. From the observation of an artifact or prototype, to the visual reasoning and planning, the creation experience highly depends on what a designer sees and imagines. In the cognitive science, the closest concept to imagination is called Visual Imagery (VI). The technological and methodological advances in this field have enabled researchers to generate VI profiles for individuals based on their specialty. However, the previous work (Kozhevnikov, Blazhenkova, & Becker, 2010) has been only focused on the VI profiles of visual artists and scientists and neglected the VI preference of designers as an independent group. The first study therefore particularly discovers the characteristics of designers' VI abilities. Returning to the goals of the I+I model in section 1.1.1, the VI profile of design students could be a predictor for their exclusive educational needs.

1.1.3 History of Imagination

Although the cognitive view of imagination has been empirically studied in the laboratory contexts (Hueur, Fischman, & Reisberg, 1986; Reisberg, Culver, Hueur, & Fischman, 1986), it does not address the intuitive, psychological, and philosophical aspects of imagination. Nigel J.T. Thomas (2014), a contemporary mind philosopher, claims that scientists invoke imagination in their processes. However, given the subjective nature of imagination, it is not seen as a phenomenon worthy of further scientific investigation. He argues that advances in the science of mental imagery have been divorced from the rich history of imagination.

This was the motivation to explore the history of imagination in the second part of this research. It was believed that the results of VI research could not be applied to the design education without reflecting on the historical context of imagination.

1.2 Justification: Imagination + Imagery as an Educational Resource

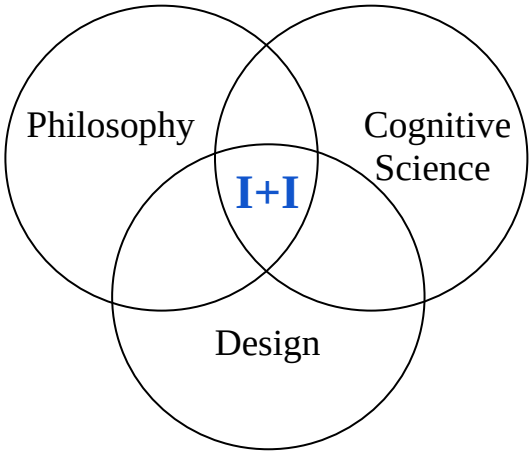

Figure 1. Justification

The contribution of the I+I model is that it expands the boundaries of design education on one hand to the cognitive neuroscience, and on the other hand to the history of mind philosophy. In this model (Figure 1.1), the concept of imagination is considered as a meaning-making capacity which has neurological dimensions and could be employed toward success in the design field. Educators could employ the I+I model toward the following goals:

- To explain object and spatial visual abilities;
- To understand the specific VI profile of the designers as an independent professional group;
- To realize the historical changes to the definitions and applications of imagination;

- To appreciate the value of imagination as a human power;
- To plan lessons that enhance awareness about this capacity among design students.

1.3 Research Goals

In order to develop the I+I model, it is necessary to recognize (a) 'how' the design students tend to form and manipulate the images in their mind, and (b) 'what' the possible applications of this power are to their personal and professional growth. Therefore, the research boundary was set according to these goals. The details of research questions and goals can be found in chapter 3.

1.4 Scope and Limitations

The ultimate goal of this study is to cultivate a research-based model to connect imagination science and history to design education. The I+I is an informative model and does not teach any skills. Hence, the reliability assessment of I+I is not attempted in the current research.

1.4.1 Study One: Visual Ability Profile

There are different cognitive theories for VI abilities (Paivio, 1970; Shepard & Metzler, 1971; Kosslyn, 1993). Stephen Michael Kosslyn's (1995) theory is the only platform that provides empirical research tools to assess the individual differences in these abilities. Therefore, his theory is the skeleton for the first study. The spatial and object VI abilities of design students are analyzed comparing them with those of students from two other majors: engineering and humanities. All of the participants are students at Arizona State University (ASU) in one of the following departments: the Herberger Institute for Design and the Arts (HIDA), the Ira A. School of Engineering, and the T. Denny Sanford

School of Family and Human Dynamics. Participants are not required to be students of a specific major. It is enough if they belong to one of the three general fields of design, engineering, and humanities. For example, any student from the following majors is considered as a design student: architecture, industrial design, graphic design, or design studies. They use a device e.g. phone or laptop in a classroom context to take the two VI tests for 15 minutes. Students do not have access to the tests prior to the class.

Some people do not possess visual imagery abilities due to brain injury or other neurological reasons (Zeman, Dewar, & Della Sala, 2015). This rare situation is called *aphantasia* and is not addressed in the scope of this study.

1.4.2 Study Two: History of Imagination

To investigate the historical meanings and purposes of imagination, primary and secondary sources from mind philosophy and psychology are studied. Many diverse notions and opinions associated with imagination are found in the literature. The ones related to the personal and professional growth in the design field are documented towards building the I+I model.

1.5 Glossary and Definitions

The generally accepted use of Visual Imagery (VI) is referred to as the ability of forming mental representations of objects without sensory input and to transform these representations in the mind (Kosslyn, 1995). VI abilities are divided into two independent categories: one for visual appearances of objects and one for their spatial representation. Described by cognitive neuroscience evidence, Object Visualization (OV) and Spatial Visualization (SV) have separate visual processing pathways in the brain (Courtney, Ungerleider, Keil, & Haxby, 1996; Mishkin & Ungerleider, 1982; Motes, Malach, &

Kozhevnikov, 2008). There are two types of visualizers, namely: object visualizers, i.e. those with stronger OV, and spatial visualizers, i.e. those with stronger SV. The details of VI abilities can be found in section 2.2.3.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reports the literature on the underlying facts of the current study. The section 2.2 presents a historical overview on the development of design as a distinct discipline which stands at the confluence of art and science fields. Then it explains the theory of Visual Imagery (VI) and its connection to success in art, science, and design. In section 2.3, a brief history of imagination as a parent concept for Visual Imagery is provided. Finally, an overview of ethical imagination in design is described in the section 2.4.

2.2 Conceptual Framework

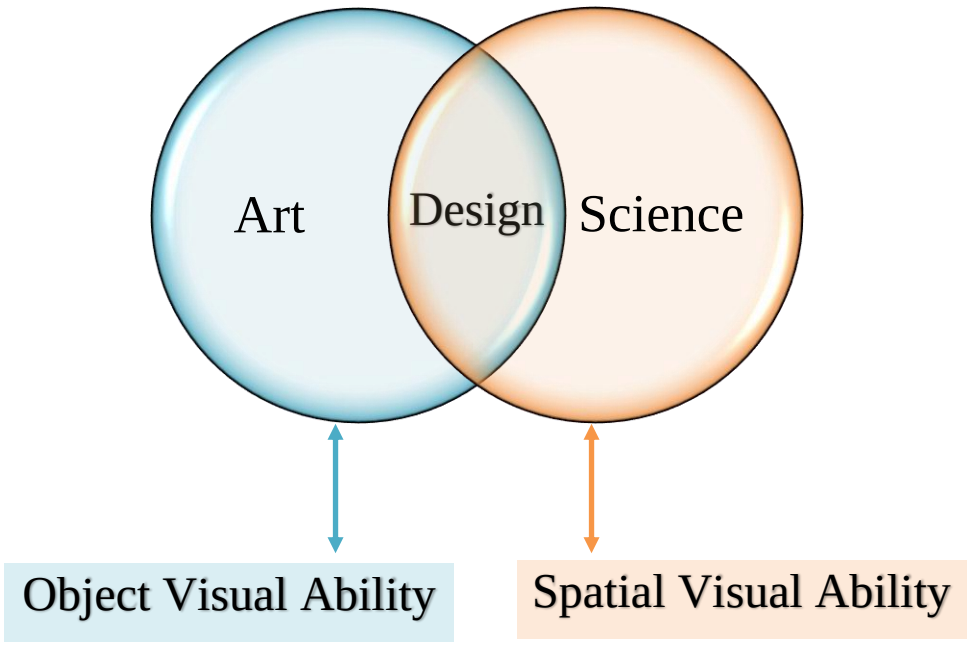

Figure 2. Conceptual Framework

2.2.1 The Bauhaus: First Design School

In 1919, Walter Gropius founded the Bauhaus in Germany. His manifesto was inspired by the wartime experience, the art and craft movement, aesthetics of William Morris's art, and most significantly by the functionalism and rationalism of the 20th century (Jamison, Christensen, & Botin, 2011). For Gropius, there was not a big difference between artist and craftsman. The only difference he noted was that the artist is a craftsman who is able to bring functionality and aesthetics together, what he saw as an *upgrading* of the craftsman (Gropius, 1919).

He also believed in an inner power in the artists that takes craftsmanship to an ethical and aesthetic level. This approach attracted artists like Johannes Itten and Wassily Kandinsky to teach at the Bauhaus. Their attempt was to provide a creative learning environment that couples functionality with metaphysics and aesthetics. Itten's approach in teaching colors, compositions and light in painting was inspired by Buddhism, and he was famous for performing Zen exercises to start his classes. Kandinsky also paid attention to the spiritual values; his book *On the Spiritual in Art* 1912 was his starting point for lecturing in the Bauhaus (Jamison et al., 2011).

As a response to the destruction from the first World War, the Bauhaus of the Weimar years paid a great deal of attention to existentialism as well as functionalism in design education. The school sought artists and engineers to tame the disastrous elements of the modern technological civilization through interdisciplinary collaborations.

In 1926, the Bauhaus moved to Dessau under the influence of the Nazi party in Weimar. Spirituality faded from the new school's curriculum and was replaced by focusing on functionalism and user needs. The school was closed down in 1933 by Nazis

(Jamison et al., 2011). After World War II, from the three components of the Bauhaus manifesto; functionalism, aesthetics, and metaphysics, the latter was removed from the design education process.

2.2.2 Design as a Distinct Discipline

After the influence of Bauhaus, the concern of design education changed from the "scientific design product" in 1920 to the "scientific design process" in 1960 (Cross, 2001). *The Conference on Design Methods* in 1962 attempted to highlight the importance of science-based design methodologies. In this conference, despite the scientific efforts of design researchers, they constantly tried to differentiate between the fields of science and design (Cross, 2001). Scientists were seen as objective analyzers whereas designers were seen as intentional creators. Christopher Alexander (1964) noted: "scientists try to identify the components of existing structures. Designers try to shape the components of new structures" (p. 130). Sydney A. Gregory (1966), similarly commented on the differences between behaviors required of scientists and designers:

> The scientific method is a pattern of problem-solving behavior employed in finding out the nature of what exists, whereas the design method is a pattern of behavior employed in inventing things of value which do not yet exist. Science is analytic; design is constructive (p. 6).

In addition to *objectives* and *behaviors*, design *problems* were also recognized as unique and different from those of science. Design problems were known as wicked problems (Buchanan, 1992). Wicked problems are ill-defined problems which are distinguished from the definable and separable problems that engineers and natural scientists deal with. Wicked problems are (a) unique; (b) it is not possible to formulate and

understand all the information needed for solving them; (c) the solutions to them are good-or-bad rather than true-or-false; (d) every attempt to resolve them is significant and consequential; (e) there are numerous ways to explain them; and (f) they could be symptoms of bigger problems (Rittel and Webber, 1973).

By the end of the 20th century, it was a common concern between design researchers to provide evidence that support design as a distinct discipline (Archer, 1979; Buchanan, 1998; Cross, 1999; Jones & Jacobs, 1998; etc.). Bruce Archer (1979) differentiated design approach from science and the humanities. He considered science as the theoretical knowledge based on experiment and observation, humanities as the body of interpretive knowledge based on criticism and contemplation, and design as the practical knowledge established from invention and implementation (Archer, 1979). Nigel Cross (1999) is another design methodologist who argued for design as a distinct area of knowledge. He introduced an intellectual culture for the design field called *Design as a Discipline*. Cross (1999) explained that 'designerly' knowledge and actions are independent from those of the scientific or artistic worlds. However, design field could draw upon scientific research and history when appropriate.

While attention was paid to distinguish design as a separate discipline, the collaboration between design and the other fields was highly valued. Herbert A. Simon (1969) proposed that 'the science of design' could build intellectual communication among art, science, and technology. He thought that design could be considered as an interdisciplinary field for all who are involved in creating the human-made world. Suggested by Simon (1969), although a composer and engineer can barely comprehend the professional content of each other's work, they can carry a satisfying conversation

about design, "[they] can begin to perceive the common creative activity in which they are both engaged, can begin to share their experiences of the creative, professional design process" (p. 137).

The most recent framework to explain design process, *design thinking*, is being used inside and outside of the design practice for systematic and creative problem-solving. This strategy has applied human-centered techniques to understand the users, define their needs, and develop innovative solutions for their problems. Design thinking is also known as 'the secret weapon for innovation' (Kelley, 2001, p. 8). Tim Brown, the president and CEO of the IDEO company, described design thinking as "a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success" (Brown, 2016).

Buchanan (1992) in the *Wicked Problems in Design Thinking*, explores the relationship between design, science, and arts. He traces the evolution of design thinking from a trade activity to a "new liberal art of technological culture" (p. 5). He considers design as a flexible field which covers a variety of ideas and methods from the fine arts as well as the natural and social sciences. In his perspective, design thinking in the 20th century is undergoing a significant practical as well as theoretical transformation that widens its dimensions to unexpected meanings and connections (Buchanan, 1992). Buchanan suggests that design should not mistakenly get identified as a division of science or the arts. However, it is a field that integrates useful intuitions from both to resolve problems of the present. The "new liberal art of technological culture" suggests that design thinking continues to explore science and art methodologies and activities to

find adequate solutions for the wicked problems of everyday experience (Buchanan, 1992).

Artereality is the other explanation of design thinking that justifies the interconnection of design, art and science. In 2009, Shank and Schnapp coined the neologism artereality as a new platform for the interdisciplinary art education arising in the Stanford Humanities Lab. Artereality has a discipline-dynamic approach toward the production of objects rather than design as a pure creation. Moreover, project and performance-based education is the heart of artereality. Shank and Schnapp (2014) claimed the possibility of considering design thinking as artereality in the service of innovative business:

> What we named "artereality", is what also gets called design thinking. Typically explored in relation to business process and the pursuit of creative innovation, design thinking as artereality also offers a model for revitalized practice-based arts and humanities in the contemporary academy that sees fit to challenge isolated disciplinary silos (Shank and Schnapp, 2014, p. 1).

Reflecting upon the brief history of design from Bauhaus to the Stanford d.school, the following conclusions can be drawn:

- The purpose of design process is beyond aesthetics and functionalism and consists of the inner growth of the designer as well;
- One of the design obligations is to tame the destructive elements of modern technology;

- Design objectives, problems, methods, and behaviors are domain specific and characterize it as a discipline distinct from art, science, and humanities;
- The application of art and science domains into innovative and strategic problem solving is the heart of design thinking.

Returning to the research goals posed at the beginning of this study, the above facts are viewed from the lens of imagination and Visual Imagery. The I+I model considers that: (a) the educational needs of designers are specific and different from the other fields; (b) design education should empower designers as individuals who need inner growth beside professional improvement, (c) proficiency in design thinking requires simultaneous development of art and science cognitive skills, (d) the ideal design education pays attention to functionalism as well as existentialism.

2.2.3 Visual Imagery in Art, Science and Design

Design is a visual field. One of the essential competencies needed for effective designers is visual imagery. Visual Imagery is the ability to represent and manipulate internal images of objects not present to the sight (Kosslyn, 1995). Kosslyn's theory of visual imagery or the Quasi-Pictorial Theory of Imagery was among the vigorous debates on the nature of visual mental imagery from the late 1970s until the early 1980s. Despite its evolution over time, the major focus of his theory has always been on the underlying cognitive and neurological pathways occurring during visualization (Tye, 1991).

Figure 3 (Kosslyn, 1980) illustrates the basic architecture of the Quasi-Pictorial Theory of Imagery. This represents what might occur when someone tries to answer whether a fox has pointed ears: The person first constructs a mental image of a fox, and

then inspects ears in that image. The mental image of the fox in this model is a “quasi-picture” or “surface representation,” which is constructed based on information from “deep representations” or descriptive data stored in Long-Term Memory (LTM). Then the “mind’s eye” analyzes it to extract the required information, which is the shape of the fox’s ear in this example.

In his introduction to mental imagery, Kosslyn (1980) refers to “deep representation” as information which is not directly available to the consciousness and demands the construction of “surface representation” to be analyzed and manipulated by the mind’s eye.

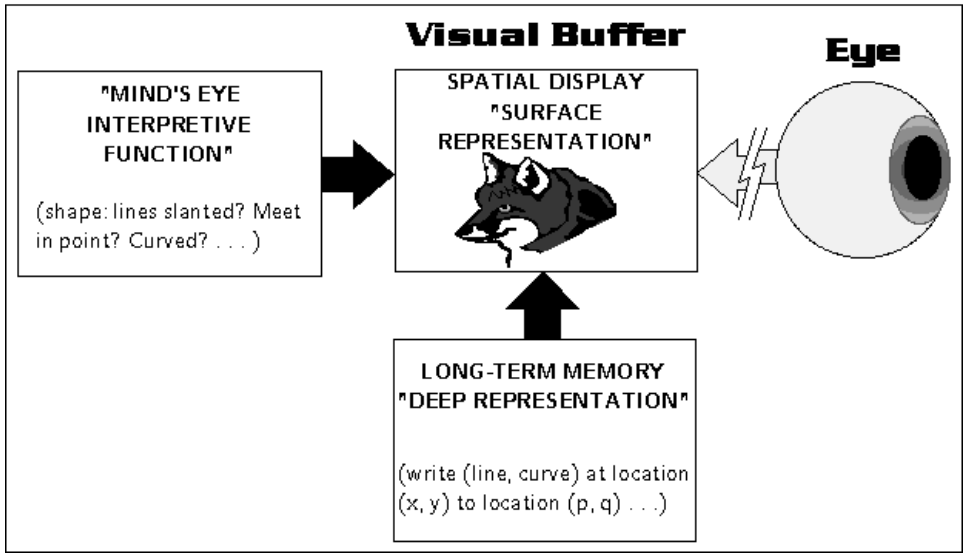

Figure 3. The quasi-pictorial theory of imagery adapted from Image and Mind (p. 6) by Stephen Michael Kosslyn (1980)

2.2.4 Object vs Spatial Visual Abilities

According to the theory of visual imagery, there are two types of mental imagery: Object and Spatial Visualization. Firstly, Object Visualization (OV) is the ability to form visual appearance of objects, for example visualizing a car next to a building. Secondly,

Spatial Visualization (SV) is the ability to manipulate spatial representations of a given object, such as rotating and manipulating shapes in the mind (Heuer, Fischman, & Reisberg, 1986; Kozhevnikov, Kosslyn, & Shepard, 2005; Reisberg, Culver, Heuer, & Fischman, 1986).

OV ability is believed to be an independent component of intelligence which is related to specialization in art (Kozhevnikov et al., 2005) and abstract-object visualization (Blazhenkova & Kozhevnikov, 2010). This ability has functional and anatomical characteristics of its own. For instance, object visualizers are able to form high resolution and vivid images of objects and scenes in their mind and report imagery preferences for visual properties of objects such as shape and color (Kozhevnikov et al., 2005). A number of studies have found that the OV scores of visual art professionals and students are above average when compared to those of engineers and social scientists (Kozhevnikov et al., 2005; Blazhenkova & Kozhevnikov, 2010). Moreover, individuals with significantly higher OV scores tend to interpret abstract art as abstract representation, whereas scientists and humanities professionals mostly interpret abstract art in a literal sense or with irrelevant information, such as the physical properties and characteristics of the abstract art (Blazhenkova & Kozhevnikov, 2010).

On the other hand, the SV subsystem of VI is responsible for processing spatial properties of objects and guiding movements (Milner & Goodale, 1995). Kosslyn (2005) describes how when imagining spatial representation, a "map" is utilized. Locations and parts of objects become depicted by distinct points on this "map". The ability to form these representations is significantly correlated with success in mathematics, physics, engineering, and science (e.g., Battista, 1990; McGee, 1979). Professionals and students

of these fields show remarkably higher spatial test scores when compared to visual artists and social scientists (Kozhevnikov et al., 2005; Blazhenkova & Kozhevnikov, 2010). Spatial intelligence also supports understanding abstract SV representation such as diagrams and graphs (Blazhenkova & Kozhevnikov, 2010).

Neuroscience research demonstrates distinct brain pathways for each of these two abilities. The object pathway for OV and the spatial pathway for SV (Courtney, Ungerleider, Keil, & Haxby, 1996; Ungerleider & Mishkin, 1982; Motes, Malach, & Kozhevnikov, 2008). The object pathway or *ventral system* runs ventrally from the occipital lobe to the inferior temporal lobe, which is responsible for the ability to process information about visible properties of objects and their pictorial characteristics (e.g. color, shape, texture). The spatial pathway, also known as occipitoparietal or *dorsal system* runs dorsally from the occipital lobe to the posterior parietal lobe (figure 2.3) ("Neural Correlates of Object vs. Spatial Visualization Abilities", n.d.). Its role is to process object spatial localization and mental spatial transformation.

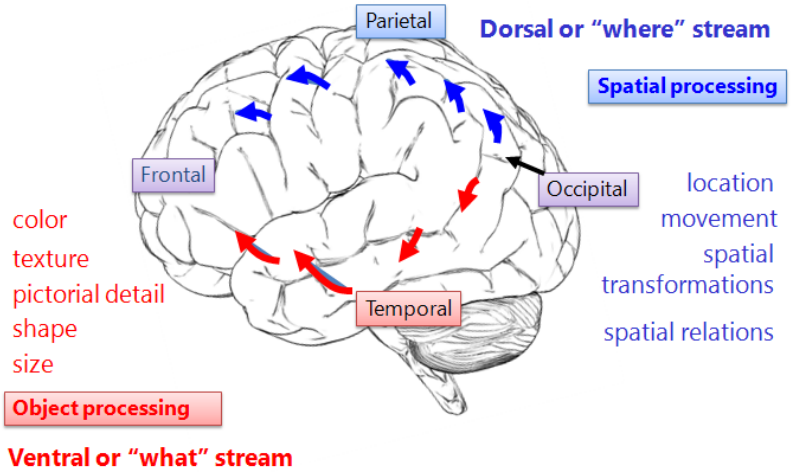

Figure 4. Neural Correlates of Object vs. Spatial Visualization Abilities, Reprinted from Mental Imagery and Human-Computer Interaction Lab, n.d., Retrieved March 18, 2018, from http://www.nmr.mgh.harvard.edu/mkozhevnlab/?page_id=663.

In contrary to most people with diverse visual abilities, a small group show the symptoms of *aphantasia* which means having no experience of VI (Zeman et al., 2015). Described by Francis Galton (1880), these individuals claim to have no power of visualizing. As stated in the introduction chapter, aphantasia among design students is beyond the scope of this research. The following section describes the role of VI particularly in design cognition.

2.2.5 Visual Imagery in Design Cognition

The purpose of designers in the 21st century is to create artifacts that serve human needs. Human-centered design is subject to the connection between appearance and purpose of the designed objects. Both form and function have external representations in the world and internal representations in the mind. In order to accomplish an influential design, a designer is required to identify and manipulate the communicative links and interactions among these mental and external representations. Many studies have been

published on the nature of design cognition and visual imagery. For instance, visual imagery has been identified as being effective for understanding a product's utilization and how it works (Johnson-Laird, 1983), and mapping how a user might respond to an artifact (Alberts, Ohmer, & Eckert, 2004). Moreover, vivid visual imagery facilitates design drawing by providing access to the underlying schema of an image restored in the visual memory (Oxman, 2002).

One of the decent systematic studies on design cognition was conducted in 2002 by Rivka Oxman. Her research highlights that visual images and shapes are fundamental features of design cognition, particularly design emergence. She claims that recognition of visual forms and shapes, provides a notable cognitive content for the visual emergence in design (Oxman, 2002)

Returning to the first research question in section 1.3, these results confirm the hypothesis that design cognition is dependent on spatial and object visual abilities or on both artistic and scientific cognition. This will be examined in the first study via empirical tools that evaluate the VI ability of design students.

2.2.6 Creative Visual Imagery

Jankowska and Karwowski (2015) introduce a new theoretical model of creative visual imagery through combining imagination and creativity studies. Their methods are driven from associative psychology (Ribot,1906), combinatorial theory (Vygotsky, 1931), theory of fantasy (Rozet,1982), and structured imagination (Ward, 1994). This model defines creative imagination as the ability to produce and transform representations that are based on the material of past observations and significantly transcend them into novel

representations. The authors reach the conclusion that creative imagination emerges from combining three key components:

- Vividness: “the ability to create lucid and expressive images that are characterized by high complexity and level of detail”;
- Originality: “the ability to produce creative imageries characterized by newness and uniqueness”;
- Transformation: “abilities to transform created imageries” (Jankowska & Karwowski, 2015, p. 3).

This model of creative visual imagery from the perspective of quasi-pictorial theory of Kosslyn, suggests that being visually creative means to possess OV abilities in order to create vivid images and SV abilities to transform them. It also requires innovation skills to make vivid transformations of images meaningful toward resolving a problem. Therefore, inclusion of both OV and SV abilities in design education has the potential to foster creative visual imagery.

2.3 History of Imagination

The concept of imagination is incredibly complex, and therefore needs to be understood in the context of its history (Thomas, 1991). It has been subject to many changes from the beginning of human mythical culture to the present time. The experience, construction, and manipulation of mental images has various meanings and applications for philosophers, scientists, and artists of all ages. From the logical philosophy of Aristotle to the contemporary cognitive science that investigates this phenomenon through the lens of empirical experiments, imagination has been a significant part of human intellectual history. However, there are both overlooked dimensions as well

as new discoveries of the nature of imagination. This makes it difficult to conclude whether our understanding of imagination has evolved or devolved.

Some researchers argue that neurobiological mental imaging has happened independently of the long philosophical and psychological history of imagination (MacKisack, Aldworth, Macpherson, Onians, Winlove C, & Zeman, 2016; Thomas, 2003). They claim that although the application of Functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) has broadly extended the knowledge of VI, it still can be furthered by investigating historical understandings of imagination (Mackisack et al., 2016). Michael Bagley (1987) and Nigel J.T. Thomas (1999) believe there are subtleties about imagination that could be clarified by unpacking the various concepts introduced throughout the centuries.

The purpose of this section is to briefly explain the consistent change of dimensions and definitions of imagination since antiquity to the 21st century. The insights provided by the following sections are utilized towards formulating the Imagination plus Imagery (I+I) model.

2.3.1 Prehistory of Imagination

The human imagination experience can be traced back to any of the earliest forms of art and self-expression including paintings and oral myths. The prehistoric parietal arts of the Ice Age (60,000 to 10,000 B.C.) are the earliest documentation of imagination (Bagley, 1987). The realistic and symbolic Paleolithic artworks depict the cave artists' ability to memorize, recall, and manipulate the mental representations of what they saw, particularly animals. Homer, Indian Vedas, Epic poets of Scandinavia, and Aeschylus are among the examples of oral myths providing evidence for the imaginative activity of

ancient people (Bagley, 1987). The primary social benefit of such highly developed imagination was to help individuals remember the tribal binds, cultural norms, and their social identity coded into the sacred myths, which would attract people's emotional commitment (Bagley, 1987).

2.3.2 Aristotelian Phantasma

It is hypothesized that Aristotle was the first philosopher who shed light on the nature of images coming from the mind or fantasy. The word *fantasy* is from the Proto-Indo-European root "*Bha"* which means "*to shine,"* and the Greek word *Phantazein* meaning *"make visible" or "display"* (Harper, 2001). Phantasia was used by Aristotle in *De Anima* to refer to the human ability that acts as a bridge between the worlds of sensation and logic. To Aristotle, intellectual activity does not occur without constant involvement of phantasma: "every time one thinks, one must at the same time contemplate some image" (De Anima, 432a). In his rhetoric, phantasia is a continuum of all five senses, not just vision, and is clearly distinguished from perception and the mind (Noel, 1997). Aristotle highlights that images of phantasia are mostly false because they are up to one's wishes rather than reality. However, they provide the basis for making assumptions and are significant in thinking and reasoning processes. He exemplifies the importance of phantasia as they are the origins of metaphors (Gendlin, 2012). Aristotle argues that as a bridge between the bodily senses and the rational mind, phantasy could be utilized to mediate the human desire for pursuit of anything hidden from the senses (Gendlin, 2012).

Imagination is an etymological descendant of *imaginatio,* the Latin translation of phantasma. It is from the Indo-European root *Aim* which means "*to copy*" (Harper, 2001). As a concept implying one of the non-rational human dimensions, imagination was

transmuted from the meaning of phantasia in Aristotle's *De Anima* (which has broad applications in the processes involved in memories, thoughts, and dreams) to the definition of mental imagery in modern science: the reproduction of an image of an object in front of the mind's eye in the absence of that object (Cornejo, 2015). It is suspicious whether the contemporary usage of imagination is equivalent to phantasma as described by Aristotle. However, there is little doubt that all theoretical discussions of imagination in the early western philosophical schools are rooted in Aristotle's elliptical explanations of phantasma (Thomas, 1999).

With the rise of conceptual revolutions in the 17th century, Aristotelian phantasma disappeared and was replaced by images as *ideas*. This switch was critical because philosophers such as Hume used imagination as a virtual synonym for *mind* (Thomas, 1999). Hume believed: "[a]ll the perceptions of the human mind resolve themselves into two distinct kinds, which I shall call IMPRESSIONS and IDEAS. Those perceptions which enter with most force and violence we may name impressions ... By idea I mean the faint images of these in thinking and reasoning" (Hume, 2003, 1.1.1.1).

2.3.3 The 18th Century

Imagination had cultural significance for many intellectuals of the 18th century such as Johann W. Goethe. Goethe criticized the ignorance of fantasy by his fellow scientists and attempted to offer a model of soul that integrated the rational and intuitive capacities of human beings (Cornejo, 2015). This model describes four dimensions for the human soul: fantasy, sensuality, rationality, and intellect (Goethe, 1810). Goethe proposed combining intellectual knowledge with 'an exact sensuous fantasy' to recover the non-rational human capacities and avoid the failures of materialism (Cornejo, 2015).

After the Romantic movement of the late 18th century, imagination was considered to be essential for creative and original thinking, especially in art (Daston, 1998). Contrary to former eras, poetic imagination received a positive evaluation as a faculty responsible for non-rational thought and passion (Thomas, 1999). The artists and writers of Romanticism believed that scientific understanding was limited, and imagination illuminates "what really matters in life" (Abrams, 1953). Samuel Taylor Coleridge was a Romantic poet who believed that the image of God could be recognized by creative imagination rather than the soul (Egan, 1992). He implied that Adam and Eve exercised their creative powers when they chose to eat the forbidden fruit. Coleridge distinguished two types of imagination: primary and secondary. The former works significantly at the unconscious level, while the latter is consciously controlled to dissolve the contents of primary imagination into creative art (Coleridge, 1971). Further, Coleridge differentiated creative imagination from "Fancy" as the non-creative act of mixing images of the memory (Egan, 1992).

> The primary Imagination I hold to be the living Power and prime Agent of all human perception, and as a repetition in the finite mind of the eternal act of creation in the infinite I Am. The secondary I consider as an echo of the former, co-existing with the conscious will, yet still as identical with the primary in the kind of its agency, and differing only in degree, and in the mode of its operation…. Fancy, on the contrary, has no other counters to play with, but fixities and definites. The Fancy is indeed no other than a mode of Memory emancipated from the order of time and space" (Coleridge, Biographia Literaria, 1847, Ch. XIII)

The above literature suggests a strong bond between imagination and creativity for the artists of the 18th century, Romanticist or not. Even to Immanuel Kant, famous philosopher of this era, imagination meant a mysterious catalyst for creativity: "The imagination is a powerful agent for creating as it were a second nature out of the material supplied to it by actual nature" (Kant, [1790] 1952, p. 314).

2.3.4 The 19th Century

The quantification of science by the mid-19th century abandoned many of the technical terms of the 18th century including fantasy as a faculty for "vital feelings" (Cornejo, 2015). In his paper, From Fantasy to Imagination, Carlos Cornejo (2015) claims that only the theoretical and aesthetic dimensions of "original fantasy" survived in the 19th century. He points out that the recovery of forgotten anthropological aspects of fantasy is a challenge for modern psychological studies. Perhaps one of the studies of imagination that radically abandoned the "original fantasy" was done by Galton. Galton (1880) issued a questionnaire *on visualizing and other allied activities* in 1879 and published the results of this study in 1880 in the *Mind* Journal. His questionnaire was the first quantitative and scientific attempt to investigate the act of imagining (Mackisack et al., 2016). Schwitzgebel (2011) argues that Galton's questionnaire was an innovative solution to the challenge of statistical modeling of individual differences in mental imagery.

The questionnaire asks participants to "think of some definite object – suppose it is your breakfast-table as you sat down to it this morning – and consider carefully the picture that rises before your mind's eye." Then, "1. Illumination – Is the image dim or fairly clear? Is its brightness comparable to that of the actual scene? ... 2. Definition – Are all the

objects pretty well defined at the same time, or is the place of sharpest definition at any one moment more contracted than it is in the real scene?" (Galton, 1880, p.302). The results of his research show a broad variety of answers. Some respondents were easily able to visualize the object in detail, as if it were the reality before them. On the other hand, some participants felt powerless and incapable of imagining (Galton, 1880).

This significant change in the direction of imagination research continued to the rise of modern science, which is now mostly focused on "imagining a concrete object" as a primary task for mental imagery studies (Mackisack et al., 2016).

2.3.5 The Contemporary Usage of Imagination

By the mid-20th century, diverse perspectives on imagination have surfaced. For some analytical philosophers like Gilbert Ryle, concept of imagination itself was questioned, demanding that "there is no special Faculty of Imagination, occupying itself single-mindedly in fancied viewings and hearings (1949, p. 257)."

For modern scientists, "to imagine" is mostly equivalent to "supposing" or "pretending" than to visualizing. Thomas (1999) believes this transformation mainly happened as a reaction against the excessive romantic rhetoric, due to the importance of linguistics in philosophy, and the rise of behaviorism in psychological theories. One example of Behaviorism exemplified in the mid-20th century was the concept of "imageless thought" in the Wurzburg school (Harvey, 1975). This school criticized the Aristotelian "dogma" that thinking is impossible without images (Hoffman, Stock & Deutsch, 1996). Although some Behaviorist psychologists such as John B. Watson (1913) questioned the existence of imagery at some point, this view did not last long and was not taken seriously especially after the rise of cognitive theories (Thomas, 1999)

About the same time with the behavioral movements, imagination was an appreciable concept to depth psychologists since the early studies in this field. Carl Jung (1960) the founder of analytical psychology, introduced the concept of "active imagination" as a facilitator for the great discoveries and achievements of humankind (e.g. scientific, literary, artistic or technological revolutions). Symbolic expressions of the mental images through art, somatosensory hypnagogic impressions, and self-reflective dialogues with inner figures are among the diverse forms of active imagination introduced by Jung. He explained active imagination as a bridge between conscious and unconscious worlds which gives birth to creativity, initiation, and originality (Jung, 1960).

This era also witnessed the vigorous attempts of cognitive psychologists who experimentally investigated imagery. Allan Paivio attempted to provide an explanatory framework for the cognitive process of visual imagery. Paivio (1963) developed an empirical experiment to study memory. His research revealed that remembering concrete nouns that can be imagined (e.g. 'tree') is easier than remembering abstract nouns (e.g. 'truth'). Compared to the Paivio's experiment, Kosslyn et., al (1993) used the modern neuroimaging technologies to study the brain regions engaged in visual imagery (Kosslyn, Alpert, Thompson, Maljkovic, Weise, Chabris, Hamilton, Rauch, & Buonanno, 1993). Kosslyn's Quasi-Pictorial Theory of Imagery was explained in the previous section. This modern research on imagination is focused through the lens of cognitive science and primarily investigates visual imagery.

As a mind and cognitive science philosopher, Thomas (1999) argued that contemporary cognitive theories of image formation are limited. Modern neuroscience views imagery as a dependent representative of another abstract mental representation

(e.g. Images of the Long-Term Memory). This representation portrays imagination as an unconscious, or at best, indirectly conscious process. However, Thomas (1999) illustrates imagination as a conscious power. He believed that a renewed theory of imagery which scientifically explores consciousness is needed to activate capacities for objective imagination or the *sensus communist* of Aristotle.

2.4 Ethical Imagination

Imagination is not instinctively good or bad, positive or negative, and constructive or destructive. While some philosophies and ideologies appreciated imagination, others had opposite views. During most of the Christian history, imagination was viewed as a dangerous faculty which leads human into sin and away from God. It was associated with magical thinking. Thus, an important challenge for some philosophers was to overcome this enemy of reason (Yates, 1966). Blaise Pascal (1999), the Christian mathematician characterized imagination as "that mistress of error and falsehood" (p. 16). Even most philosophers who claimed positive attributes for imagination, did not believe that every type of imagination is authentic (Coleridge, 1971; Jung, 1960; Corbin, 2013).

Many People believe that the solution for the moral confusion is to clarify moral principles that protect our everyday lives and to learn the rational application of them to different situations. Most people disagree about the source of these moral laws, some believe that they come from God, others consider them as originated in universal human reason or feelings. However, they agree that moral life depends on *moral insight* and the *strength of will* to act based on it (Johnson, 1993). The fundamental role of ethical imagination is missing in this wide argument around morality. As imaginative creatures whose reasoning and conceptualization is derived by various structures of imagination,

humans depend on images of mind for ethical understanding. According to Mark Johnson (1993), moral imagination could be cultivated by refining “the powers of discrimination”, “envisioning new possibilities”, and imaginatively tracking “the implications of our metaphors, prototypes, and narratives” (p. 198). Peter Lloyd (2008) points out that this explanation of moral imagination is dramatically similar to the activity of designing. Lloyd (2008) lists three aspects for the ethics in design: “First, the aim of acting in the world to change or influence behavior. Second, the imagination of alternative actions and their consequences. Third, the evaluation of those consequences in terms of good or bad” (para. 2).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methods and methodology that were used to conduct the proposed research are described in this chapter. As stated in the introduction, the main objective of this study was to create a pedagogical model that implements the science and history of visual imagery into the design education. Two studies were specifically designed to provide the essential information to form this model. The first study investigated the visual imagery preference of designers as a professional group, while the second study explored the transformation of the meanings and applications of imagination through its history.

This chapter is divided into several sections discussing the research design and procedure in detail. The topics, questions, and their significance are described at the beginning. Then the data collection, sampling, and analyzing methods are explained along with the critical reasons for selecting each of them. The final section presents the methods justification table consisting of the summary of listed information.

3.2 The Visual Imagery Style of Design Students

To join the form and function of an artifact, the designers need to build and manipulate the object's visual representations in their mind. They also use mental imagery to recognize the communicative links among the mental and real-world representations. A large body of empirical research demonstrates the relevance of VI abilities to the visual reasoning in design (explained in section 2.2.5). Oxman (2002) pointed out: "The most common medium of design is the manipulation of symbolic shape representations" (Shapes as a medium for understanding and representing the visual world, para. 2).

Furthermore, mental imagery is dependent on the recall of information from memory. Thus, it is a key concept for visual cognition in general and, specifically for a visuospatial field such as design (Oxman, 2002).

In the first (Gero & Tversky, 1999), second (Gero & Tversky, 2001) and third (Gero & Tversky, 2004) International Conference on Visual and Spatial Reasoning in Design, several interesting studies on the nature of visuospatial reasoning were presented. Most of these studies have only focused on the contribution of mental imagery to the design problem solving. However, there has been little discussion on the VI profile of designers. As explained previously in the literature review section 2.2.3, the VI ability is proved to be domain specific for artists and engineers. In the most studies on the VI profiles of individuals from different fields, design students were neglected or considered as a subgroup of visual art (Kozhevnikov, Blazhenkova, & Becker, 2010). The current research is an attempt to analyze the VI preference of designers as a distinct group. Design is considered as a field that is entailed to the art and science domains, however independent from both.

3.2.1 Research Questions

This study seeks to address the following questions due to the lack of current research on the VI profile of design students. More details about the significance of these questions could be found in the introduction chapter, section 1.1.2.

3.2.1.1 What is the VI profile of designers?

The VI profile of designers is worth mentioning as a pure cognitive feature that underlies mechanisms of thinking and problem solving. The answer for this question may suggest practical applications for the future of design education.

3.2.1.2 Is it possible to have both OV & SV scores above average?

Kozhevnikov et al, (2010) claimed that there is a tradeoff between visual abilities. They assessed the OV and SV scores of different specialized groups and concluded that none of the studied groups showed both above-average SV and above-average OV scores. The main limitation of their study was to consider designers as a subgroup of visual artists. One of the purposes of this question is to reexamine Kozhevnikov et al's conclusion about the VI abilities of designers. The results could strengthen the idea that design cognitive ability is domain specific and demands exclusive educational plans.

3.2.2 Research Methods

This section describes different research methods and data collection tools that were used to answer the questions of this study. In the following section, Vividness of Visual Imagery Questionnaire and Paper Folding Test are explained.

3.2.2.1 Vividness of Visual Imagery Questionnaire

Individuals have a metacognitive awareness about their own internal experiences including mental imagery. They can reliably appraise the vividness of their imagination (Pearson, Rademaker & Tong, 2011). This raises the question that, "In What ways does the behavior of a man who states that he has vivid visual imagery differ from that of another who says that his imagery is vague and dim?" (Marks, 1972, p.83). In response to this question, Marks (1972) made the Vividness of Visual Imagery Questionnaire (VVIQ) in the context of cognitive research. VVIQ is the most frequently used measure to evaluate how vividly individuals can shape a mental image of an object in their mind.

VVIQ-2 (Marks, 1995) is the new version of VVIQ that consists of 16 items in 4 groups of 4 items (appendix C). Each group of items in the questionnaire ask participants

to think about a specific scene and situation (relative/friend, rising sun, a shop, a landscape). Then on a 5-point scale from 5 (highest vividness) to 1 (lowest vividness), they rate the vividness of mental images they were asked to form in their minds. Some examples of the items are: “The sun is rising above the horizon into a hazy sky” and “A strong wind blows on the trees and on the lake, causing waves.” Participants answer the questionnaire two times; once with eyes open and once with eyes closed. The total score is the aggregation of answers from closed and open eye tests. This could range from 32 to 162 with higher scores indicating stronger imagery ability. The internal reliability of the questionnaire is 0.88 (McKelvie, 1995).

Because of its high reliability, VVIQ-2 has been used for many research studies investigating the correlation between the visual imagery and its underlying neural activities (Amedi, Malach, and Pascual-Leone, 2005, Cui, Jeter, Yang, Montague, & Eagleman, 2007, Motes,Malach, & Kozhevnikov, 2008). Another common application of this test is to examine visual cognitive differences among individuals based on their gender (Richardson, 1995), specialization (Kozhevnikov, Blazhenkova, & Becker, 2010), age (Campos, 2014), and mental health (Bryant & Harvey, 1996). A sample of the VVIQ-2 for this research study is provided in the Appendix C.

3.2.2.2 Paper Folding Test (PFT)

The Paper Folding Test (Ekstrom, French, & Harman, 1976) is a cognitive test that measures spatial visualization ability, which means the ability to apprehend, encode, and mentally manipulate abstract spatial forms (Lohman, 1988).

The test has 2 parts each consisting of 10 items (total of 20 items). Each item illustrates a square sheet of paper which is folded for two or three times and then pierced.

Five alternative drawings are presented on the right side of each item. Participants are to select one from the five options illustrating how the target punched sheet would look like if fully reopened. There is only one correct answer for each item (examples of the items could be found in the appendix D). Participants have a total of 6 minutes to complete both parts of the test; 3 minutes for each 10 items. The test scores are calculated based on this formula: Score = R - (W / n-1). R is the number of correct answers, W is the number of wrong answers, and n is the number of alternatives for each item (n =5). The minimum score for the PFT is 0 points and the maximum is 20 points. According to Ekstrom et al, (1976), the test-retest reliability is 0.84. In comparison to the other tests for spatial ability such as the Mental Rotation Test (Shepard & Metzler, 1971), PFT is simple and less time-consuming. A sample of the PFT for this research study is provided in the Appendix D.

3.2.3 Sampling method

In educational research, sampling is usually performed for the detailed study of part of a population rather than its whole. Then the sampling result is employed to develop valuable generalizations about the population. In this study, the population of students is considered as a collection of different sized ‘clusters’ of sampling components. Cluster sampling (Ross, 2005) is a research method which is usually used as an alternative to simple random sampling for large target populations. The advantage of this method is reducing research costs and time (Ross, 2005). For instance, instead of performing a study 80 times for 80 individuals, the sampling process could be conducted fewer times, each time for one cluster of participants.

The entire population was all of the students from the Herberger Institute for Design and the Arts, the Ira A. School of Engineering, and the T. Denny Sanford School of Family and Human Dynamics at Arizona State University (ASU). The sampling objective was to select 3 groups of students representing each department's population. The first stage was to use the university's online website to randomly select one cluster sample for each department (Table 1). Each cluster sample consisted of the selection of 10 classes, each containing more than 50 students. The recruitment email then was sent to 30 professors (10 from each department) asking for their permission to run the test in their classes. The class of the first professor who agreed to contribute was chosen as the final cluster sample.

All the students in each of the three final cluster samples were included as subjects unless they were from unrelated majors. ASU provides the opportunity for students to register for classes outside their degree of study. In order to assure that all participants belong to their clusters, their majors were asked at the beginning of each test. If they were not from one of the design, humanities, and engineering groups, their test results were neglected. For instance, 20 participants from the Social Change class were nursing students and unrelated to the research objectives. Their answers therefore were deleted from the data before any further analysis.

Department	Herberger Institute for Design and the Arts	Ira. A School of Engineering	T. Denny School of Family and Human Dynamics
Online Class Search on the Arizona State University Website			
Stage One (ten random classes with more than 50 students were selected)	Class 1, Class 2, Class 3, … Class 10	Class 1, Class 2, Class 3, … Class 10	Class 1, Class 2, Class 3, … Class 10
Sending Recruitment Emails to the Professors			
Stage Two (one random class was selected)	Creative Environment (120 Students)	Perception in Robotics (83 Students)	Social Chang (180 Students)
Conducting the Experiment			
Eliminating the Unrelated Participants from Each Cluster			
Final Subjects	95 Design Students	83 Engineering Students	62 Humanities Students

Table 1. Sampling Process

Final subjects were 240 ASU students categorized in three groups: 95 design students, 83 engineering students, and 62 humanities students.

3.2.4 Analysis Method

Following the guidelines for each test, PFT and VVIQ, the participants' scores were calculated. Given the mean and deviation of the list of scores for each test, z-scores were achieved independently by normalizing the original scores to have zero mean and unit deviation. Formally:

$$z = \frac{x - \mu}{\sigma}$$

where x was the vector including original test scores, μ is the average, and σ is the deviation from average for the original scores, and z contains the normalized scores.

To compare the difference between different groups, a two-sample t-test was performed on every pair of study groups (design, science, and humanity) to evaluate the hypothesis that the scores of the two groups of interest comes from populations with unequal means. Assuming z_D and z_s are the z-scores for design and science students, their two-sample t-test was formulated as:

$$t = \frac{\mu_D - \mu_S}{\sqrt{\frac{\sigma_D^2}{m} + \frac{\sigma_S^2}{n}}}$$

Where μ_D and μ_S are the sample means, σ_D^2 and σ_S^2 are the standard deviations, and m and n are the sample sizes of z_D and z_S, respectively.

3.2.5 Prototype Test

The prototype study was conducted in one of the graduate studios at HIDA. This study consisted of four tests: The Vividness of Visual Imagery Questionnaire 2 (VVIQ-2) (Marks, 1995) to assess the OV ability, the Paper Folding Test (PFT) (Ekstrom et al, 1976) and the Mental Rotation Test (MRT) (Shepard & Metzler, 1971) to examine the SV ability, and the Object-Spatial Imagery Questionnaire (OSIQ) (Blajenkova, Kozhevnikov, & Motes, 2006) to evaluate the VI style. Four students volunteered to participate. It took 35 minutes of their time to answer the four tests.

For the following reasons researchers decided to eliminate the MRT (appendix B) and OSIQ (appendix A) from the final methods: most of the students who refused to participate claimed: “the study seems too long”. Therefore, the challenge was to reduce

the study's length without influencing the quality of methods. Then the MRT was removed because of its complexity and length. Moreover, the PFT could provide enough information regarding the research goals. The OSIQ was also eliminated because the researchers were not successful to get the author's official permission to employ the test.

3.2.6 Data Collection

Students were asked to bring either a laptop or a phone to connect to the internet and access the google form consisting of the tests. On the first page of the form they could see the consent form explaining that participation is not mandatory, and they can leave the study whenever they wish.

After giving the instruction about the VVIQ-2, participants spent 9 minutes to take the test with open and closed eyes. Then they were asked to stop and wait for the researcher's notice to start the second test. The PFT had 2 parts, each for 3 minutes. This instruction was verbally explained for all students and a timer set for 3 minutes started to count. Participants were asked to stop answering the questions after hearing the alarm. At the end, the only information asked was each participant's major of study.

3.3 From Phantasma to Visual Imagery

As explained in section 1.1.3, the cognitive view of imagination does not address the historical dimensions of this concept.

3.3.1 Historical Research question

The goal of this study is to answer which aspects of imagination history could be applied to the design education? In order to develop a reliable model to integrate imagination and design education, it is necessary to study the rich background of imagination in philosophy and psychology.

3.3.2 Research Method

The method selected to answer the second research question was historical research (Borg, 1963). There are three main steps for the historical research: locating the primary and secondary source materials of the history, evaluating them critically, and finally, developing and presenting a synthesized narrative of the findings (Borg, 1963). Historical research provides solutions for contemporary problems, by delivering systematic body of principles to examine what has happened in the past (Hill & Kerber, 1967). Moreover, the process of studying the background and evolution of a concept could offer insight into future possibilities. This dual quality of history to employ the present to describe the past, and use the past to predict the future, has made it useful for all types of academic research (Hill & Kerber, 1967).

Despite the natural and social sciences that conduct direct observation and experiments, the historical method interprets the past events by investigating the remains of them? (Hockett, 1955). Another key difference between historical research and the other forms of research is related to data manipulation. Since this type of study depends on the past information, it is not possible to manipulate any data.

In an attempt to investigate the connective links between imagination history and design education, the historical research structure was employed to explore the topic. More detailed information could be found in the following sections.

3.3.3 Sampling Method

There are two kinds of sources for historical research: Primary and secondary (Howell & Prevenier, 2001). Primary sources provide direct evidence of events e.g. record of an eyewitness, piece of creative writing, original documents, results of experiments,

relics, and remains. Secondary sources present description, summary, analysis, evaluation, or interpretation of a primary source. The author of a secondary source is a person who did not directly observe the original event or condition. Articles in newspapers, textbooks, encyclopedias, and scholarly articles are some examples of secondary sources.

Both primary and secondary sources were explored corresponding to the research needs; primary sources from experimental psychology and secondary sources from mind philosophy.

The sampling strategy was to acquire in-depth and relevant information from reliable sources (Garraghan, 1946). The first step was a broad search on the keywords related to, or with the same meaning as imagination. Such as phantasma, visualization, and fantasy. The second step was an attempt to keep the search scope narrow and focused on the topics related to design education. To discuss the topic thoroughly, only professional articles from psychology and philosophy academic databases were selected.

3.3.4 Analysis Method

To analyze the gathered data and information, historical criticism (Cohen, Manion, & Morrison, 2013) was conducted. Historical criticism has two major steps: external criticism to assure the authenticity of the data, and internal criticism to evaluate the worth and accuracy of the documents. These two steps were followed by the evaluation of direct or indirect relevance of evidence to design education. The following table illustrates the analysis steps in more details:

Table 2. Analysis Method	
External criticism	The article should be published in a scholarly journal (Cohen, Manion, & Morrison, 2013).
Internal Criticism	The author should be a trained professional (Cohen, Manion, & Morrison, 2013).
Relevance to Design Education	There should be a reliable evidence to demonstrate direct or indirect connections between the article and the design field (section 2.2).

Table 2. Analysis Method

3.4 Method Justification Table

The following chart shows the rationale for choosing research methods to answer each question.

Table 3. Method Rationale		
Research Question	**Research Methods**	**Justification/Rationale**
Do designers possess domain specific VI abilities?	1. Vividness of Visual Imagery Questionnaire 2. Paper Folding Test	VVIQ is the most frequently used measure to evaluate how vividly individuals can shape a mental image of an object in their minds. PFT is a cognitive test that measures spatial visualization ability
Which aspects of imagination history are applicable to the design education?	Historical Research	Historical research offers insight into the future educational possibilities by studying the background and evolution of imagination concept

Table 3. Method Rationale

CHAPTER 4

RESEARCH FINDINGS

4.1 Introduction

This chapter reports on the general findings of this research. The first section provides the results of cognitive study on the VI profile of design students. The second section describes the findings of research on the applicable aspects of historical accounts of imagination to design education.

4.2 Cognitive Research Findings

As stated in section 3.2.3 regarding the types of students, 240 students participated in the study. The main hypothesis to validate was whether design students possess high OV and SV, compared to the science and humanities students. To this end, two tests were performed, PFT and VVIQ, on the students from the three majors. Table 4 shows the mean and standard deviation of scores (Mean ± SD) achieved by the participants of each group in each test.

	Design	Science	Humanities	Total
PFT	12.63 ± 4.51	13.56 ± 3.72	10.28 ± 4.14	12 ± 4.4
VVIQ	3.93 ± 0.46	3.75 ± 0.50	3.77 ± 0.52	3.83 ± 0.5

Table 4, Paper Folded Test (PFT) and Vividness of Visual Imagery Questionnaire (VVIQ) results. The mean and standard deviation of each group and the overall is reported.

To compare the performance of each group in each test, the z-scores were calculated and then a paired t-test was applied to study the significance of the differences. As shown in Figure ‘z-score results’, the highest score achieved in PFT (SV) belongs to

the science major students, followed by design students. Both design and science students' PFT scores were significantly higher than humanities' students corresponding scores (p-value <0.001). However, the difference between design and science students' PFT scores was not significant (p-value = 0.18). In the VVIQ test, design students outperformed other students significantly (p-value < 0.05) and the humanities students showed slightly better performance than science students, but the difference was not significant (p-value = 0.84).

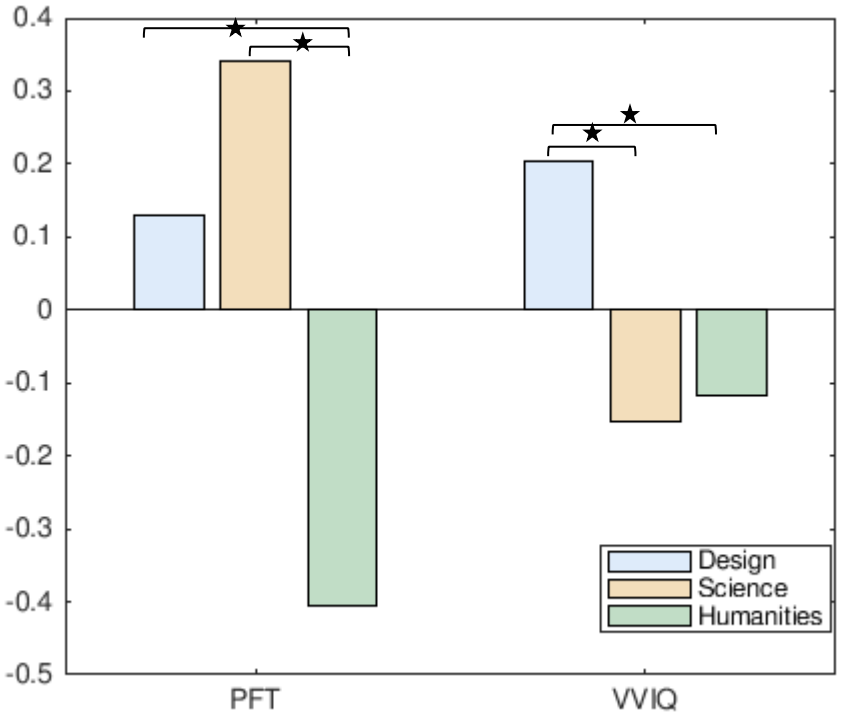

Figure 5. Z-score

Comparing the design students' average score with the average of all students (Figure 5, columns 2 and 5), interestingly, design students are the only group who performed above the overall average in both tests. These results, therefore, suggest that the design students have high OV and SV, while science students have high SV, but low OV and the humanities students have both low SV and OV. Their SV scores are less than

engineering students yet significantly more than humanities students. This might have been caused by the different educational opportunities provided by each of these three fields. As determined by this study, design education would seem to empower both SV and OV abilities of students.

4.3 Historical Research Findings

For the purpose of articulating applicable aspects of historical accounts of imagination to design education, several primary and secondary sources were studied and reported in the literature review, section 2.3. Due to the extensive nature of imagination, a framework was necessary to keep the study within the scope of design education. The objectives and characteristics of the design field provided in section 2.2 formulated this framework.

A list of critical expressions about imagination other than their relations to design education is presented (Figure 6). The findings suggest three major connections between the nature of a visual situation and design process: (a) Active Imagination (wellbeing and inner growth); (b) Ethical Imagination; and (c) Applied Imagination (problem-solving).

Results in Figure 6 show creativity as another communicative link between design and imagination. One of the definitions of creativity is *bisociation* or the power of uncovering connections between different phenomenon (Koestler, 1964). Imagination can be a bridge for finding balance between the conscious and unconscious, the rational and intuition, and the senses and logic. On the other hand, design is defined as a field that connects the worlds of art and science. Taken together, these insights suggest that design imagination grows from the heart of creativity.

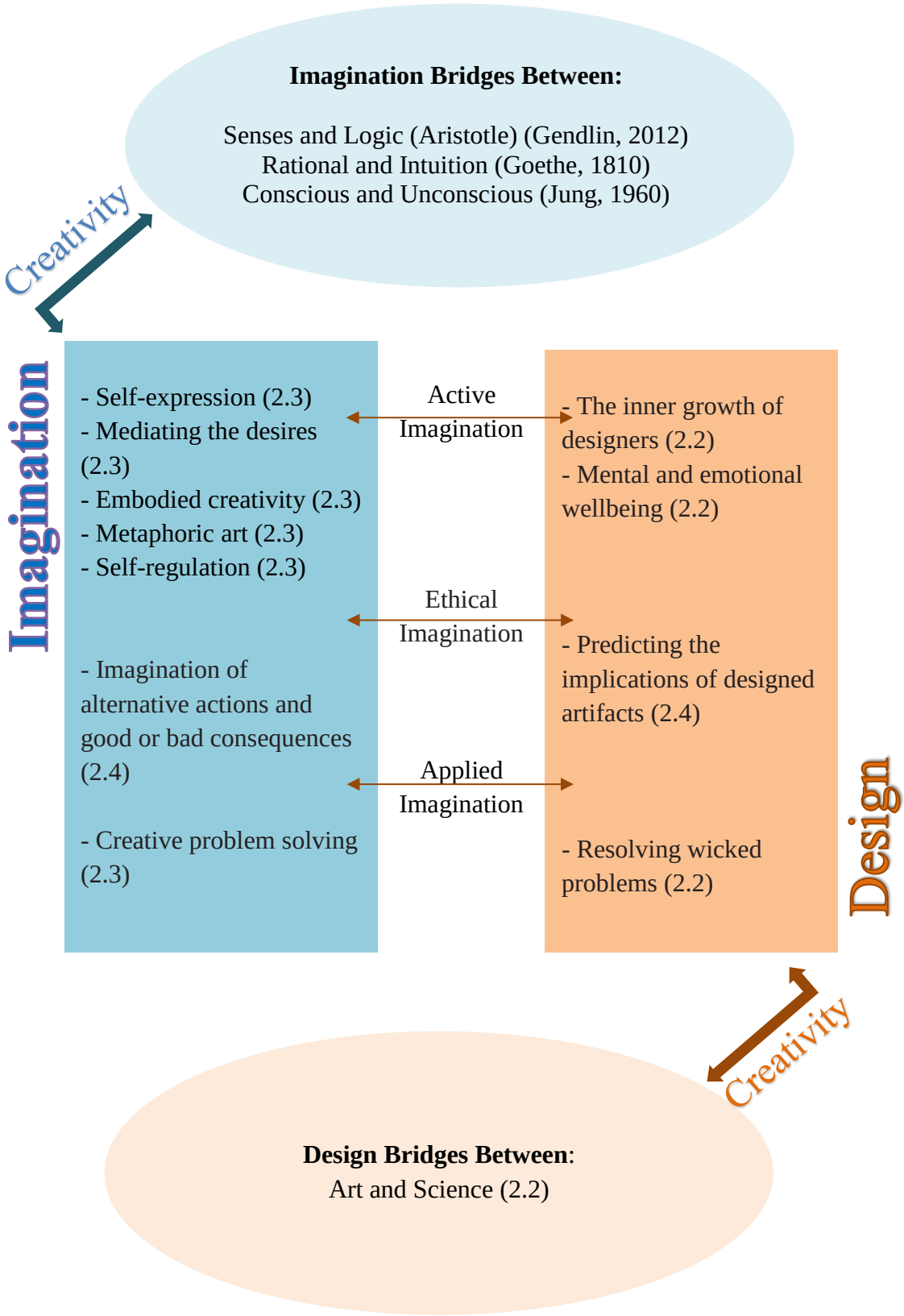

Figure 6. Historical Research Findings

4.3.1 Active Imagination

Active Imagination consists of visualizing the unconscious and directing its emotional and rational components to the conscious level. This process that happens by artistic and embodied expressions, can help integrating the opposites of the mind while accomplishing individuation. According to the literature in section 2.3, this type of imagination is essential for creative discoveries as well as emotional health. As concluded from the history of Bauhaus in section 2.2, a design work being the manifestation of the designer's innermost self, active imagination seems paramount to enrich design process.

4.3.2 Ethical Imagination

The findings of this study suggest an alternative point of view to the idea that imagination is a free flowing and subjective activity that is not managed by any rules. There is also a strong evidence of relation between imagination and ethical reasoning particularly in the design field. Designers use the imaginative materials of cognition to envision how other people might be affected by a design project, and to evaluate the probable implications of creating an artifact. Together, the present findings confirm that ethical imagination is one of the important dimensions of design cognition.

4.3.3 Applied Imagination

Applied Imagination is an effective way to improve general and design-oriented creative problem solving. Section 2.2.5 explains how designers employ their visual abilities to resolve a design problem. For instance, they use imagination to identify and manipulate mental and external representations of form and function, map the design process, and predict how the conceived artifact will operate.

CHAPTER 5
CONCLUSION AND DISCUSSION

5.1 Introduction

The purpose of this research was to propose a pragmatic model for the application of imagination science and history into design education. Two studies were conducted for this goal. The first one illustrated the Visual Imagery profile of design students and the second one discovered the philosophical and psychological dimensions of imagination. This chapter presents the conclusions that has been carried out from these studies to develop the I+I model.

5.2 Applications of the Visual Imagery Profile

It was the main purpose of the first study to answer the following questions: (a) what is the VI profile of designers? And (b) is it possible to have both OV & SV abilities above average? It was hypothesized that in comparison to the other fields (humanities, and engineering), both OV and SV abilities are essential for design thinking. The investigation of visual imagery profiles of three groups of students; humanities, engineering, and design has shown that design students are the only group who possess both OV and SV abilities above the overall average. It was also shown that engineering students are better spatial visualizers than design and humanities students, and design students are better object visualizers in comparison to engineering and humanities students (Figure 5). The most obvious finding to emerge from this study is that design thinking depends on both vivid visualization of the pictorial details of objects and transforming their spatial relations in mind. This result supports the hypothesis that as a field at the confluence of art and science, design demands both artistic (object) and scientific (spatial) visual cognitive

abilities. In turn, this enables designers to work in interdisciplinary settings where they can act as the bridge between specialists from both art and science.

A comparison of the VI abilities of subjects from different fields of study suggests that education plays a significant role in the formation of cognitive visual abilities. Another implication is that design education could and should support the advancement of both OV and SV abilities. Although there is a tradeoff between these two abilities in all subject groups, the nature of these differences is more complicated than simple categorization. For example, science students are spatial visualizers with OV scores lower than average, but design students are object visualizers with SV scores higher than average (Figure 5). Given that design students are the only subgroup that have higher than average scores in both SV and OV, it confirms the need for an education that addresses both the artistic and scientific dimensions of visual abilities.

The findings of this report are subject to two main limitations. First, the lack of data about the VI profile of art students does not allow for comparison of the VI abilities of design and science students with artists. As explained before in section 2.2.4, previous studies showed that art students have higher OV abilities than science students. Although design students have higher object visualization than science students, further experiments are required to examine VI differences between design and art students.

The second major limitation is the means by which data was collected. Some students used their mobile phones while others used a laptop to participate in the study and this different screen size might have influenced their answers. Future research would take this into consideration and use the standard data collection method of laptops to ensure uniformity.

5.3 Implications of the History of Imagination

As stated in the introduction chapter, this research focused not only on the cognitive aspects of imagination, but also on the historical definitions and applications of this concept. The second study therefore was conducted to answer which aspects of imagination history could be applied to the design education. It was hypothesized that the purely scientific cognitive view is not able to expose all dimensions of the potentials of imagination. Neurocognitive research enables a deeper appreciation for the mechanistic processes by which imagination occurs.

However, ancient understandings of imagination shed light on the applications of this human power. The broader research on the history of imagination from Aristotle to Kosslyn disclosed three common grounds between imagination and design field; active, ethical, and applied imagination which are explained in detail in section 4.3. Cognitive studies have focused primarily on tangible, object visualization as a proxy for understanding the human capacity for imagination, whereas historical understandings of imagination illuminate the intangible processes involved in imagination. For example, imagination was seen as the expressive artist's tool to manifest their internal emotional, wonders, needs, and philosophies. This is a direct application of imagination. However, given the intangible nature of the artist's internal subjectivity, it has been overlooked by cognitive science. In the context of design education, this intangible dimension is an untapped resource. If design education explicitly recognizes the subjectivity of the design students, they may be far more capable of harnessing their imaginations. Not only could this allow for more innovative product and service design, but it would offer opportunities for deeper fulfillment and meaning in the work designers are producing.

The main limitations of the second portion of this research study which focused on the history of imagination was the Western focus. The historical texts utilized in this project were drawn exclusively from Western thought. There is a deep need to integrate Eastern and Southern perspectives on imagination. Additionally, each writer has brought forth their understanding of imagination within a specific socio-historical context. Given the scope of this research, the nuances of each time period could not be addressed. For example, it would be important to situate Aristotle in the elite position of power he was benefiting from. During Aristotle's time, there were undoubtedly other perspectives on imagination that were overlooked given that there was no avenue to document their voices. Future research could bring in non-Western perspectives and analyze all text as situated within the realities of power dynamics and privilege.

5.4 Design Implications

The ultimate goal of these two studies was to develop a pedagogy model that connects imagination history and science to design education. The Imagination+Imagery model is presented in Table 5. This model is developed to offer a method of evaluating a designer's ability to have a strong imagination.

5.4.1 The Imagination + Imagery Model

Findings from the first study (Figure 5) offer vital evidence for the impact of education on the VI style of individuals. This suggests that design education should provide an environment that allows students to use and develop both object and spatial visualization abilities interactively. The second study results explained in section 4.2 clearly shows that although internal or external stimulus can invoke imagination and lead it in different directions, imagination could be subjective or objective depending on the

level of control of its content. It can be a tool for cognitive fallacies or rational reasoning depending on how it is used. Therefore, it is vital to integrate understandings of active, ethical, and applied imagination to design pedagogy.

Table 5. The Imagination + Imagery Model
What does it mean for a designer to possess strong imagination?
To have the ability to form vivid images of objects in front of the mind's eye
To have the ability to transform and manipulate the spatial representations of a given object, such as rotating and manipulating shapes in the mind
To direct the artistic and embodied expressions of imagination toward mental and emotional health (Active Imagination)
To empathetically understand how others experience a situation, to picture the open possibilities, and to predict the consequences of a decision or action. (Ethical Imagination)
To employ imagination for creative problem solving (Applied Imagination)

Table 5. The I+I Model

5.4.1.1 Active Imagination Implications

User-centered design can provide an excellent experience for the consumers on the receiving end of such products. Often overlooked in this process are the designers themselves. By paying attention to the mental and emotional wellbeing needs of designers, there may be a radical shift in their creative capacities and the artifacts they produce. If a designer is unable to empathize with their own needs, how can they be expected to take their users' needs into account? In order for designers to have enough empathy for the context they are working in, they must learn the innerworkings of their internal worlds. Designers must be capable of navigating their own needs to tap into the needs of others.

To address this concern, Carl Jung's understanding of active imagination has deep implications for one's ability to absorb the diverse world around them, which is critical for empathy, and respond creatively. Not only can this be used as a therapeutic device, but it is also a tool for discoveries of greater human potentials. The author's personal experience offers a testimony of the power of such methods. After working with the techniques offered in Jung's "Red Book," the author underwent a transformation into a more vivid visualizer. Initially, the author's primary creative language was verbal. Upon working with techniques focused on visual detail, the author noticed changes in both how she received the world, and how she could imagine and create in response. The author's poetry dramatically changed, bringing crisper visual metaphors.

This experience of active imagination was very similar to the concept of flow explained by Mihaly Csikszentmihalyi. As stated by him, the reason for a satisfying experience is a state of consciousness called *flow* (Csikszentmihalyi ,1997). At this state of concentration, the author was completely immersed in the active imagination activities that she absorbed the entire experience.

One of the captivating active imagination activities that she created was this concept of "mandala painting" inspired by Jung's work which balances conscious and unconscious influence. For this activity, she poured water on a piece of round watercolor paper and dropped random colors on that paper. Then, she let her unconscious take control by allowing meaning to emerge from the splattered color. Jung recognizes this as the ability of the unconscious to recognize and attribute meaning to patterns. The author would then decide which patterns she wanted to solidify into the artwork and would

complete those images by drawing them with marker. One example of this activity could be found in Appendix G.

Another activity the author generated was “change the camera” which again draws on both OV and SV. The author would begin by reimagining one memory from the past. Then, she would view the scene from different points of view and actively observe the emotional reactions. This method is similar to changing the camera’s position while recording different videos of one location. Surprisingly, the feelings about one single memory could be changed by looking at it from different angles.

As stated by Carl Jung, active imagination acts as a bridge between conscious and unconscious mind. Unfortunately, this creative connection is being suppressed by the influence of modern digital technology. The flood of information provided by the fast pace new technologies is an obstacle for the patience needed for unconscious discoveries. The active imagination tools can address this by leading to creative insights and could be implemented in design education curriculum to help students reach out to the resource of unconscious creativity.

5.4.1.2. Ethical Imagination Implications

Since designers are creating the artifacts that mediate experiences with the world, it is imperative to integrate ethical imagination. Not only are designers helping create the current reality, but they are shaping the future with the products and services they design. Questions of ethics are immensely complex given the diversity of perspectives and lived experiences. Ethical thinking needs to be the soul of design culture. The same way that designers learn to consider user needs to deliver a project, they should consider the holistic impact of each product they design. Design education that fosters a deeper sense of

empathy that includes designer's self, user, other humans, and nature, will promote the creation of products and services that support a society oriented toward meaningful progress. While each culture carries its own set of beliefs and values, there can be common ground found in distilled ethics framed as something like the *golden rule*.

Ethical questions must be brought into consideration throughout the design process. Who is the user? What is their goal in using this product? What are the ripple effects that the use of this product will have on the rest of society? Will it support the ability to live in a more harmonious way or will it create more conflict and dissonance?

The field of Design for Social Change has begun to address some of these questions. This is adding the layer of socio-environmental challenges into the design process. This can offer radical potential in supporting creative solutions to the wicked problems of this time. The field of Sustainability recognizes the inextricable linkages between the many dimensions of economic, political, social, cultural, symbolic, and environmental realities. Given the need for this holistic view, designers must be prepared to allow their vision to be complexified by taking into account these different dimensions.

In creating new strategies to support using design for social change, precaution must be taken to prevent this from becoming another fad. There is an unfortunate tendency to run away from the complexity of reality and simplify situations as something a designer can "fix."

One clear trend of this time period is the rampant consumerism induced by industrialization. There has been an undoubtable increase in material wealth, but what about intangible aspects of human development? Humans are social creatures in need of connection. There is an innate drive for a sense of meaning and purpose in the human

experience. Central to this is the symbolic reality made up from our mental, emotional, and spiritual qualities. Can designers support society through creation of non-consumptive experiences that offer a sense of purpose?

The challenge of ethics in the world today is the obsession with the source of ethical rules. Religious and cultural norms often point to different sources of "purity" or "truth" or "holiness." Focusing on this origin or source of what is "good" results in conflicts that distract attention away from the impact of living with an ethic. It is far more important to view ethics in their embodied form and observe how different ethics translate into action.

5.4.1.3 Applied Imagination Implications

Applied imagination undoubtedly has received the most attention from educators in the design field. As stated in section 2.2.2, the basis of design education today is design thinking which is a famous method of creative problem solving and applied imagination. This type of imagination is goal oriented and could be utilized all through the design process. Applied imagination is also related to visual thinking and problem solving.

5.4.2 Imagination + Imagery as a Tool for Facilitators

The nature of interdisciplinary teamwork in the 21st century demands better understanding of individual capabilities and potentials. Cognitive style is one of the critical components of effective decision making in teamwork. As claimed by Armstrong and Priola (2001): "differences and similarities in cognitive style are likely to have a significant effect on the behavioral tendencies of individuals working in teams" (Effects on Team Composition Section, para. 2). Several facilitating organizations have been developed recently that aim to enhance team efficiency by recognizing each member's

cognitive styles. For example, the FourSight company provides assessment tools that discover the thinking profiles of individuals and organizations. These profiles foster innovative leadership by presenting the problem-solving style of each person involved in a project ("About FourSight," n.d.).

The results of this current research provide information about the VI preferences of individuals from three different fields: design, engineering, and humanities. This cognitive insight could be employed by facilitators to improve communication and productivity among the members of interdisciplinary teams. For instance, an industrial designer with a high Object Visualization (OV) score would be invited to explain the pictorial visual details underlying his decision making, while presenting to a team of engineers with lower OV abilities.

5.5 Future Research

This section explains what would have been done if this research was repeated. It also describes what other areas of research would be needed to extend this study.

5.5.1 Research Challenges

The biggest challenge in this research was to narrow down the research questions. The imagination concept is too broad which offers so many research possibilities and makes it difficult to investigate a specific question. However, the study of this topic from different perspectives-psychology, philosophy, and cognitive science-was very informative. This multidimensional approach allowed to accomplish some unexpected results as the relation between ethical imagination and the design process. It is highly recommended to the future design students to conduct cognitive research experiments within the historical and philosophical context.

5.5.2 Future Research Opportunities

Further studies are required to evaluate how the I+I model could be applied to design education. For instance, the influence of active imagination and self-expression on design creativity, the role of ethical imagination in sustainable design, and the impact of applied imagination on design problem solving should yet be assessed. Moreover, the VI abilities of different majors within the design field could be an interesting topic for further research studies. The differences between the VI abilities of architects, industrial or graphic designers would suggest valuable insights for further educational strategies within this field. Another research direction could be to create and assess new visual tools that empower the visual cognitive abilities of designers.

5.5.3 Opportunities for Improvement

Art students' VI profile should be included in future studies. This could provide more evidence to conclude whether the visual cognition in design is different from visual arts. As explained in section 3.2.5, the methods could be more reliable if included the Object Spatial Imagery Questionnaire (Appendix A) and Mental Rotation Test (Appendix B). Future research would also define a standard data collection method of laptops to control the possible influence of monitor size on responds.

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APPENDIX A

OBJECT-SPATIAL IMAGERY QUESTIONNAIRE

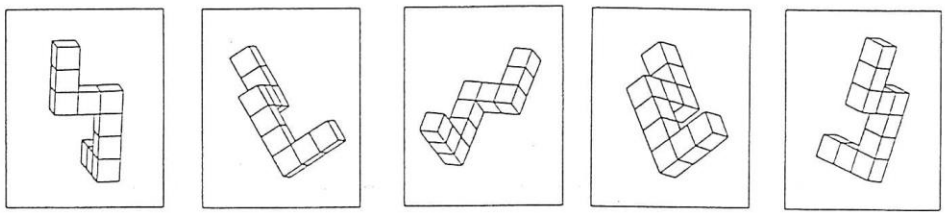
1 I was very good in 3-D geometry as a student.
2 If I were asked to choose between engineering professions and visual arts, I would prefer engineering.
3 Architecture interests me more than painting.
4 My images are very colourful and bright.
5 I prefer schematic diagrams and sketches when reading a textbook instead of colourful and pictorial illustrations.
6 My images are more like schematic representations of things and events rather than detailed pictures.
7 When reading fiction, I usually form a clear and detailed mental picture of a scene or room that has been described.
8 I have a photographic memory.
9 I can easily imagine and mentally rotate 3-dimensional geometric figures.
10 When entering a familiar store to get a specific item, I can easily picture the exact location of the target item, the shelf it stands on, how it is arranged and the surrounding articles.
11 I normally do not experience many spontaneous vivid images; I use my mental imagery mostly when attempting to solve some problems like the ones in mathematics.
12 My images are very vivid and photographic.
13 I can easily sketch a blueprint for a building that I am familiar with.
14 I am a good Tetris player.
15 If I were asked to choose between studying architecture and visual arts, I would choose visual arts.
16 My mental images of different objects very much resemble the size, shape and colour of actual objects that I have seen.
17 When I imagine the face of a friend, I have a perfectly clear and bright image.
18 I have excellent abilities in technical graphics.
19 I can easily remember a great deal of visual details that someone else might never notice. For example, I would just automatically take some things in, like what colour is a shirt someone wears or what colour are his/her shoes.
20 In high school, I had less difficulty with geometry than with art.
21 I enjoy pictures with bright colours and unusual shapes like the ones in modern art.
22 Sometimes my images are so vivid and persistent that it is difficult to ignore them.
23 When thinking about an abstract concept (e.g. 'a building') I imagine an abstract schematic building in my mind or its blueprint rather than a specific concrete building.
24 My images are more schematic than colourful and pictorial.
25 I can close my eyes and easily picture a scene that I have experienced.
26 I remember everything visually. I can recount what people wore to a dinner and I can talk about the way they sat and the way they looked probably in more detail than I could discuss what they said.
27 I find it difficult to imagine how a 3-dimensional geometric figure would exactly look like when rotated.
28 My visual images are in my head all the time. They are just right there.
29 My graphic abilities would make a career in architecture relatively easy for me.
30 When I hear a radio announcer or a DJ I've never actually seen, I usually find myself picturing what he or she might look like.

APPENDIX B

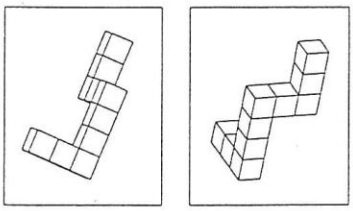
MENTAL ROTATION TEST

AUTOCAD drawings of Vandenberg & Kuse (1978)* items. Michael Peters, PhD, Dept. Psychology, University of Guelph, Guelph, ON, Canada N1G 2W1

Look at these five figures.



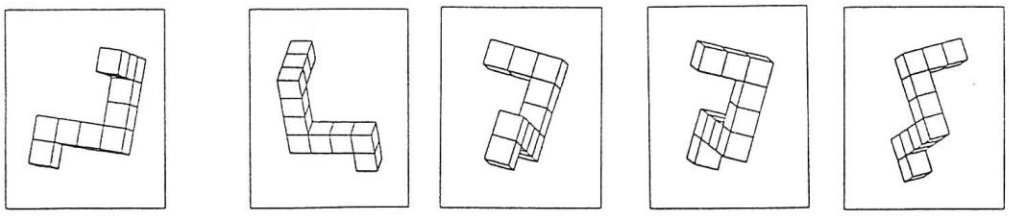
Note that these are all pictures of the same object which is shown from different angles. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next.



Here are two drawings of a new figure that is different from the one shown in the first 5 drawings. Satisfy yourself that these two drawings show an object that is different and cannot be "rotated" to be identical with the object shown in the first five drawings.

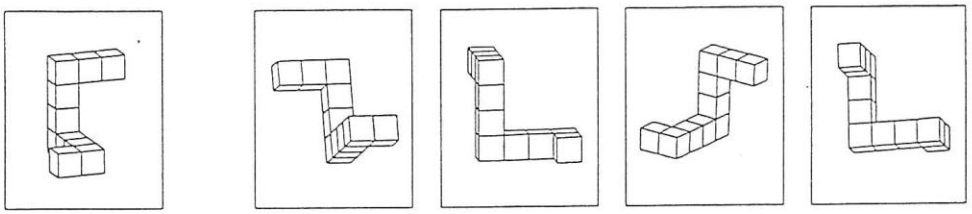
Now look at this object:

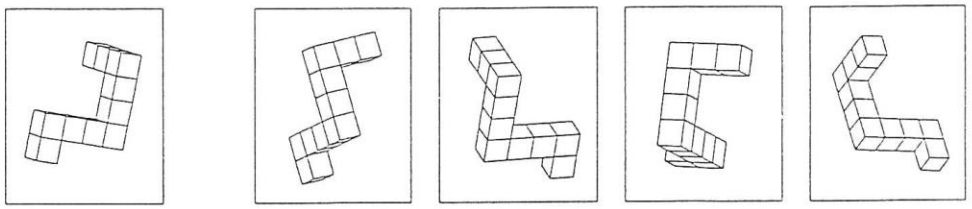
Two of these four drawings show the same object. Can you find those two ? Put X's in the lower right corner.

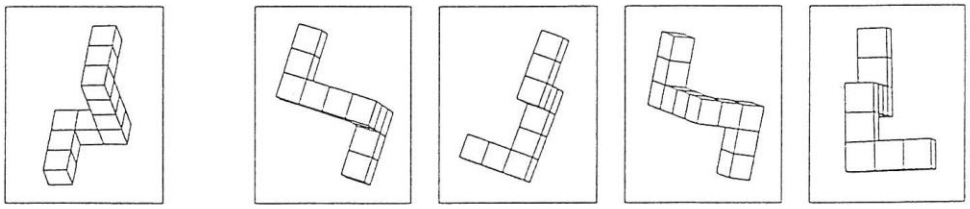


If you marked the first and the third drawings, you made the correct choice.

Here are three more problems. Again, the target object is shown twice in each set of four alternatives from which you choose the correct ones.





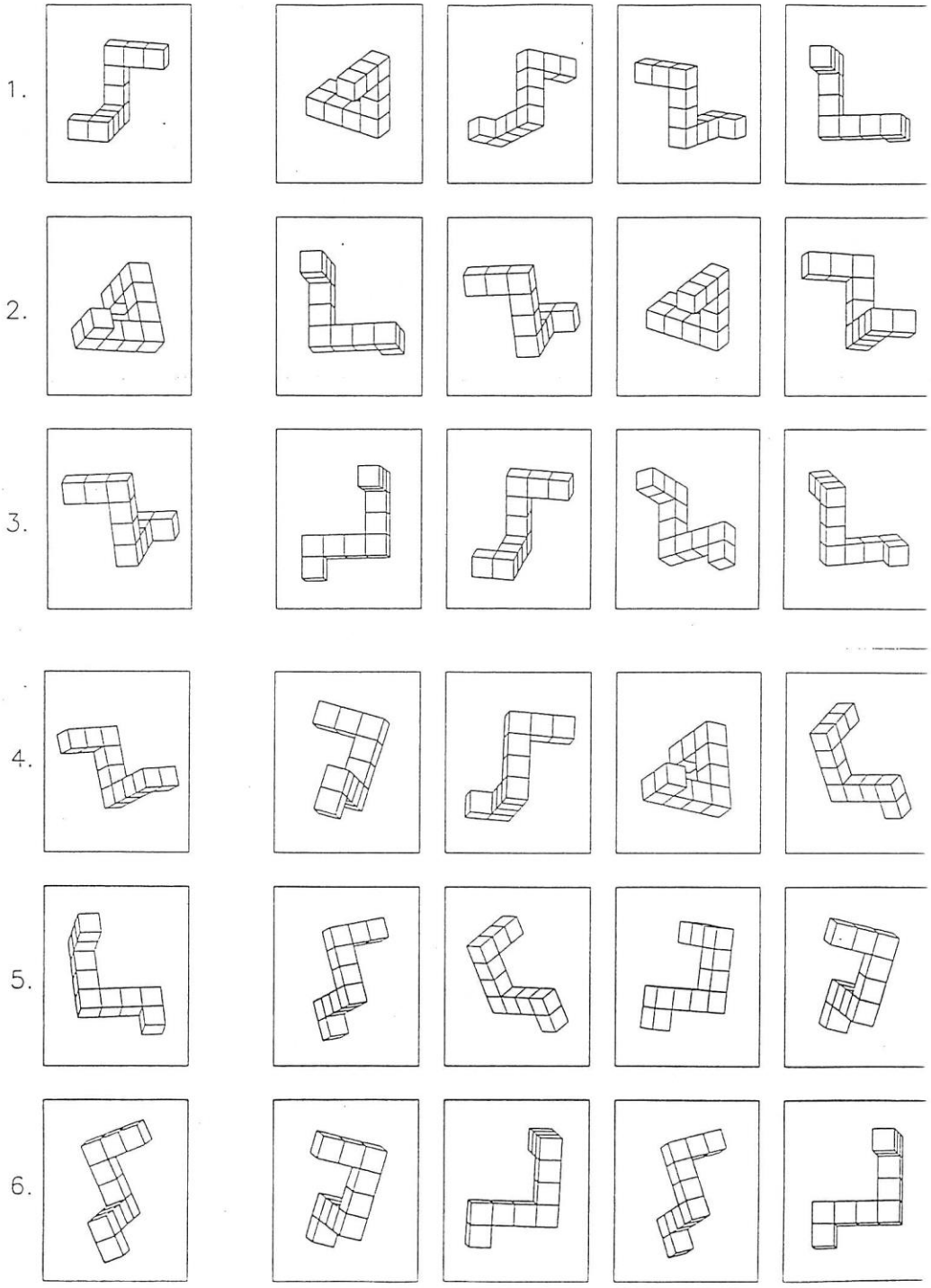


Correct choice for 1: second and third, for 2: first and fourth
3: first and third

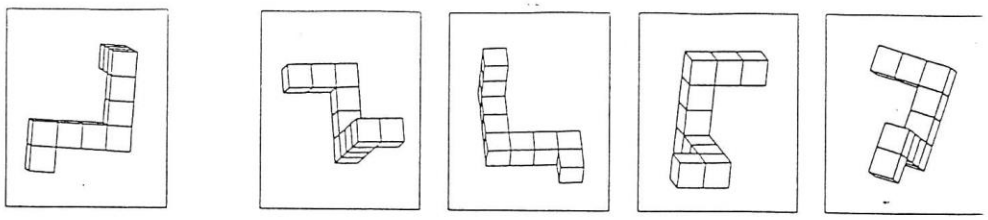
When you do the test, please remember that for each problem set there are two and only two figures that match the target figure. What is your best strategy in doing the problems ? Because an incorrect choice is subtracted from a correct one, you are better off to check only one of the figures if you can be only sure of one. Of course, you will always try to get both of the figures that match.

---

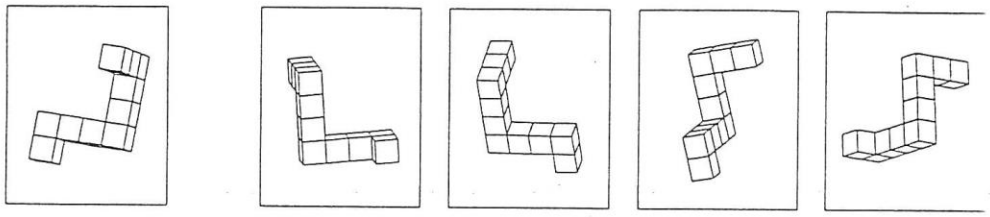
* S.G. Vandenberg of the University of Colorado selected this subset of figures from a larger set devised by Shepard and Metzler. Two versions of the mental rotations test exist: one with 20 problems and one with 24 problems; this is the latter one. Because the quality of available reproductions has deteriorated over the course of making copies of copies, we have redrawn the set of figures with help of the AUTOCAD drawing program (the AUTOCAD drawings were done by Diane Duncan, School of Engineering, U of Guelph). It was decided not to use the natural perspective option provided by the program because the perspective shown here seems to give the clearest representation of the problems.


1.
2.
3.
4.
5.
6.

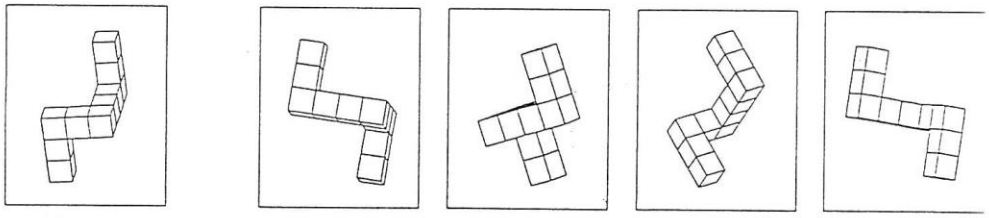
7.



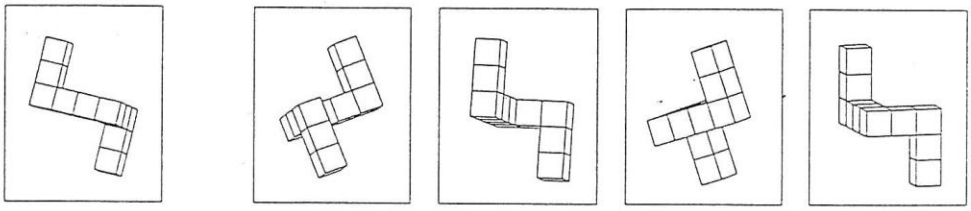
8.



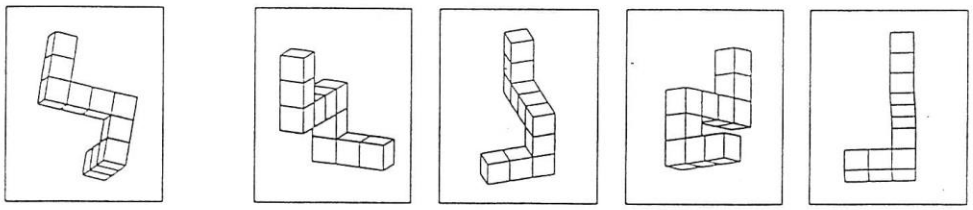
9.



10.



11.



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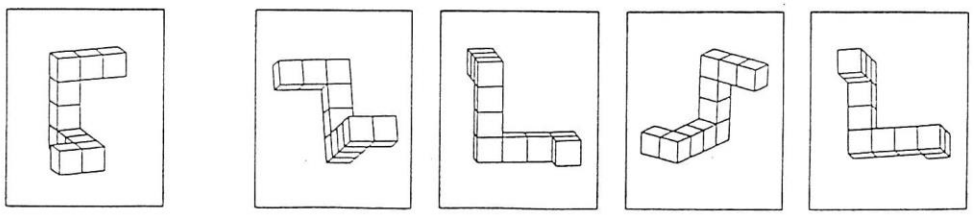
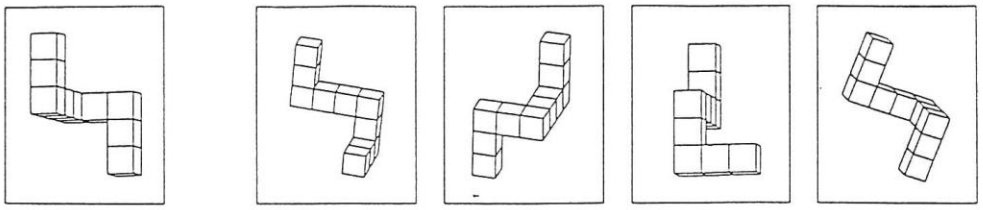
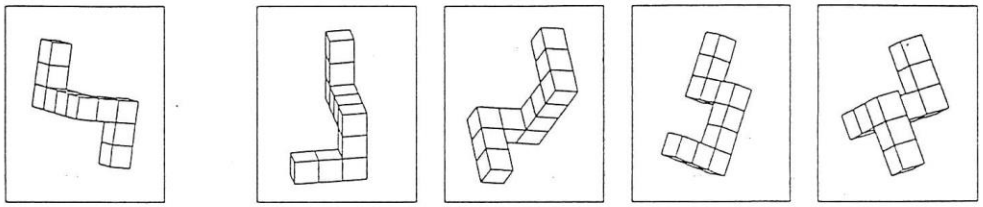
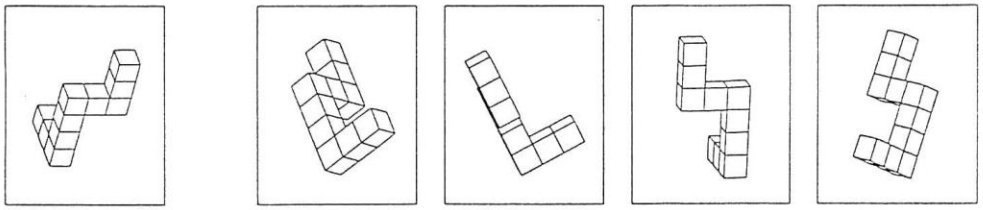
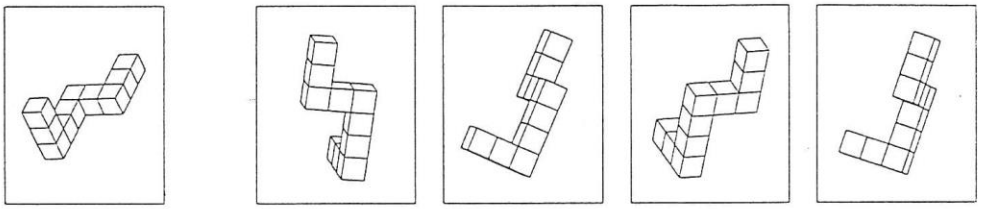
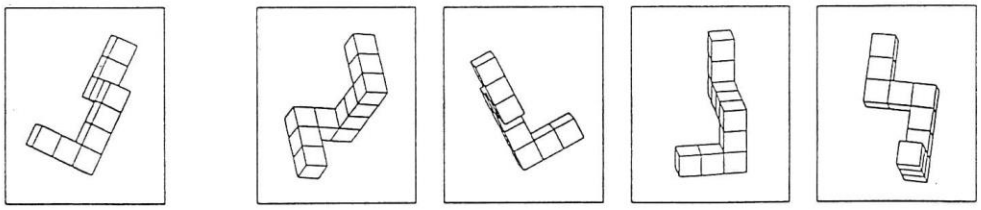


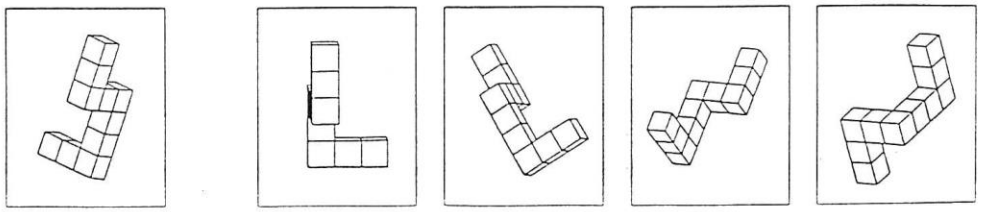
13. 

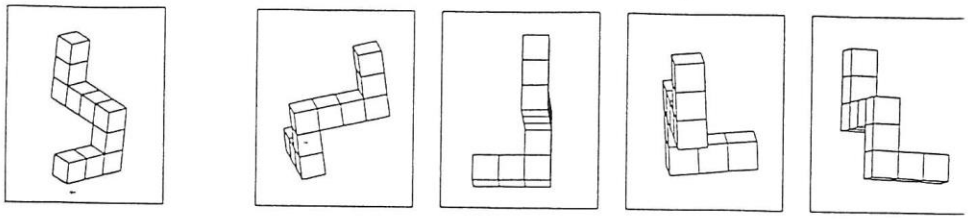
14. 

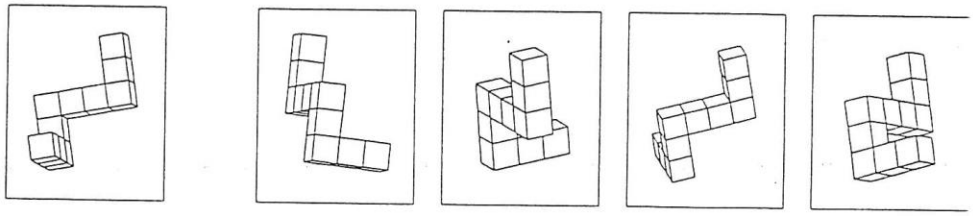
15. 

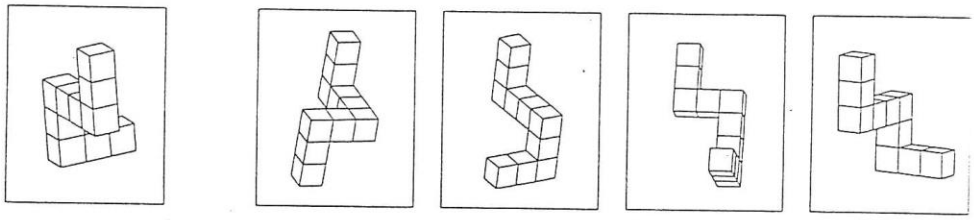
16. 

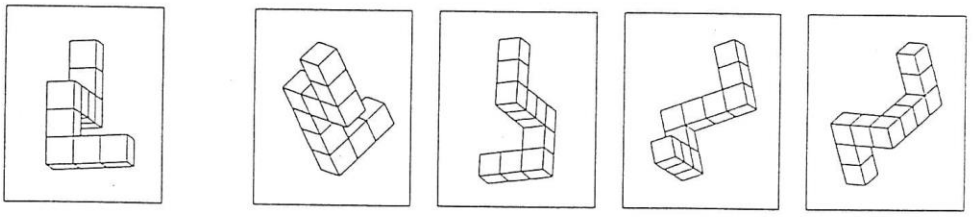
17. 

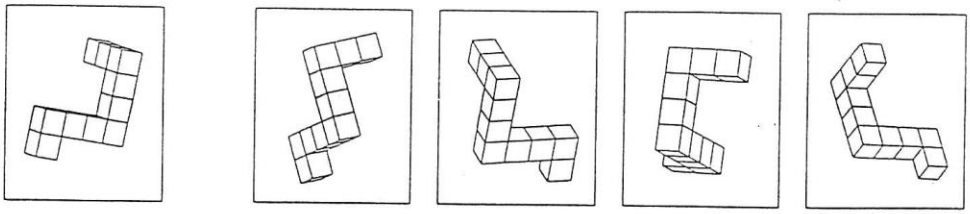
18. 

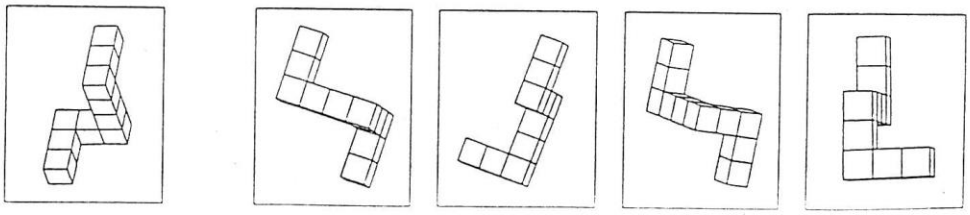
19. 

20. 

21. 

22. 

23. 

24. 

APPENDIX C

VIVIDNESS OF VISUAL IMAGERY QUESTIONNAIRE

For each item on this questionnaire, try to form a visual image, and consider your experience carefully. For any image that you do experience, rate how vivid it is using the five-point scale described below. If you do not have a visual image, rate vividness as '1'. Only use '5' for images that are truly as lively and vivid as real seeing. Please note that there are no right or wrong answers to the questions, and that it is not necessarily desirable to experience imagery or, if you do, to have more vivid imagery.

Perfectly clear and vivid as real seeing	5
Clear and reasonably vivid	4
Moderately clear and lively	3
Vague and dim	2
No image at all, you only "know" that you are thinking of the object	1

For items 1-4, think of some relative or friend whom you frequently see (but who is not with you at present) and consider carefully the picture that comes before your mind's eye.

1. The exact contour of face, head, shoulders and body _____
2. Characteristic poses of head, attitudes of body etc. _____
3. The precise carriage, length of step etc., in walking _____
4. The different colours worn in some familiar clothes _____

Visualise a rising sun. Consider carefully the picture that comes before your mind's eye.

5. The sun rising above the horizon into a hazy sky _____

6. The sky clears and surrounds the sun with blueness _____

7. Clouds. A storm blows up with flashes of lightning _____

8. A rainbow appears _____

Think of the front of a shop which you often go to. Consider the picture that comes before your mind's eye.

9. The overall appearance of the shop from the opposite side of the road _____

10. A window display including colours, shapes and details Of individual items for sale _____

11. You are near the entrance. The colour, shape and details of the door. _____

12. You enter the shop and go to the counter. The counter assistant serves you. Money changes hands _____

Finally think of a country scene which involves trees, mountains and a lake. Consider the picture that comes before your mind's eye. _____

13. The contours of the landscape _____

14. The colour and shape of the trees _____

15. the colour and shape of the lake _____

16. A strong wind blows on the trees and on the lake causing waves in the water. _____

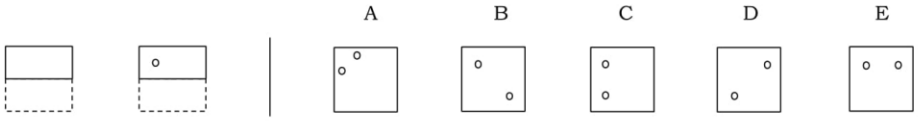
APPENDIX D

PAPER FOLDING TEST

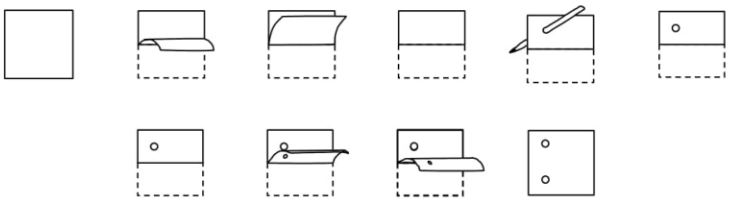
Paper Folding Test—Vz-2-BRACE

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures on the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper).



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



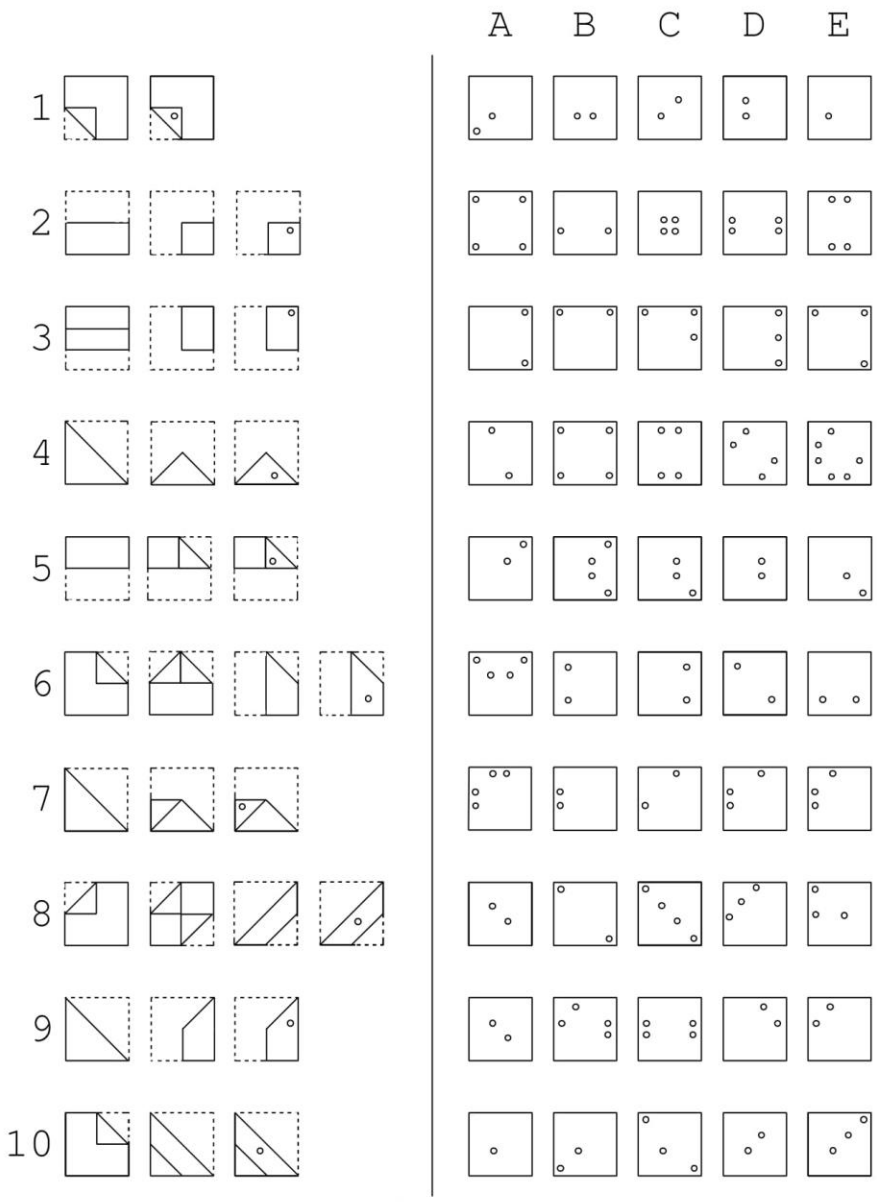
In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Some of the problems on this sheet are more difficult than others. If you are unable to do one of the problems, simply skip over it and go on to the next one.

You will have three minutes for each of the two parts of this test. Each part has one page. When you have finished Part One, STOP. Please do not go on to Part Two until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

PART ONE (3 MINUTES)



STOP

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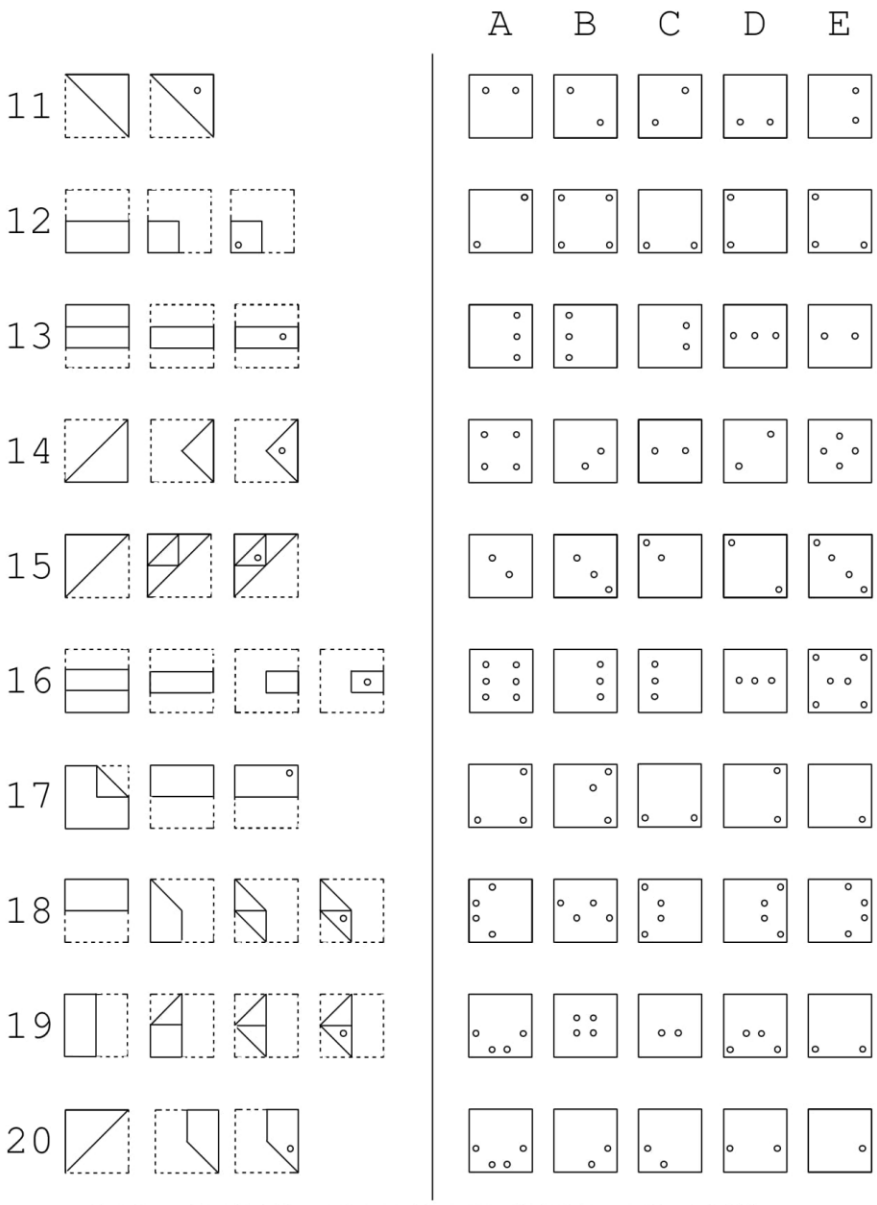
PART TWO (3 MINUTES)



STOP AND WAIT FOR FURTHER INSTRUCTIONS
DO NOT GO BACK TO PART ONE

APPENDIX E

INSTITUTIONAL REVIEW BOARD

APPROVAL: MODIFICATION

John Takamura
The Design School
480/965-7171
John.Takamura@asu.edu

Dear John Takamura:

On 2/27/2018 the ASU IRB reviewed the following protocol:

Type of Review:	Modification
Title:	Neurocognitive Approach toward Design Thinking Education
Investigator:	John Takamura
IRB ID:	STUDY00007041
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• CIT, Category: Other (to reflect anything not captured above); • Vividness_of_Visual_Imagery_Questionnaire_(VVIQ).pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Consent Form (2).pdf, Category: Consent Form; • Paper Folding Test Vz-2-BRACE Version 07.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Recruitment.pdf, Category: Recruitment Materials; • Visual Abilities in Design Education.docx, Category: IRB Protocol; • citiCompletionReport5179478 (1).pdf, Category: Other (to reflect anything not captured above);

The IRB approved the modification.

When consent is appropriate, you must use final, watermarked versions available under the “Documents” tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Farzaneh Hedayati
John Takamura
William Heywood
Farzaneh Hedayati